ORIGINAL RESEARCH ARTICLE

Development and assessment of a locally designed fish smoking kiln using insulating materials

*[1]Seyi O. Ogundana, [1]Juneid M. Yahaya, [1]Anthony Alonge, & [2]Wunmi T. Owa

Affiliation

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

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

***For Correspondence**

odunmansam@gmail.com

Abstract

The origin of fish smoking dates back to antiquity. In ancient times, fish was hung over a fire which helped to reduce its moisture content. 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 Area in Nigeria at minimum production cost. The preliminary test performance of the kiln has been conducted using *Clarias gariepinus,* known generally as catfish. 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.

Keywords: *Fish, preservation, smoking, kiln, refractory materials*

Introduction

As renewable natural resources, fish is known to be a rich source of protein and other essential nutrients required for a balanced human diet. [8] 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 [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 [6]. 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.

In Nigeria, fish products are one of the cheapest, commonest and staple food supplements available to the teeming population [4]. Besides, fish culture, handling, processing, storage and distribution have also provided livelihood for millions of its people. In view of the highly perishable nature of fish worsened by the hot weather conditions in Nigeria, harvested fish quickly get prone to spoilage due to action of enzymes and bacteria said to be present in the fish [4]. Appropriate processing of fish is

thus expedient to enables maximal use of the raw material, to obviate wastage and enhance production of value-added products for more profitability [9]. Traditionally, several means of fish handling and preservative methods have been developed to in attempt to extend the shelf life of harvested fish and commonly known are smoking, salting, sun-drying, freezing, chilling and brining further expatiated in [9].

Smoke drying among other traditional methods therefore has remained a choice means of preserving fish products, one of the cheapest sources of animal protein in Nigeria. Among the fish processor in Kainji Lake Basin areas, the most commonly found fish smoking facility for small-scale fish processing is the open top/barrel type while few people have sought for an enclosed structure to achieve more effective heat work [5]. Also, the use of *Chorkor* kiln which seems to be an improvement over the traditional open fish smoking system has been adopted. It was observed that most of the local efforts on developing viable smoking kilns do not consider heating efficiency and conservation which could in no little means can reduce the firing cost and enhance profitability for the artisanal fisheries sector. In order to improve on these methods, several technological approaches has been reported, including harnessing the solar energy for fish drying, the use of electric heaters [1]. The advantages of smoking fish are manifold. Fish smoking enhances flavor and prolongs shelf life.

Therefore, this study therefore 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.

Materials and Methods

Sourcing of Raw Materials and Brick Making

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) with composition of 30% sawdust, 60% kaolin and 10% ball clay. Kaolinite clay, the main refractory material used in the brick making was sourced from a neighboring material site in New Bussa, Niger State [6]. The combustible material, sawdust, was collected from Dogongari sawmill. The raw kaolin was screened with the builder's mesh to have a consistent particle grain. About six hundred bricks were moulded within two weeks. Having attained a good drying time, the bricks were set for firing.

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.

The Kiln Design

The rate of fish processing production was considered in the design of the fish kiln structure. The design of fish kiln using gas 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 deforestation of Kainji national park reserve.

Kiln Building

The fish kiln was built with clay to enable sustainability of heat within the heating chamber having an iron frame structure inside the clay 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. 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.

Smoking Process

Fish Preparation

Samples of fresh 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 approach of [3] is recommended.

Cleaning

The fish was cleaned by descaling, eviscerating and thorough washing in water. Large fish are beheaded and split, then cut into small chunks to leave a large surface area for smoke absorption.

Immersion in Brine

The dressed fish were immersed into a clean solution of brine for one hour. 60% saturated brine has been 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 [7].

Hanging

The fish were removed from the 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 dipteran insects. The fish are now ready for smoking. In all cases good quality raw materials should be used. Poor quality fresh fish become soft and flabby breaking easily on handling after smoking though the surface colour may appear normal.

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 controller at one hour interval for five hours. After fish have been dressed for smoking, they were placed on wire meshes inside the chamber which has a capacity of handling 15 to 20kg 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 then be shifted to the medium position for another one hour after which the regulator remained at maximum position until the smoking was complete. At this

point, temperature in the kiln remained essentially between 100 - 120^{0}C. Excess heat and smoke in the smoking chamber left the kiln through the chimney. Heat and smoke were uniformly distributed in the smoking chamber hence it was not necessary to alter the position of the fish on the racks until the process was complete. This also saved 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

Results and Discussion

Results

Fish smoked using the gas-powered fish kiln was found to be better in terms of appearance and based on the black golden luster, which the smoke from the fish oil may have conferred on the product as opposed to those with the traditional smoking kiln. The gas-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 (Table 1).

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

Time (hr)	Moisture content (g)	% weight loss (wb)	Drying cham 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, are not to a safe level. The short time given is 1hr as seen in Table 1. 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 lesion 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.

Discussion

The oil from the fish drier does not drop on to the flame, thereby reducing cancerous element from depositing on the smoked products and the weight loss of 15% after 5 hours of processing showed an improvement over the weight loss reported by Adamu et al., (2013). 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 the construction is presented in Table 2.

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

S/N	MATERIALS	COST OF PRODUCTION (#)
1	Gas cylinder	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 pipe	3,000
11	One roll of binding wire	300
12	Workmanship (Welder)	15,000
	Ground Total	**#60,000**

Conclusion

A gas-powered fish kiln structure to accommodate 15 – 20 Kg fish was designed and fabricated. The developed fish smoking kiln is easy to operate and maintain, it's 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 gas burner as source of energy with clay wall and other needed equipment is about #60,000.00k

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. Bolaji BO (2005). Performance Evaluation of a Simple Solar Dryer for Food Preservation. 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 by SEET, Federal University of Technology, Minna, Nigeria.

4. 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.

5. 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

6. 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.

7. 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

8. 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

9. 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.