The International Journal of Engineering and Science (IJES)
|| Volume || 9 || Issue || 04 || Series III || Pages || PP 29-33 || 2020 ||
ISSN (e): 2319-1813 ISSN (p): 20-24-1805

Fish Smoking Kiln Using Agricultural Wastes as Energy Source (A)

Daramola, J. A.[a*] Fasakin, E. A.[b] and Famurewa J.A.V.[c]
[a] Department of Biological Sciences, Bells University of Technology, Ota, Nigeria.
[b]Department of Fisheries and Aquaculture Technology, Fed. Univ. of Tech. Akure
[c] Department of Food Science and Technology, Fed. Univ. of Tech. Akure, Nigeria.
[*]Corresponding Author: Daramola, J. A.

---*ABSTRACT*---

A unique fish smoking kiln was constructed to use agricultural wastes such as sawdust, palm kernel shell and rice bran as alternative to the usual conventionally used charcoal as energy source for smoking fish. The smoking kiln has an estimated capacity of 40kg of fish/batch with six fish trays and 36 fish hooks. Heat transfer is by conduction and convection. Also, the rotatory wheel and axle on which the fish drying trays are anchored ensured even distribution of heat. Calculation further showed that the kiln has 69.4% energy efficiency and drying period of 10 hours at an average temperature range of 60 – 120^oC, depending on the type of agricultural waste used as source of fuel energy. Also determined were the fuel conversion ratio, drying rates and calorific values of the different agricultural waste products. Calorific value of the four agricultural wastes ranged between 16.2MJ/Kg in palm kernel to 30MJ/Kg in charcoal. The drying rates of the sawdust and rice bran ignited in the kiln compared favourably with that of the charcoal and they produced smoked fish similar in dryness and quality with fish smoked with charcoal. Palm kernel had the least drying rate of smoked fish in terms of weight per hour during the 10 hours period of smoking.

KEYWORDS: *fish smoking kiln, agricultural wastes, heat transfer, drying rate*

Date of Submission: 23-04-2020 Date of Acceptance: 04-05-2020

I. INTRODUCTION

Fish is a major source of animal protein and an essential food item in the diet of Nigerians because it is relatively cheaper than meat [1]. Fish protein is an excellent source of amino acids especially, the three that are lacking in protein of plant origin namely lysine, methionine and tryptophan. It also contains mineral elements such as: zinc, phosphorus, iron and calcium [2]. In addition, fish is a good source of riboflavin, vitamin A and D [3].

However, large quantum of fish wastage occurs in the artisanal fishery of Nigeria due to poor infrastructural and storage facilities. It has been estimated that fish wastage due to spoilage is between 30 and 50 percent of the total domestic fish production in the sector [4]. Also, [5] stated that low levels of technical know-how, improper processing techniques, packaging and marketing problems contribute to post-harvest losses to about 20-30% of fish catch. [6] reported that 40% of total fish catch in Nigeria are lost annually due to inadequate or poor preservation, processing and handling. This trend of fish wastage is actively checked by smoking, an ancient food preservation practice. According to [7], the smoking of fish from smouldering wood for its preservation dates back to civilization. In Nigeria, the most common technologies being utilised are the indigenous smoking kilns, which include, the traditional mud or drum oven, rectangular oven, Magbon-Alade kiln, Chorkor smoker and recently, the Altona oven [8]. Most modern smoking kilns already developed in Nigeria or elsewhere in Africa, such as that of the Nigeria Institute of Oceanography and Marine Research-NIOMR [9], Kainji Gas Kiln [10] and Altona Kiln [11] are rather too expensive and depend exclusively on scare and competitive energy sources for their effective operation. It is noteworthy that all these kilns have no provision for the control of smoke and temperature. However, this fish smoking kiln (FUTA model) has a unique characteristic in terms of design and operation. It has comparative overall advantage of producing evenly smoked fish products. The smoked fish products can compare favourably in the international markets. In addition, the use of agricultural wastes by the kiln portends a viable option and cost effective approach to fish smoking in commercial quantity in Nigeria. Consequently, this study evaluated the efficiency and other parameters of the fish smoking kiln using agricultural wastes as sources of fuel energy.

II. MATERIALS AND METHODS

The fish smoking kiln (Figure 1) was constructed through a collaborative research effort between the Departments of Agricultural Engineering (AGE) and Fisheries and Aquaculture Technology of the Federal University of Technology, Akure, Ondo State. Nigeria. The kiln was designed and fabricated to use different agricultural wastes. The smoking kiln consists mainly of two sections: the combustion and smoking chambers. In testing the performance of the fish smoking kiln to get the efficiency, drying rates and calorific values of the energy sources, smoking of sampled fish was carried out. Prior to smoking, fresh *Clarias gariepinus* were washed, degutted, washed again to remove the blood stain, drained for 20 minutes, soaked in 15% brine solution for 30 minutes and drained. Big fish were cut into chunks (125±1.05g) to create large surface area for heat and smoke transfer. Prepared fish were arranged on trays and made ready for smoking in the kiln. Four agricultural waste products- rice bran, palm kernel shell, sawdust and charcoal were procured and used in smoking the fish separately for 10 hours. Fuel sources were fed from the combustion chamber and the heat generated moved by convection to the fish in the trays at the smoking chamber. Three dial thermometers were attached to the roof, smoking and combustion chambers respectively to monitor the changes in temperature at each unit. At intervals of one hour, the fish hangers were turned through the manual hand crank to allow for even distribution of heat. Temperature of the smoking chamber was regulated between 80 and 100^{o}C. This was achieved by controlling the opening of the lid to the temperature regulator and moderating the air inlet to the combustion chamber, through the sliding slits. Mercury thermometer was used to measure ambient temperature, the mean daily temperature during the 10-hour of smoking was recorded and represented as T_0. The mean daily temperature within the combustion chamber was calculated and denoted as while the mean temperature in the smoking chamber was depicted as T_2. The values recorded from the temperature measurements ($T_{0,}$ T_1 and T_2) were used in the calculation of the energy efficiency.

Table 1: Specifications of the Fish Smoking Kiln

Parameters	Specifications
Height of kiln	1.6 metres
Width of kiln	0.8 metres
Depth of kiln	0.8 metres
Distance of fish tray to combustion chamber	0.3 metres
Length of the wheel and axle	0.7 metres
Depth of the wheel and axle	0.5 metres
Lagging material	Fibre glass
Sources of heat	Charcoal/palm kernel/sawdust/rice bran
Means of heat transfer	Convection/Conduction
Length of the smoking chamber	0.7 metres
Length of the combustion chamber	0.3 metres
Number of fish trays	6
Number of fish hooks	36 (6 per row)
Estimated capacity of the kiln	40 kg of fish/batch
Weight of the kiln	~ 300 kg

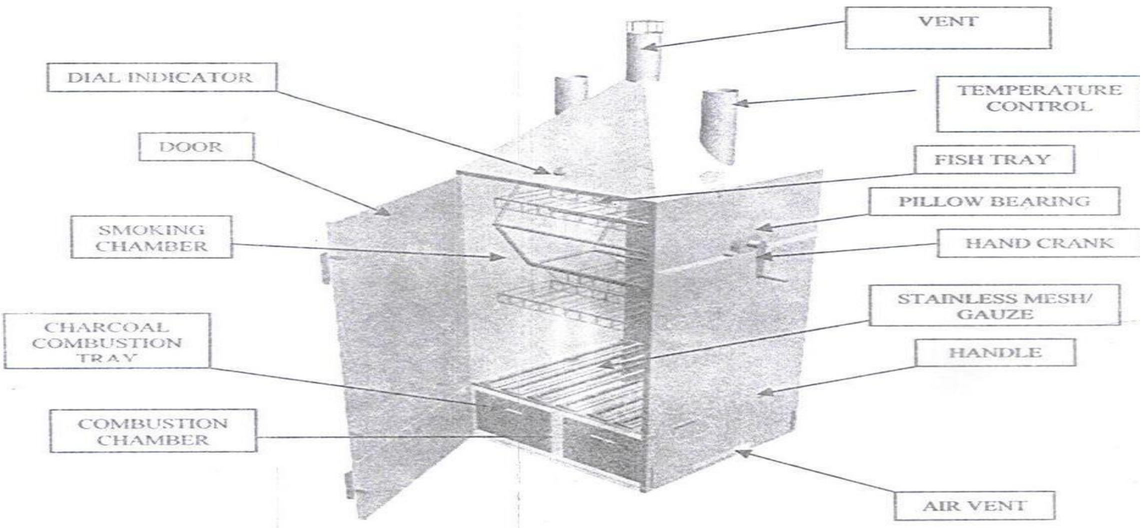

Figure 1: Details of the Fish Smoking Kiln (FUTA Model)

III. RESULTS AND DISCUSSION

Fish sample smoked with charcoal had the least water activity (A_w) at the end of the 10 hours of smoking. This was followed by fish smoked with sawdust and rice bran while palm kernel had the highest water activity. The mean moisture content of *Clarias gariepinus* smoked with charcoal was 10.41%, sawdust (11.54%), rice bran (12.27%) and palm kernel shell (16.43%). The drying rate curve (Figure 2) of charcoal and sawdust were similar, followed by that of rice bran and on top is that of the palm kernel. This implies that charcoal smoked best, followed by sawdust and rice bran while fish smoked with palm kernel shell was the poorest. Therefore, it is not surprising that in a review of the previous studies of agricultural wastes as fuel sources in modern kilns, palm kernel had not been mentioned or used [12 – 15].

Evaluation of the calorific value (burning temperature range) of the four agricultural wastes (Table 2) showed that charcoal produced the most stable and highest heat energy value of 30.0 MJ/Kg at 90-120^oC while palm kernel produced the least value of heat energy of 16.2 MJ/Kg between 60-80^oC. This result is similar to the work by [16], who reported the calorific value of rice husk to be 11.9 MJ/kg, groundnut shell 12.6 MJ/kg, palm kernel shell 20.3 MJ/kg and sawdust 19.1 MJ/kg. However, [17] revealed the same calorific value of 18.8 MJ/kg for both rice husk and sawdust while [18], showed the calorific value of coal to range between 25.8-27.6 MJ/kg. It is noteworthy that the palm kernel shell burnt poorly, requiring frequent fanning and giving of the least heat energy (temperature).

Energy Efficiency:

$$\eta = \frac{E_1}{E_2} = \frac{T_1 - T_2}{T_1 - T_0} \quad [19]$$

Where: T_0 = Mean Ambient Temperature (Outside the kiln) = 28.8 ^0C

T_1 = Mean inlet air Temperature (Combustion chamber) = 87.6 ^0C

T_2 = Mean outlet air Temperature (Smoking chamber) = 46.8 ^0C

$$\eta = \frac{87.6 - 46.8}{87.6 - 28.8} = \frac{40.8}{58.8} = 0.6939$$

% energy efficiency = η x 100 = 0.6939 x 100 = 69.4%

In this study, the model smoking kiln was found to be fuel efficient either in the use of charcoal, sawdust and rice bran (Table 3). The kiln produced evenly smoked fish products, better than traditionally smoked fish. Meanwhile, it has been reported that the amount of energy consumed during smoke-drying operation depends on the design of the kiln [20]. Though, [21] stated that excessive heat treatment impairs nutritional value of fish protein. In addition, less exposure to direct fire reduces the impact of phenol, which from public health angle is carcinogenic and damage human kidneys [22]. Control of temperatures in the model kiln also reduces physical loss caused by charring [23].

Table 2: Calorific Values of the Agricultural Wastes

Agricultural Wastes	Source	Calorific Value (MJ/kg)	Burning Temperature Range (^0C)
Charcoal	Wood	30.0	90 – 120
Sawdust	Mixed wood	19.5	80 – 110
Rice bran	Rice	16.6	90 - 100
Palm kernel	Oil Palm	16.2	60 – 80

Table 3: Drying and Fuel Consumption Analysis

Treatment	Wt of fresh fish (grams)	Wt of smoked fish (grams)	% Wt loss (Moisture content)	Smoking time (hours)	Fuel consumed (kilograms)	Kg of fuel per kg fresh fish	Kg of fuel per kg smoked fish	Cost of fuel per kg fish (Naira)
Rice bran	124.9	89.2	28.58	10	0.99	7.98	11.18	0.12
Sawdust	125.3	73.2	41.58	10	1.03	8.21	14.05	0.08
Palm kernel	125.9	99.6	20.89	10	1.36	10.79	13.63	0.16
Charcoal	126.1	72.3	42.67	10	1.15	9.11	15.88	0.13

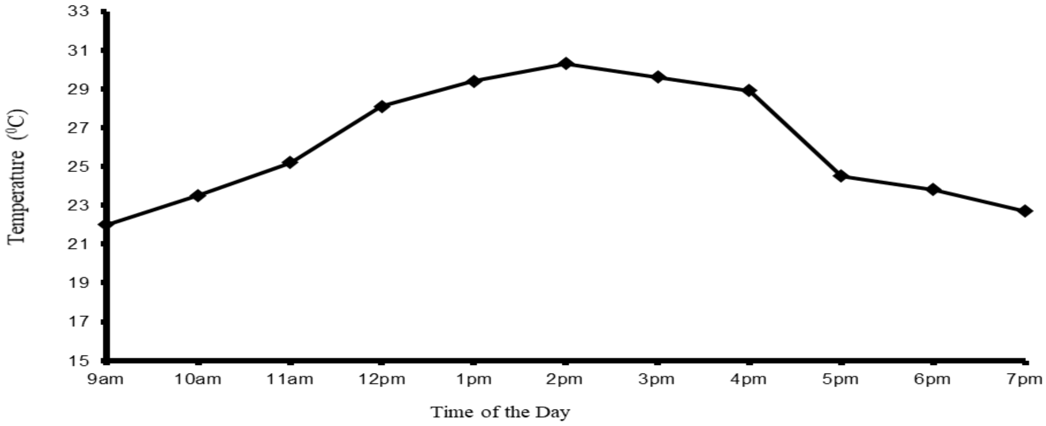

Figure 2: Average Ambient Temperature during the 4 days of smoking (Mid-February)

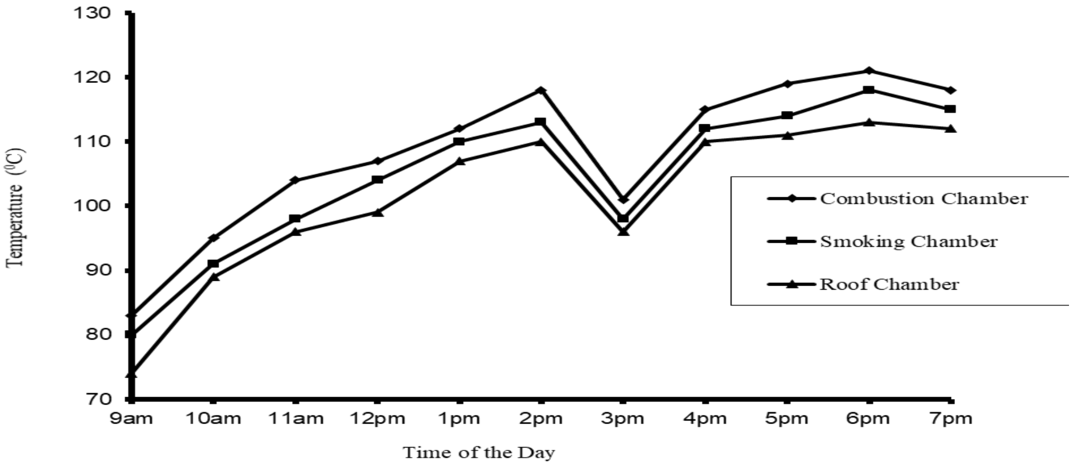

Figure 3: Average Temperature Changes within the chambers per unit hour

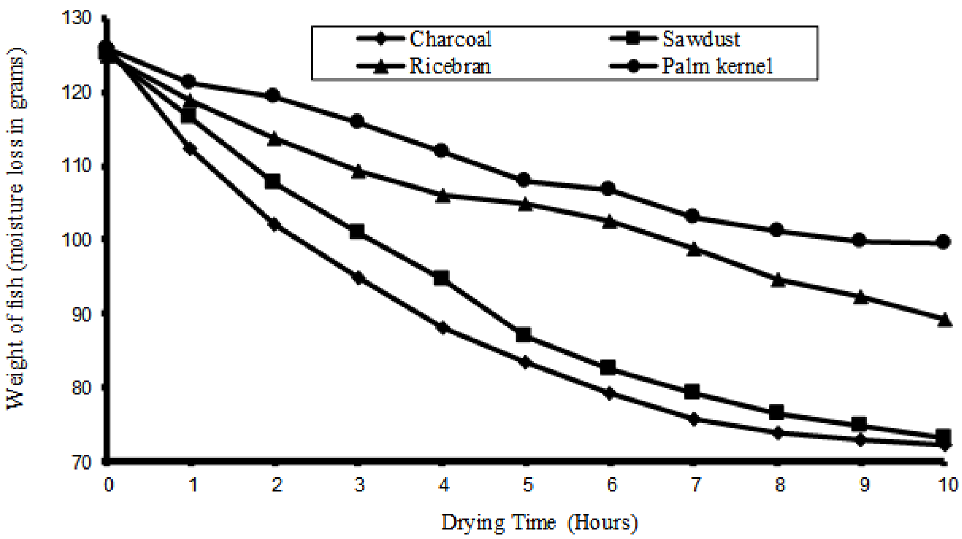

Figure 4: Drying Rate Curve of smoked *Clarias gariepinus*

IV. CONCLUSION

Agricultural wastes such as sawdust and rice bran are good substitute to the conventionally used charcoal in terms of heat generation and cost effectiveness. Palm kernel shell is not recommended because of the drudgery associated with fanning and slow burning process. The FUTA model fish smoking kiln is recommended to fish processors and other government agencies because of the unique quality of the kiln, such as capacity utilisation, heat and smoke regulation and quality of smoked fish products. To end with, the FUTA model fish smoking kiln is being popularised for general acceptance by the entire fisherfolks and processors in Ondo State and beyond

ACKNOWLEDGEMENT

The management of Federal University of Technology, Akure (FUTA), Ondo State, Nigeria is appreciated for providing a research grant for this innovative project.

REFERENCES

[1]. Onyia, L.U., E.F., Adebayo, K.O., Adewuyi, E.G., Ekwunife, and I.J., Ochokwu. Comparative economics of fresh and smoked fish marketing in some local government areas in Adamawa state, Nigeria. IIFET 2014 Australia Conference Proceedings. 2014
[2]. Famurewa, J. A. V., Akise, O. G. and Ogunbodede, T. Effect of storage methods on the nutritional qualities of African Catfish Clarias gariepinus (Burchell, 1822). African Journal of Food Science,Vol. 11(7) pp. 223-233. 2017
[3]. Olaleye, O. N. and Abegunde T. A. Microbiological Safety Assessment of Selected Smoked Fish in Lagos Metropolis. British Microbiology Research Journal 9(3): 1-5, Article no. BMRJ.17161. 2015
[4]. Tobor, J.G. A review of the fisheries and industry in Nigeria and status of fish preservation methods. NIOMR Technical Paper No 7, 14 pp. 1990
[5]. Jallow, A. M. Contribution of improved Chorkor Oven to Artisanal fish smoking in the Gambia. In Workshop on seeking improvement in fish technology in West Africa, Pointe-Noire (Congo), 7–9 Nov 1994 (p.66). IDAF, Technical Report. 1995
[6]. Oladosun, O. H., Akande, G.R and Tobor, J. G. Technology Needs Assessment in the Conceptualization and design of Magbon-Alade fish smoke-drying Equipment in NIOMR. In: FAO Expert consultation of fish technology in Africa. Kisumu, Kenya, 27 - 30th August, 1996
[7]. Olokor, J. O., Ihuahi, J. A; Omojowo F.S., Falayi B.A. and Adelowo E.O. Handbook of Practical Fisheries Technology. Fisheries Technology Division, National Institute for Freshwater Fisheries Research (NIFFR). New Bussa, Niger State, Nigeria. 2007
[8]. Balogun, A.M. Fish Handling an d Quality Control. In: Aquaculture Development in Africa, Training and References Manuals for Aquaculture Extentionists (Cowx I.G., ed.), Commonwealth Secretariat, London. Pp. 290-318. 1992
[9]. Talabi, S.O. and Igbinosun, J.E. A New Equipment for smoke drying of fish in Nigeria: Part 1. NIOMR Occasional Paper No. 33. 1975
[10]. Eyo, A.A. The construction and operation of a new mechanical gas smoking kiln (Kainji Gas Kiln) Kainji Lake Research Institute of Technical report Series No 7. 1981
[11]. Clucas, J.J. Fish handling, preservation and processing in the tropics. Part 2. Report of the Tropical Products Institute. G145, vii + 144 pp. 1982
[12]. Abolagba O.J., Uwakina, S. and Odiko, A.E. Utilisation of rubber wood (Hevea brasillensis) and sawdust as energy sources on the characteristics of smoked fatty fish. Applied Fisheries and Aquaculture, Volume 1(1):17-20. 2002
[13]. Abolagba, O.J. and Osifo, S.J. The effect of smoking on the chemical composition and keeping qualities of catfish, Heterobranchus bidorsalis using two energy generation sources. Journal of Agriculture, Forestry and Fisheries.Vol.5. pp 27-30. 2004
[14]. Abolagba O.J. and Melle, O.O. Chemical composition and keeping qualities of a scaly Fish Tilapia, Oreochromis niloticus smoked with two energy sources. African Journal of General Agriculture. Vol. 4, No. 2. pp 113-117. 2008
[15]. Oyewole, B.A., Agun, B.J. and Omotayo, K.F. Effects of different sources of heat on the quality of smoked fish. Journal of Food, Agriculture & Environment (JFAE). Vol. 4 Issue 2. 95-97 pp. 2006
[16]. Musa, N. A. Fuel Characteristics of Some Selected Biomass Briquettes. International Journal of Science and Technological Research. Vol. 3, No. 2. 2006
[17]. Bhattacharya, S.C. A study on Improved Institutional Biomass Stoves. Energy Program, Asian Institution of Technology, Thailand. 1- 6 pp. 2001
[18]. Adegoke, C.O. and Ajueyitsi, O.N.A. Optimum proportion of starch binders and paper waste additive in the formation of Coal Briquettes for Domestic Cooking. Nigerian Journal of Mechanical Engineering. Vol. (1), 1:62-68. 2003
[19]. Mujumdar, A. S. Drying fundamentals. In: C.G.J. Baker (ed.). Industrial drying of Foods. Blackie Academics and Professional, London. Pp 112-149. 1995
[20]. Abolagba, O.J., Aliu, B. S., Okonji, V.A., Eboka, F.Y. and Igene, J.O. A comparative study of the economy and efficiency of four types of smoking kilns used in Nigeria. Report and Proceedings of the sixth FAO expert consultation on fish technology in Africa. FAO Fisheries Report No. 574.pp 67-69. 1996
[21]. Roger, J.F. Improved cement block fish smoking kiln. In: Occasional papers, No. 3 of 1970. Fisheries Department, Ministry of Animal Industry, Game and Fisheries. Entebbe: Government Printer. 1970
[22]. Coan, M.L., Baggs, R.B. and Bosman, M.B. Demonstration of phenol on kidney, Res. Commun. Chem., Path. And Pharmacol., 36(2), 229-239. 1982
[23]. Technical Centre for Agricultural and Rural Cooperation-CTA. Improving fish preservation and processing in West Africa. Seminar Proceedings, Dakar, Senegal, 3-21 November. 1986