Original Research Article

Design and construction of a locally designed fish smoking kiln powered by bio-gas

Odunayo S. Ogundana[*1], Muhammed J. Yahaya[1], Anthony Alonge[1], & Taiwo W. Owa[2]

Affiliation

[1]Department of Agricultural Technology, Farm Mechanization Unit, Federal College of Freshwater Fisheries Technology, P. M. B. 1500, New Bussa, Nigeria.

[2]Ondo State Fadama Coordination Office, Alagbaka Akure, Nigeria.

***For Correspondence**

Email: odunmansam@gmail.com; **Tel:** +234 (0) 803 229 6102

Abstract

The origin of fish smoking dates back to antiquity. It is thought that the process was started by hanging the fish product over a fire which was used to reduce the moisture content of the product. Further advancement was made traditionally by the erection of mud, bricks or corrugated iron angle bar. The gas smoking kiln has been developed using locally available materials in the study area towards improving the existing fish smoking kiln techniques. The objective of this work is to improve the quality of smoked fish in Kainji Lake Basin in Nigeria at minimum production cost. The preliminary test performance of the kiln has been conducted using *Clarias gariepinus.* The result obtained shows that the kiln is less labour intensive and can handle different sizes of fish faster with better appearance of the end product than the conventional smoking methods.

Biological: Agriculture. Keywords: fish preservation, smoking kiln design, refractory materials, biogas

1.0 Introduction

As a renewable natural resource, fish is known to be a rich source of protein and other essential nutrients required for a balanced human diet. Okusanya et al [1] noted that fish, in addition to being a good source of vitamins and minerals, contains lysine, an essential amino acid found in proteins suitable for supplementing high carbohydrate diet. According to Adewuyi et al [2] fish is an important source of protein to the large teaming population in Nigeria and across Africa. It is a major source of income for coastal-dwelling communities and traders. In Nigeria, smoking is the most widely-used method for preserving fish and is the most common activity for women in fishing communities [3]. Practically all fish species available in the country can be smoked. It has been estimated that between 70 and 80 percent of the domestic marine and freshwater fish catch is consumed in smoked form [4].

In Nigeria, fish products are one of the cheapest, commonest and staple food supplements available to the teeming population [5]. Besides, fish culture, handling, processing, storage and distribution have also provided livelihood for millions of people. In view of the highly-perishable nature of fish worsened by the hot weather conditions in Nigeria, harvested fish is quickly subjected to

spoilage due to action of enzymes and bacteria said to be present in the fish [5]. Appropriate processing of fish is thus expedient to enable maximal use of the raw material, to obviate wastage and enhance production of value-added products for more profitability [10]. Traditionally, several methods of fish handling and preservation have been developed in attempt to extend the shelf life of harvested fish. The commonly known methods are smoking, salting, sun-drying, freezing, chilling and brining [10].

Renewable energy is that energy that comes from renewable resources such as the sun, wind, organic matter and so on. These resources are constantly replenished by nature and cleaner sources of energy. Agricultural waste such as cow dung, poultry droppings and so on pose a lot of difficulties in terms of their disposal [3]. These wastes from the basic raw materials are used for the generation of a renewable energy known as bio gas. Biogas is produced by the anaerobic digestion or fermentation of biodegradable materials such as, manure, sewage, municipal waste, green waste, plant material, and crops. Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S), moisture and siloxanes [3]. Lack of biogas industry especially in Nigeria, increase in fuel prices and availability of waste makes biogas inevitable [3]. The development of a biogas technology provides a lot of benefits economically and technologically [3]. In the rural area, biogas finds great application in fish processing [3]

Multiple studies have been undertaken to develop an air-heating burner that can be used for a variety of purpose heating or drying food products. Piegne et al. [9], conducted an experimental study of the use of simple heat exchangers type gas heat exchangers for air heating utilizing wood fuel, with the use of fins on the cold-fluid side to increase heat transfer currents. All components of the heat exchanger made of high corrosion resistance stainless steel which are expensive.

Yunus et al. [12] investigated the design of heat exchangers that are integrated directly into simple biomass stoves for food drying purposes (primarily intended for use in developing countries). The plan of the base system involves a simple parallel concentric current tube heat exchanger. The fins are also included on the cold-fluid side as shown above to increase heat transfer. Stainless steel (AISI 304) material was selected, although it has low thermal conductivity. Therefore, this study focused on the design and development of a novel fish kiln borrowing from ceramic kiln construction technology. The project was executed by utilizing insulating, dense bricks and other locally available resources. The evaluation of the kiln design suggested that the applied knowledge of ceramic kiln thermal technologies could be a pragmatic way towards improving fish smoking techniques.

2.0 Materials and Methods

2.1 Sourcing of Raw Materials and Brick Making

Nwadibie carried out two major tests (heat resistant and the shrinkage test) on the various mixes of clay, sand, grey cement and white cement. After the optimization, the ratio 5:3:1:1 was selected out of all the samples because it had a good strength, minimal shrinkage, minimal crack, high resistance to heat and was more economical [7]. The clay, sand, grey cement and white cement were mixed in proportion of 5:3:1:1 and wet-mixed until a satisfactory even distribution of aggregates was achieved. The prepared clay was used to build the kiln wall and fill the door casing.

An insulating and dense firebrick was chosen as the main building block using a brick size of 20 x 10 x 8 cm. The bricks were made manually with a slop-mould (wooden frames) [8].

2.2 Firing and Sorting of Bricks

Dried bricks were fired with a 45 cubic foot wood kiln using wood as fuel and following a standing rule of one finger apart in the arrangement of the bricks for firing. The temperature attained for the firing was 900^{o}C, after which the kiln was allowed to cool down for brick offloading. Fired bricks were sorted out and set in a dry place from where they were transferred to the building site [6].

2.3 The Kiln Design

The rate of fish processing production is to be considered in the design of fish kiln structure. The design of fish kiln using biogas as source of energy goes a long way to encourage fish processors in Kainji lake basin area to process high quality of fish and reduce aforestation at Kainji National Park Reserve.

2.4 Kiln Building

The fish kiln built to enable sustainability of heat within the heating chamber having an iron frame structure inside the wall with structural dimension of 0.92 x 0.76 x 0.70m. The gas burner is sited at the center base of the combustion chamber and oil collecting pan is above the heating chamber which collects the fish oil extracted during drying and also serves as interface between combustion chamber and drying chamber. There are provisions for 3 rails of wire mesh trays in the chamber; each tray rests on the structure frame. The kiln door was fabricated with galvanized iron having a thick clay cover which minimizes heat loss from the kiln system. At the upper most point of the kiln, an opening (chimney) was provided for exit of excess heat and pressure in the kiln system [8]. The constructed kiln is shown in plate 4.

3.0 Bio-gas

3.1 Collection and Preparation of Materials for Biogas

Bio-gas digester was filled with 20 kg of cow dung and 40 kg of water were the raw materials used for this research. Fresh cow dung was collected from the cattle ranch of Federal College of Freshwater Fisheries Technology, Agricultural Department, New Bussa, Niger State, Nigeria. Cow dung and vegetable wastes were mixed together and poured inside the digester. Generated gas was stored inside tube, ready to be used. The biogas burner is shown in plate 2.

4.0 Smoking Process

4.1 Fish Preparation

Catfish were used for this research work. Trials so far conducted have indicated that fish prepared in the normal way could be smoked using this kiln but for best results of the finished product the following approach is recommended [7].

4.2 Cleaning

The fish was cleaned by de-scaling, eviscerating and thorough washing in water. Large fish should be be-headed and split, then cut into small chunks to leave a large surface area for smoke absorption.

4.3 Immersion in Brine

The dressed fish was immersed into a clean solution of brine for one hour. 60% saturated brine was observed to give the smoked product a glossy appearance and good taste. The brine also helps in the osmotic removal of free water from the tissues thereby assisting the drying process.

4.4 Hanging

The fish was removed from brine solution and allow moisture to drip by leaving the fish in a perforated basket or hanging them in the open well protected from flies and other dipterans insects.

4.5 Performance Evaluation of the Smoking Kiln

The heating and smoking efficiency of the smoking kiln was evaluated by heating up the empty kiln for five hours and the temperatures were measured with digital temperature controller at one-hour interval for five hours. The prepared fish were placed on wire meshes inside the chamber which has a capacity of handling 25 to 30kg of fresh fish. The heating system (gas burner) at the center base of combustion chamber is controlled by valve. Heat gradually rises as soon as the gas burner is ignited. The gas regulator was shifted to the medium position for one and half hours (cold smoking) to reach a maximum temperature of 40°C, after which the regulator remain at maximum position until the smoking is complete. At this point temperature in the kiln will remain essentially between 80 - 120^0C. Excess heat and smoke in the drying chamber leave the kiln through chimney. Heat and smoke are uniformly distributed in the smoking chamber hence it is not necessary to alter the position of the fish on the racks until the process is complete. This also saves the product from mechanical damage.

Plate 1; Fish in the kiln

Plate 2; Combustion chamber

Plate 3; Evaluation of the kiln

Plate 4; Plate 4; Kiln structure

5.0 Results and Discussion

5.1 Results

5.1.1 Appearance: Sensory evaluation of the fish samples was conducted using ten panelists in Agricultural Technology processing laboratory, (FCFFT). A 9-point hedonic scale ranging from 9 = like extremely to 1 = dislike extremely was used to evaluate the samples for appearance, flavour, taste, texture and overall acceptability. Fish smoked using the biogas powered fish kiln was found to be better in terms of appearance and based on the black golden luster, which the smoke from fish oil may have conferred on the product as opposed to those with the traditional smoking kiln. . The biogas powered fish smoking kiln was rigid and operates perfectly with less manual effort in operation. The smoking kiln was tested with fresh catfish of 1.5kg on each tray (See table 1).

Table 1: Drying rate of catfish, drying temperature and drying time.

Time(hr)	Moisture content (g)	% weight loss (wb)	Drying chamber Temp. (^{0}C)
1	1.5	12.0	35
2	1.25	13.3	40
3	933	13.1	70
4	712	14.6	76
5	486	15.2	81

The moisture content though averagely low but are not to a safe level. The short time give is (1hr) as seen in Table 1 above. If the following parameters are properly considered i.e., the moisture

content at onset, fish weight, fat content, heat intensity supplied, including the smoking chamber heat dynamics; a moisture content reduction to a safety level of 10% -15% can be achieved by a projected 4-5 hours of Smoking. This system will replace the local method of smoking fish that normally spans over 24 hours in addition to intensive labour and heat skin laison effects. The residence temperature of the system is 81. 4 ^{0}C and 35.4 ^{0}C in the chamber and may increase the drying rate by recycling the drying process.

5.2 Discussion

The oil from fish drier does not drop on to the flame, thereby reducing cancerous element from depositing on the smoked products (Polycyclic Aromatic Hydrocarbon) and the weight loss of 15% after 5 hours of processing showed an improvement over the weight loss reported by some researchers which implies a longer shelf life of the finished products. The duration of the operation can be regulated according to the customer's demand and the temperature rose to above 40 ^{0}C within the first 2 hours and continued even after gas burner has been switched off through the night due to quality local composite materials used for the kiln wall construction.

The drying chamber is easy to operate, the temperature distribution is uniform inside the smoking kiln and the external body temperature is equal to the surrounding temperature due to quality of materials used thus, operators are safe to be close to the system when operating it. The dried fish is not covered with black soot because the design prevents direct contact of flame to the content of the smoking chamber. The cost analyses of construction are presented below;

Table 2: Cost analyses of construction of gas-powered kiln

S/N	MATERIALS	COST OF PRODUCTION(#)
1	Tubes	18,000
2	Gas burner	7,500
3	Hose	1,000
4	Gas Regulator	7,500
5	One Packet of Electrode	1,000
6	One Padlock	500
7	One length of hollow pipe	2,000
8	Two Angle bar	3,000
9	One flat bar	1,000
10	One and Half-length of inch	3,000
11	pipe	300
12	One roll of binding wire	15,000
	Workmanship (Welder)	
	Ground Total	**#60,000**

6.0 Conclusion

A bio-gas powered fish kiln structure to accommodate 25 – 30 Kg fish has been designed and constructed. The developed fish smoking kiln is easy to operate, maintain, cheap, portable and environmentally friendly. The kiln was tested using Catfish and found to perform efficiently while drying the fish with a safe moisture content of 10% to 15% within five (5) hours. It can also be used for drying and re-drying soft tissue of animal and plant food sources. The fish smoking kiln attains a recommended temperature within the shortest possible time. The cost of the fish kiln

structure using bio-gas as source of energy and other needed materials is about #60,000.00k which would be profitable and reliable if all the necessary environmental factors are observed, to Kainji lake artisanal fish processor.

References

1. Adamu IG, Kabri HU, Hussaini ID, & Mada AD (2013) Design and construction of fish smoking kiln. J. Engr. and Technol. Res. Vol. 5(1), pp. 15-202.

2. Adewuyi SA, Phillip BB, Ayinde IA, & Akerele D (2017). Analysis of Profitability of Fish Farming in Ogun State, Nigeria, J Hum Ecol, 31(3): pp 179-184

3. Bello SK & Alamu OS (2016). Design and construction of domestic biogass degester. *International Journal of Applied Engineering and Technology* ISSN: 2277-212X (Online) An Open Access, Online International Journal Available at http://www.cibtech.org/jet.htm2016 Vol. 6 (2)

4. Bolaji BO (2005). Performance Evaluation of a Simple Solar Dryer for FoodPreservation. Proceeding of 6th Annual Engineering Conference of School of Engineering and Engineering Technology, Federal University of Technology, Minna, O.K. Abubakre, E.N. Onwuka and B.A. Alabadan (Eds.) 8-13. Published bySEET, Federal University of Technology, Minna, Nigeria.

5. Eyo AA (2004). Provost alerts Federal Government over foreign fishermen in Lake Kainji. In The Guardian Newspaper Thursday, October 7, 2004 Vol. 21, No. 9. pg. 50

6. Issa WA, Fatile OE, Abdulmumuni B, Ologunye OB, & Okpara IN (2020). Design and Fabrication of a Charcoal Fish Smoking Kiln. International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-9 Issue-1

7. Nwadibie F (2015). Development of a muffle furnace. Msc thesis submitted to the department of Agricultural and Bioresource Engineering. Federal University of Technology, Minna, Niger State.

8. Ogundana OS, Abdulkadri A, Jibril D, & Owa TW (2020). Design and construction of electric fish smoking kiln using locally available composite materials. *Journal of Engineering Research and Reports*, Vol. 13(4): 15-21.

9. Okusanya MA, Oluwagbayide SD, & Ogunlade CD (2021). Impact of Improved Smoking Kiln Design on Hygiene and Timeliness of Drying of Smoked Fish. *Turkish Journal of Agricultural Engineering Research (TURKAGER)*, 2(1): 133-155. https://doi.org/10.46592/turkager.2020.v02i01.010

10. Silva BO, Adetunde OT, Oluseyi TO, Olayinka KO, & Alo BI (2011) *Effects of the methods of smoking on the levels of polycyclic aromatic hydrocarbons (PAHs) in some locally consumed fishes in Nigeria. African Journal of Food Science* Vol. 5(7), pp. 384-391, Available online http://www.academicjournals.org/ajfs

11. Tawari CC & Abowei JFN (2011). Traditional Economics of fish production in Kaduna State, fish handling and preservation in Nigeria. Asian Nigeria. ARPN. *Journal of Agricultural and Journal of Agricultural Sciences*, 3(6): 427-436.

12. Yunus YM, Al-Kaviem HH, & Albaharin KAK (2011). Design of a Biomass Burner/Gas-to-gas Heat Exchanger for Thermal Backup of a Solar Dryer. *Journal of Applied Sciences, 11: 1929-1936.*