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Smoke-drying weights and economic analysis of processed catfish using two different kilns

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Abstract

Processed catfish can be found in many markets in Nigeria and is considered a delicacy in Nigerian dishes. Inconsistent quality of the African Catfish *Clarias gariepinus* processed via smoke-drying and paucity of documented economic data involved in the use of Traditional Drum Kiln (TDK) in Lagos State prompted the standardization of TDK and the construction of Eco-Friendly Kiln (EFK). Market parameters, total costs and revenue generation in eight fishing villages in Lagos State were investigated and smoke-drying was done at a stretch of an average of 24 ± 3 hours. The standardization of TDK and EFK was done by maintaining the smoke-drying temperature in both kilns between 60^0C and 80^0C with the use of temperature sensor, audio smart alarm and Light Emitting Diode. EFK fitted with two layers of 0.3 smoke filters was found to have the highest quality smoke-dried from the drying profile. The market characteristics indicated that smoke-drying process was predominantly carried out by women with little formal education and there were differences in the mechanics of fresh fish procurement, processing methods and marketing channels. The cost and revenue estimation using both kilns showed that the use of EFK had greater turnover and would generate about ₦ 2,715,752 as compared with ₦ 1,127,752 with the use of TDK over an estimated 2 years lifespan of EFK.

1. Introduction

Fish is an important global source of animal protein and supplies about 50 % of total protein intake of the average Nigerian [1]. It is generally considered to be more affordable than other animal protein sources such as eggs and meat, has high nutritive values and improves overall human health [2]. Consumption of fish, especially by humans is encouraged in many parts of the world because it is known to supply amino acids, vitamins, mineral elements and fatty acids when incorporated in the diet [3, 4]. For regions that have easy access to large areas of water, fish is a major source of nutrients for their community.

Nigeria is presently one of the biggest importers of fish in Africa because of her teeming population of about 170 million people which has a fish demand estimate of 2.1 million metric tons [5]. The domestic fish production however can only supply about 900,000 metric tons, with the deficit mostly resolved by importation [6].There is however high deficit in supply of fish in Nigeria due to high incidence of post-harvest losses of fresh fish [7]. This shortage is caused because freshly harvested fish cannot always be sold and/or consumed within a few hours after death.

Fish are usually dehydrated as a means of preservation, as fish is well-known for its perishability issue. In addition, dried fish differs from place to place and culture to culture, from the type of fish used

to the drying methods and ingredients used in the drying process. The processing of freshly harvested fish is thus common in order to delay natural deterioration process, extend shelf life and bridge fish production deficit [8]. Hence, harvesting, processing and marketing of fish products provide major foreign exchange for many countries including Nigeria.

Processing with the use of cylindrical metal drum kiln also called Traditional Drum Kiln (TDK) is presently the most popular in Nigeria due to its relatively low cost of purchase and little special training which makes it agreeable to most fish processors with little or no formal education [9-11]. Heat is applied to the fresh fish at 600 to 120 ^{0}C and combines cooking, drying and smoke application till moisture content of 25% or less is achieved. The low moisture content in the smoke-dried fish ensures freshness for at least twenty-four hours before re-smoking can then be carried out [6]. The major challenge associated with the use of TDK is the subjective process of the smoke-drying which depends on the skill and experience of the processor. This causes a lack of standardization of both the smoke-drying process as well as the smoke-dried fish product. Another major challenge is the paucity of documentation of the market characteristics, costs incurred, revenue and profit generated from smoke-drying business.

African mudfish (*Clarias gariepinus*, Burchell, 1822) also called African sharp tooth catfish is a species of catfish of the family Clariidae or the air breathing catfishes. It is an air-breathing catfish with a scaleless, bony elongated body with long dorsal and anal fins and a helmet-like head and colour varies dorsally from dark to light brown and is often mottled with shades of olive and grey, while the underside is usually pale cream to white in colour [12]. *C. gariepinus* is known to have higher nutrient components such as amino acids as well as a greater ratio of polyunsaturated fatty acids to saturated fatty acids over other fishes such as Tilapia zilli, *Pseudotolithus typus* and *Pentanemus quinquarius* [13]. Fresh and processed catfish can be found in many markets in Nigeria and is considered a delicacy in Nigerian dishes. It is presently the most successfully cultured fish in Nigeria because of its resilient nature, ability to thrive under stressful conditions such as low oxygen concentrations and its high feed to muscle conversion ratio [14]. However, there is a major challenge of high incidence of post-harvest losses as a result of spoilage of fresh catfish after harvesting. Up to 50 % of the total fish catch in Nigeria is lost annually due to inadequate or poor handling, preservation and/or processing of the freshly harvested fish by both artisanal fishermen and farmers who own or run fish farms [15].

The oldest and most widely practiced form of fish processing particularly in the tropics is smoke-drying. Smoke-drying is the main traditional processing method used in extending fish shelf life in Nigeria with a percentage of about 45 % as against 27 % eaten fresh [16]. Smoke dried fish is an integral part of the diet of many Nigerians and processing by smoke-drying is the main source of income for many people, especially in rural areas [17]. Smoking kilns can generally be classified into three mainly on the basis of carrying capacity and efficiency into traditional, improved traditional and mechanical smoke-drying kilns. Relative humidity plays an important role on how quickly smoke-dried fish spoils and is different in wet and dry seasons in Nigeria [18]. There is however lack of information on Smoke-drying weights and economic analysis of processed catfish in Nigeria. The aim of this study was to compare the smoke-drying weights and economic analysis of processed catfish (*Clarias gariepinus*) using two different kilns (Traditional Drum Kiln and constructed Eco-Friendly Kiln).

2. Methodology

2.1 Construction of Smoke-Drying Kilns

Traditional Drum Kiln (TDK) (Figure 1) was built according to the specifications as used in fishing villages in Lagos State, Nigeria. It comprised of a cylindrical metal drum with dimensions 72 cm height, 187 cm circumference and 55 cm diameter. The aperture through which wood fuel was placed was of

diameter 36 cm. A circular rack of diameter 76.5 cm was placed on the open end for smoke-drying the catfish samples. Eco-Friendly Kiln (EFK) (Figure 2) was built to comprise of three chambers namely the flame, drying and electronic.

Figure 1. Traditional Drum Kiln (TDK)

Figure 2. Constructed Eco-Friendly Kiln

The flame chamber was constructed with dimensions 93.1 x 77.5 x 85.2 cm^3 using interlocking bricks coated with lagging material composed of clay, sawdust and silicon carbide in the ratio 4:2:0.5. The wood fuel used for smoke-drying was arranged in it via an aperture with dimensions 29.6 x 16.8 cm^2. The drying chamber was separated from flame chamber at the back with the use of smoke filters size 0.3 cm, was built from a metal drum with same dimensions as TDK and was coated with same lagging material as the flame chamber. A drying rack composed of three layers with dimensions 44.3 x 44.2 cm^2

on lowest layer, 40 and 49.5 cm diameters in middle and topmost layers respectively was then placed in the drying chamber. The electronic components comprised of a temperature sensor built as a nub that was placed in smoke-drying catfish sample mouth. The nub transmitted heat message to visual light emitting diode and also an audio alarm which made no sound when the smoke-drying temperature was less than 60 ^{0}C, made a beeping sound with a second interval at optimum drying temperatures of 60 - 85 ^{0}C and a loud blaring sound when the drying temperature rose above 85 ^{0}C.

2.2 Sample collection, preparation and smoke-drying process

Samples of catfish, *Clarias gariepinus* were obtained live from the Aquaculture Unit of the Department of Marine Sciences, University of Lagos, stunned with a wooden club, washed with clean pipe borne water and then arranged on covered metal racks to drain in Instrumentation Unit, University of Lagos. The freshly prepared fish were not seasoned in any way and were then arranged in the two kilns namely Traditional Drum Kiln and Eco-Friendly Kiln. The smoke-drying process using both kilns was carried out at a stretch at a temperature range of 60 - 85^{0}C maintained with the aid of temperature alarm and Visual Light Emitting Diode. The fish were measured on an hourly basis till a fairly constant weight was achieved, lasting an average of 24±3 hours using both kilns.

2.2 Drying profile determination and economic analyses

The drying profiles of Traditional Drum Kiln (TDK) and Eco-Friendly Kiln (EFK) were calculated by plotting the average weights of the smoke-drying catfish in both kilns against time. This was done on an hourly basis of the total time spent smoke-drying the catfish. The economic analysis was done by determining the market characteristics, total costs, recurrent costs and revenue generated from the use of traditional drum kiln in eight (8) randomly selected markets in Lagos State. Personal interviews were done with the use of structured questionnaires validated to avoid ambiguous and leading questions and total investment, projected recurrent expenditure, profit per day and payback period over two years were also determined.

2.3 Statistical analysis

All data are presented as means ± standard error (SE). Analysis of variance (ANOVA) was set at 0.05 level of significance and the data collected from structured questionnaire administration was used in determining market characteristics and profit assessment.

3. Results and Discussion

3.1 Drying profiles of catfish

The initial weights of the fresh catfish prior to smoke-drying and final weights after smoke-drying were averaged at 271.00 g, 228.80 g, 219.86 g and 219.50 g and 95.00 g, 74.35 g, 69.51 g and 51.76 g using TDK and EFK fitted with two layers of 0.1cm smoke filter, two layers of 0.3cm smoke filter and four layers of 0.3cm smoke filter respectively as shown in Figures 3 and 4. Most rapid weight loss of an average of 50 % was in the first five (5) hours using both kilns. The smoke-drying process however had to be stopped at eighteen hours using TDK as the catfish samples had become very brittle and were starting to disintegrate. The highest clogging of the smoke filters was found with EFK using combination of two layers of 0.1cm smoke filters and the least clogging was found in EFK using combination of two layers of 0.3cm smoke filters.

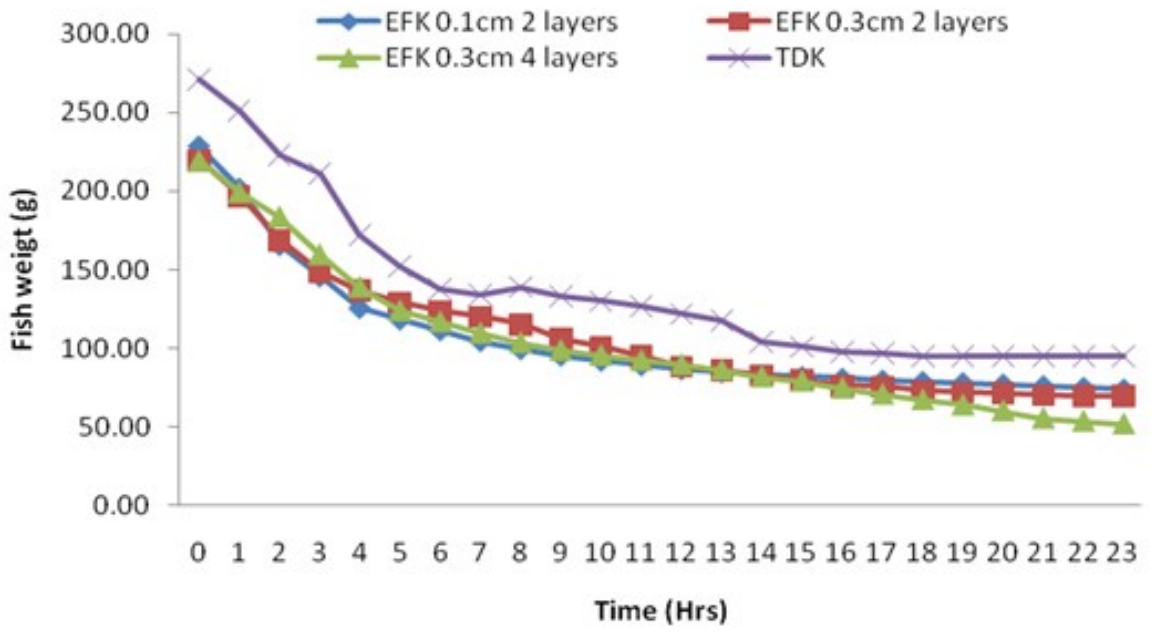

Figure 3. Fish weight of smoked-dried catfish with Traditional smoking and Eco-Friendly kilns

Rapid moisture loss in the first six hours of smoke-drying was observed when both TDK and EFK were fitted with smoke filters with 0.1 cm diameter in two layers and also when both kilns were fitted with 0.3 cm diameter in two and four layers. Moisture loss rate reduced and tapered off after the first six hours. EFK with the use of 0.1 cm smoke filters in two layers showed the poorest drying profile and could be attributed to the smoke filters being highly clogged by smoke particles and so prevented easy passage of heat to the smoke-drying fish. EFK fitted with 0.3 cm smoke filter in two layers showed the best drying profile as there was a gentle curve showing the continued weight loss of the smoke-drying catfish samples and so would be recommended as the best fitting when EFK is used for smoke-drying catfish.

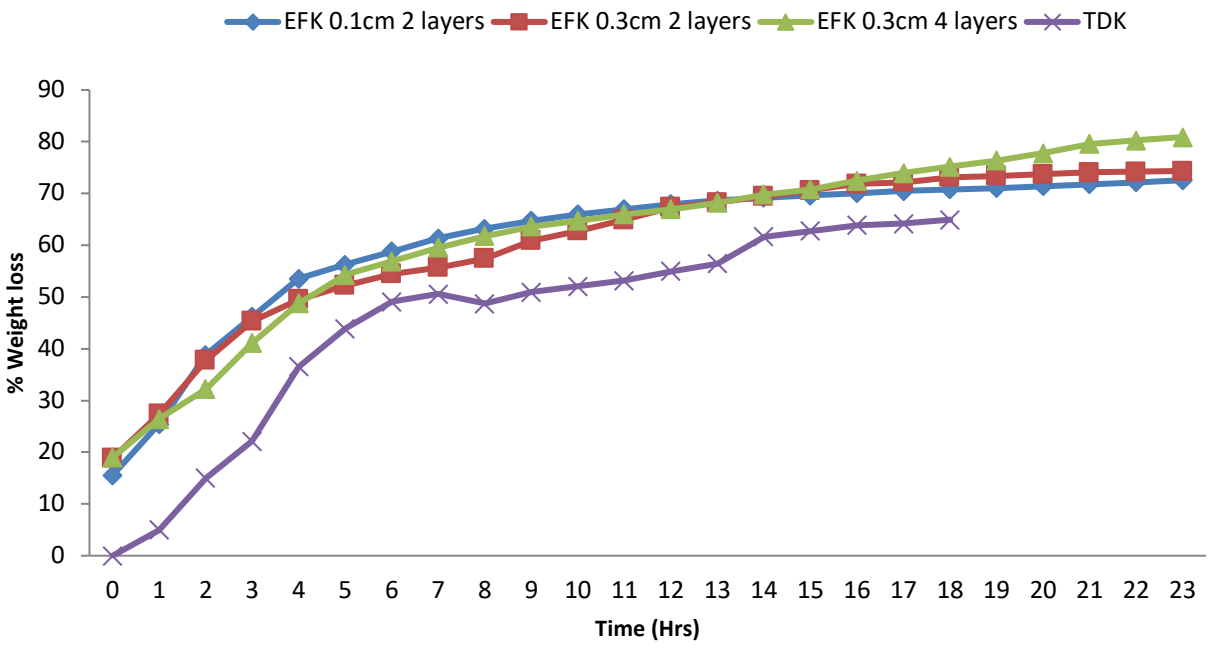

Figure 4. Weight loss of smoked-dried catfish with Traditional smoking and Eco-Friendly kilns

Smoke-drying with the use of traditional kiln is often a subjective process with the resultant smoke-dried fish product dependent on the experience of the fish processor and not on specific standards and thus there is a lack of uniformity in the quality of smoke-dried fish product [19]. Temperatures much higher than 85^0 C burns the flesh of the fish thus denaturing the protein and also impart an unpleasant taste [20]. The standardization of TDK and EFK by maintaining the smoke-drying temperature between 60 and 85^0C ensured that there was consistency in the quality of the smoke-dried catfish product by properly drying the fish from inside out and preventing charring of the smoke-dried fish product.

3.2 Proximate analysis

The proximate compositions of smoke-dried catfish using two kilns are shown in Table 1. The fish smoked-dried in TDK had higher protein content (61.42 ± 1.86 g/100 g) and ash content (10.73±1.80 g/100 g) but lower fat (3.19±0.91 g/100 g) fibre content (1.84±0.36 g/100 g) and moisture (23.94 ± 1.53 g/100 g) compared to the protein (56.08 ± 2.42 g/100 g), fat (12.45 ± 0.51 g/100 g), fibre content (2.72 ± 0.22 g/100 g) ash content (3.64 ± 0.25 g/100 g) and moisture (25.03 ± 1.14 g/100 g) for EFK. The values of fat and ash content of catfish in TDK and EFK fish were significant different ($P < 0.05$). The results indicate that the catfish smoked-dried in TDK retains protein better compared to EFK. Protein content in the smoke-dried fish increased with decreasing moisture content, agreeing with previous work [21] that protein nitrogen may not have been lost during drying resulting in increase in protein concentration as the moisture reduced. The lower the moisture content of the product to be stored the better the shelf stability of such product [22].

Table 1. Proximate composition of smoked dried *Clarias gariepinus* using two kilns

Proximate (g/100 g)	TDK	EFK	P-Value
Protein	61.42 ± 1.86	56.08 ± 2.42	0.10
Fat	3.19 ± 0.91	12.45 ± 0.51	0.02
Fibre	1.84 ± 0.36	2.72 ± 0.22	1.50
Ash	10.73 ± 1.80	3.64 ± 0.25	0.01
Moisture	23.94 ± 1.53	25.03 ± 1.14	0.15

Keys: Mean±Standard Error; significantly different at ($P < 0.05$)

3.3 Economic analysis

Table 2 shows the economic attributes of the processed catfish using different kilns. Weekly fixed cost of smoke-drying kiln was found to be lower using EFK at ₦625 compared to TDK at ₦750. The variable costs were the same regardless of the type of kiln to be used in the smoke-drying processing. The weekly profit was estimated at ₦65,250 and ₦65,375 for EFK and TDK respectively. The revenue earnings from catfish smoking varied with the type of kiln used. The study showed that processors made highest weekly profits with EFK. Contrarily, catfish smoke-drying business is most profitable with traditional drum kiln in Ondo and Taraba States [23, 24]. However, the processing and distribution activities of smoke-drying catfish were found to be profitable as estimated. This agrees with the various works that assessed smoke-drying processors in Ekpoma and Benin Cities of Nigeria [25, 26].

Table 2. Economic characteristics of processed catfish using two different kilns

Variables	TDK	EFK
Cost of Kiln	9,000 (3 months lifespan)	2,500 (Monthly rent)
Weekly depreciated cost of kiln	750	625
20kg Fresh Fish Basket containing about 80 fish @ 250g each	40,000	40,000
3 baskets/week = 60kg	120,000	120,000
Condiments/week	4,000	4,000
Packaging	2,000	2,000
Total Weekly Costs	**126,750**	**126,625**
Weekly Smoke-dried number of fish	80 x 3 = 240	80 x 3 = 240
Selling Price/Smoke-dried fish	800	800
Weekly Revenue ₦	240 X 800 = 192,000	240 X 800 = 192,000
Weekly Profit ₦	192,000 – 126,750 =65,250	192,000 –126,625 = 65,375

Conclusion

This study has shown that with Eco-Friendly Kiln fitted with two layers of 0.3 cm smoke filters, the best drying profile would be achieved. It was also revealed that smoke-dried catfish is a good source of animal protein with catfish smoked-dried in Traditional Drum Kiln having higher protein content. Furthermore, the results showed that the use of Eco-Friendly Kiln would generate a little more than the profit generated with the use of Traditional Drum Kiln. The lower overall cost, greater turn over and increased profit with the use of Eco-Friendly Kiln would also make it easy to recommend to fish processors.

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References

[1] E. Odioko, and Z. A. Becer. The economic analysis of the Nigerian Fisheries Sector: A Review. *Journal of Anatolian Environmental and Animal Sciences*, 7(2) (2022) 216-226.

[2] P. Kumar, N. Mehta, A. A. Abubakar, A. Verma, A. K. Kaka, U. Sharma and J. M. Lorenzo. Potential alternatives of animal proteins for sustainability in the food sector. *Food Reviews International*, (2022) 1-26.

[3] G. Mahadevan, M., Pouladi, A., Stara, and C. Faggio. Nutritional evaluation of elongate mudskipper *Pseudapocryptes elongatus* (Cuvier, 1816) from Diamond Harbor, West Bengal, India. *Natural Product Research*, 35(16) (2021) 2715-2721.

[4] O. A. Ajala, M. R. Oke, T. F. Ajibade, F. O. Ajibade, B. Adelodun, J. O. Ighalo and L. F. Silva. Concentrations, bioaccumulation, and health risk assessments of heavy metals in fishes from Nigeria's freshwater: a general overview. *Environmental Science and Pollution Research*, (2022) 1-21.

[5] F. O. Issa, S. Aderinoye-AbdulWahab, and J. H Kagbu. Assessment of aquaculture development programmes in Nigeria. *Journal of Agricultural Extension,* 26(1) (2022) 10-17.

[6] M. M. Ogunbambo. Seasonal and temperature dependent variations in proximate parameters and mineral elements of smoke-dried catfish (*Clarias gariepinus*, Burchell, 1822) using traditional and eco-friendly kilns in Lagos, Nigeria. *Journal of Applied Sciences and Environmental Management*, 24(4) (2020) 639-643.

[7] O. A. Akpoka. Microbiological assessment of roasted dried periwinkle (*Tympanotonus fuscatus*) sold in Yenagoa Bayelsa State. *International Journal of Applied Biology*, 4(2) (2020) 37-48.

[8] E. K. Asamoah, Nunoo, F. K., Addo, S., Nyarko, J. O., Acquah, S. A. and G. Hyldig. Effect of smoking and gamma irradiation on the nutritional and sensory quality of Atlantic chub mackerel in Ghana. *Radiation Physics and Chemistry*, 201 (2022) 110458.

[9] M. Omananyi. Involvement of small and medium scale enterprises in culture fish value chain in Niger State, Nigeria (Doctoral dissertation) (2021) 98 pp.

[10] O. Osineye, A. J. Abiodun-Solanke, E. Mangai, E. Okeke and B. Jahnezim. Comparison of polyaromatic hydrocarbon residue concentrations in *Clarias gariepinus* smoked with traditional and mechanical kilns. *Journal of Health and Pollution*, 10(8) (2020) 36 – 45.

[11] H. A. Moruf, M. M. Ogunbambo and R. O. Moruf. The relevance of information of shellfish quality on consumers' purchase decision in Lagos metropolis, Nigeria. *Journal of Agricultural Economics, Environment and Social Sciences*, 6(1) (2020) 71 – 79.

[12] S. B. Suleiman, M. Y. Diyaware, M. Aliyu and Z. B. Mohammed. Genetic Characterization of farmed and wild populations of African catfish (*Clarias gariepinus* Burchell, 1822) using the Random Amplified Polymorphic Marker. *Journal of Agricultural Sciences, Belgrade,* 65(4) (2020) 375-389.

[13] M. M. Ogunbambo, B. O. Bassey and L. O. Chukwu. Seasonal and temperature dependent variations in amino acid profiles of smoke-dried catfish (*Clarias gariepinus*, Burchell, 1822) using traditional and eco-friendly kilns in Lagos, Nigeria. albanian journal of agricultural sciences, 18(1) (2019) 32-37.

[14] S. I. Ogah, G. D. Miteu, E. O. Oyewole, J. O. Adebayo and E. O. Benneth. The role of technology in Nigerian Catfish production: A review. *Agricultural Reviews*, 43(3) (2022) 304-311.

[15] F. O. Areola. An evaluation of multidimensional justice conflicts in small-scale fisheries in Nigeria. In Blue Justice. Springer, Cham (2022) 161-178.

[16] S. K. Amponsah, H. Asare, H. Okyere, J. O. Owusu-Asante, E. Minkah and H. K. Ketemepi. Performance characterization of a locally developed fish smoke-drying kiln for charcoal and briquette. *Journal of Agricultural Science*, 14(11) (2022) 43-53.

[17] M. M. Ogunbambo. Drying profiles and quality evaluation of smoke-dried catfish (Burchell, 1822) using traditional and ecologically friendly kilns in Lagos, Nigeria. *Egyptian Academic Journal of Biological Sciences, B. Zoology*, 11(2) (2019) 147-156.

[18] I. P. Oboh, O. Sanni, N. Egun and C. P. Wilfred-Ekprikpo. The effect of actellic dust treatment on the proximate and mineral composition of *Synodontis nigrita* and *Tilapia mariae. Food & Environment Safety*, 18(1) (2019) 60-66.

[19] D. T. Otolowo. Assessment of storage stability of parts of dehydrated catfish (*Clarias gariepinus*) as influenced by treatments and packaging materials. *Journal of Agriculture and Food Research*, 1(2019) 100005.

[20] M. O. Jimoh and O. E. Oni. Performance evaluation of a fabricated smoking kiln. *Nigerian Journal of Technology*, 41(3) (2022) 476-482.

[21] G. K. Lelwela, T. N. Wijesinghe, S. M. C.Himali and E. D. N. S. Abeyrathne. Effect of Selected Wood Smoke on Physicochemical and Sensory Qualities of Tilapia (*Oreochromis niloticus*). *Journal of Aquatic Food Product Technology*, 30(1) (2021) 85-94.

[22] A. O. Lawal-Are, R. O. Moruf, M. M. Ogunbambo and B. R. Abimbola. Chemical compositional characteristics of shellfish crackers: reference to proximate and mineral profiles. *Journal of Chemical Society of Nigeria* 47 (1) (2022) 060 – 066.

[23] O. Olagunju. Profitability assessment of catfish marketing in Ondo State, Nigeria. *International Journal of Agricultural Science, Research and Technology in Extension and Education Systems*, 9(3) (2019) 163-169.

[24] E. P. Danba. A survey on socio-economic status, profitability of *Clarias gariepinus* by fish sellers along River Taraba, Taraba State, Nigeria. *International Journal of Fisheries and Aquatic Studies*, 10(2) (2022) 32 – 37.

[25] I. G. Ikoyo-Eweto. Analysis of fish value chain for nutrition security in Esan West Local Government Area, Edo State, Nigeria. *African Journal of Agricultural Science and Food Research*, 6(1) (2022) 1-11.

[26] O. M. Wangboje and O. E. Okhuarobo. Heavy metal profile in smoked Atlantic cutlass fish (*Trichiurus lepturus*, linnaeus 1758) from some major markets in Benin metropolis, Nigeria. *Adan Journal of Agriculture*, 2(01) (2021) 104-116.

(2022) ; http://www.jmaterenvironsci.com