Design, Fabrication and Operation of a Smoking kiln

Emmanuel Munakurogha Adigio, Abiodun Oluseye Adeyemo, Damilola Awosusi

***Abstract*— This project is the development of an innovative fish drier that is energy efficient and overcome major technical barriers that currently preclude their wide–spread use both locally and industrially. Although, the system is fuelled using coal or wood, the drier is environmentally friendly due to the incorporated energy recovery technology, increase in hot air residence time. The materials for the fish drier are locally and cheaply sourced. The main advantage of this drier is its usability at anytime and anywhere. The drier can be fabricated in any size and test indicates that the increase in size does not reduce the effectiveness of the equipment. The operation of the drier is safe since there is no need to open the drier for displacing the content of the drying chamber. This particular model can dry over 210 kg of cat fish per day when using pinning rods provided in the package. After a long use and observation of the kiln, experiment was performed for about 10 kg of fishes, Clarias Gariepinus, to determine some operational qualities of the kiln. Test results indicated an average operational temperature of is 80^0C and weight loss of > 60% on the smoked fishes. Quality of finished product was good in colour and dryness, indicating a long shelf life.**

***Index Terms*— fish drier, catfish, drying, energy efficiency.**

I. INTRODUCTION

Fish is an important source of food and income to many people in developing countries. In Nigeria, most people depend wholly or partly on the fisheries sector for their livelihood.

In recent time, many individuals and cooperatives are going into small and big scale fish farming [1, 2, 3]. Results from these ventures are so encouraging that the problem of preservation is becoming a serious issue, thus, the need in providing new affordable and effective method to reduce post harvest losses cannot be overemphasized. Several researchers [4, 5, 6] reported that most of the fish processing communities are employing traditional techniques that have existed for over 10 years. Various traditional methods are employed to preserve and process fish for consumption and storage. These methods include chilling, super chilling, freezing, drying, smoking, salting and fermentation [7]. In using the traditional methods, quality control and sustaining good hygienic conditions are difficult where market values diminishes due to damage and non attractive appearance of the processed fish [8]

In Africa, drying from direct sun and smoking using wood or coal are the most widely practiced methods of fish preservation. In order to improve on these methods, several technological approaches has been reported, including harnessing the solar energy for fish drying [9, 10, 11], the use of electric heaters [12] and the use of smoking kiln [13].

The advantages of smoking fish are manifold. Fish smoking enhances flavor, prolongs shelf life, and increases utilization in soups and sauces. Smoking is inexpensive, requiring little energy, little equipment needed; quality and nutritional value reasonable. It increases protein availability to people throughout the year and makes fish easier to pack, transport and market [14]. Davis *et al* [6] reported same reasons for processors engaged in fish smoking, including storage for lean times and adding more market value.

The aim of this project is to develop an innovative fish drier that will be energy efficient that will overcome major technical barriers that currently preclude their wide – spread use both locally and industrially.

II. DESIGN AND FABRICATION

A. Materials

The fish drier was designed to use locally available materials for the fabrication and maintain high energy efficiency that allows maximum combustion of the fuel used. The product is such that the principles of the working of the drier can be replicated in any size to suit operators need.

The materials for the fabrication include galvanized plate of gauges 16 and 20 for the main body, 4 mm plate for the coal pot, stainless steel grill for the coal support, 4" pipe for the exhaust and high density rock wool lagging materials, obtained from the local market. The wool thickness over the drier is 5 cm selected from the thermal insulation handbook [15]. The choice of material is made from the effective costing and material availability. The rack for placing the fishes and the pins in the drying chamber is built from ½" angle iron and one quarter rod respectively. The smoker body and the coal pot are supported from thick 2" angle iron structure.

B. Dimensioning

This drier is designed to dry about 70 pieces of catfish with an average mass of 3 kg. Due to the lack of electricity in most rural area and the demand for tasty smoked fish, the source of heat energy is from wood or coal. The coal pot is designed to carry a load of 3.0 kg at a time.

The design is such that the residence time of the hot flue gas can be controlled by adjustable baffles and valve mounted on the exhaust. Hence, the heat distribution inside the equipment is uniform. The design also prevents the fish oil from dropping into the flame; a plate separates the flame from the processed fish. Since, there is no direct contact of the fish to the flame; the fishes will only loose moisture and would not be charred. The drying is effected in a uniform temperature of about 80^0C.

Manuscript received March 22, 2015.

Emmanuel Munakurogha Adigio , Department of Mechanical/Marine Engineering, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria

Abiodun Oluseye Adeyemo , Department of Fisheries and Aquatic Studies/Animal Science

Faculty of Agricultural Technology, Niger Delta University, Wilberforce Island

Damilola Awosusi , Department of Fisheries and Aquatic Studies/Animal Science Faculty of Agricultural Technology, Niger Delta University, Wilberforce Island

A cat fish of 3 kg, cleaned and prepared for drying, occupies a space of 15 x 15 x 10 cm^3 = 2250 cm^3, thus, the volume 70 cat fish will occupies = 70 x 2250 cm^3 = 157,500 cm^3. Assuming the space between the fish (for maneuverability) space occupied by the racks is half of the fish space, then, the total volume of the drying chamber is 1.5 x 157,500 = 236,250 cm^3. Fixing the rows in the drying chamber to be four (4), taking about twenty cat fishes per row, the height of the chamber is estimated to be 1.5 x 15 x 4 (rows) cm = 90 cm.

A fish pin takes five fishes, thus, the depth of the chamber is 1.2 x 15 x 5 = 80cm. The width of the drying chamber is therefore, 236,250/90/80 = 32 cm. For esthetic purpose, evenness and operation convenience, the volume for the chamber was taken as 90 x 80 x 60 cm^3. The air passage is 15 cm to accommodate the adjustable baffles.

Again, in order to reduce material, but allowing enough space for the flame, the lower part is inclined on the left and right side at an angle of 45^0 towards the coal pot.

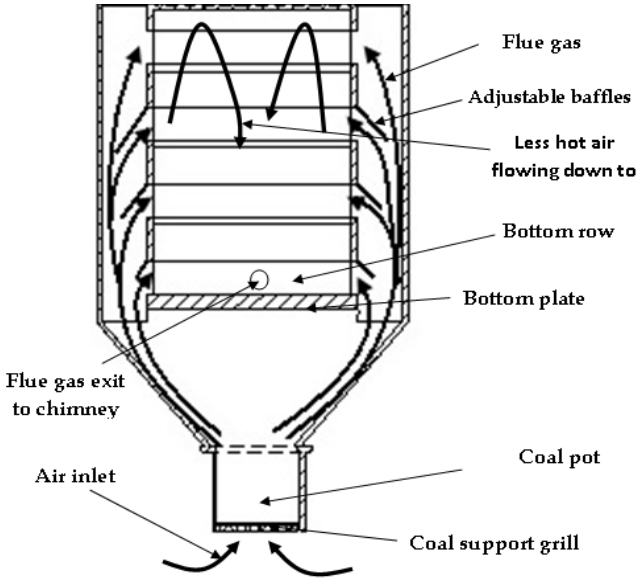

Figure 1 Sketch Diagram of the Drier.

C. Operations

In the operation of the drier, after lighting the charcoal in the coal pot, it is kept opened for a while, until the amber is uniform. On closing the pot the air supply will flow mainly through the bottom of the coal grill, thus, maximizing the absorption of the heat by the flue gas and maintaining a maximal combustion rate. The fish prepared for drying can be loaded using pins provided on racks or placed on aluminum foils.

The smoke chamber should be firmly shut, and opened at intervals of 1.5 to 2 hours for inspection of the smoking process. Figure 1 is a sketch diagram of the drier showing the flue gas flow, with the adjustable baffles for the gas distribution control. The bottom plate prevents the direct contact of the flame to the content of the drier. The plate also prevents the oil from dropping over the flame, reducing the production of cancerous gases [16].

The flue exhaust is situated just above the bottom plate so that only less hot air will leave the chamber, thus, increasing the hot air residence time. The lagging ensures that the drying chamber remains hot for a long period after the coal or wood is burnt out.

D. Production

The design was produced using CAD software, SOLID EGDE, and the drier was fabricated in a workshop, Ingenieurs Pratique Company situated in Yanagoa, Bayelsa State, Nigeria. The galvanized plates and supports were put together by welding.The exhaust of flue is situated at the bottom row and regulated with a valve to control the residence time of the hot gases in the drying chamber.

Pins for the pinning of the fish and racks for the support so that the products will not rest on the plates, are fabricated. This is to ensure the reduction of contamination from the metals. The drier is then totally lagged with the rock wool and finally covered with 0.5 mm aluminium sheet, to protect operators' skin.

The coal pot is made from a thick steel plate and fitted to the bottom of the drier with bolts and nuts. The support for the unit is a thick 2" angle iron with space under the coal pot for the collection ash droppings.

III. QUALITY CHARACTERISTICS OF THE COAL FISH DRIER

A. Energy Assessment

The calorific value of the dry coal is 28.3 MJ/kg. From the test running of the drier, the quantity of coal to reduce the moisture content by > 60%, while smoking 210 kg cat fish is about 15 kg, running for 20 hours. Total energy input is therefore, is 424.5 MJ, and the energy input per kilogram of fish dried is 2.02 MJ. The total cost for the energy input is 15/2 x 300 Naira, that is, N 2250.

There is minimal loss of heat from the drier due to the lagging. The fall in temperature in the drying chamber during a shutdown of 10 hours after an eight hours operation is less than 10%. Hence, the drying could be sustained through the night without adding more coal.

B. Economic Assessment

The total cost of production of this model of fish drier is N 178,000. It has low maintenance cost, from the report of its use for the past 3 years report of the first prototype. The fuel, charcoal, is readily available and since emission is low from observation, the new fish drier is environmentally friendly. The air flow is natural drought, thus, eliminating the addition of electric fans.

IV. EXPERIMENTATION

A study of the smoking kiln was carried out in the Department of Fisheries and Aquatic Studies and Animal Science, Faculty of Agricultural Technology, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria. The smoking kiln was designed, fabricated and supplied by Ingenieurs Pritiques Company (IPC), situated in Yenagoa, Bayelsa State, Nigeria in 2011.

The University is situated at 4.97^0 North and 6.11^0 East, and 79 m above sea level. The relative humidity is 83% with a maximum temperature of about 30^0C.

Over 100 *Clarias Gariepinus* fishes (mud fish) were bought from a fish farm in Yenagoa, about 25 km from the University. The fishes were then prepared, degutted, washed with clean water and folded using their spines to keep the

folded, for smoking. The washed fishes were weighed in fives due to the sizes and the precision of the weighing machine (Salter Weighing Scale).

For the purpose of the experiment, the 50 pieces pre-weighed fishes were placed on wire meshes that are oiled with palm oil to prevent them from sticking to the separation plates. Charcoal was also weighed to fill the coal pot before lighting. Since, the coal pot capacity is 3 kg, fresh coal was added every hour for the first six hours. After the sixth hour the kiln was allowed to run without any addition of coal until the next day 13 hours later.

The temperature (Mercury Thermometer) of the smoke chamber was recorded and samples of fishes weighed every 2 hours. Data collected was tabulated and studied. A total of five fishes were sampled from the kiln.

From the initial weight of the fishes, the standard deviation, variances and mean were calculated. Using the values obtained from the smoking operation, the weight every 2 hours were calculated.

V. RESULTS

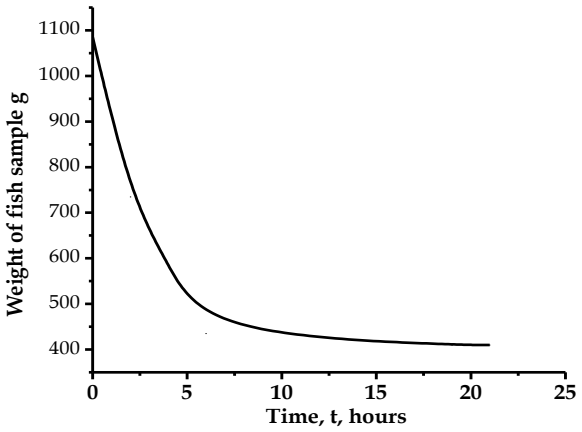

Figure 2: Graph of Fish Sample Weight Variation versus Processing Time

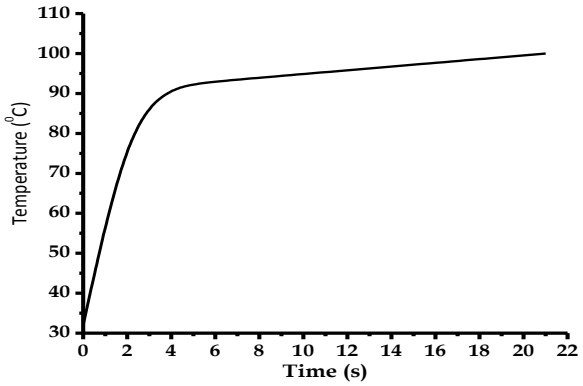

Figure 3: Temperature versus processing time

A. *Data*

The total initial weight of the fish processed is 10,850 g, with a mean weight of 217 ± 118.4g. Sample weight after statistical analysis, used for the determination of the weight loss was 1,085 g.

B. *Weight Los*

Figure 2 shows the fish sample weight versus the time obtained through the processing period It was considered that at the zero hour the sample weight was 1,085 kg respectively. In the first 2 hours, 32% of weight loss was recorded. The fish samples continued to lose weight until stagnation at 62%, after over 19 hours of processing. It is worth noting that the weight losses after 4 hours and 6 hours were 46% and 60%

C. *Processing Chamber Temperature Variation*

Results of temperature measurement in the processing chamber are illustrated by Figure 3. Readings were taken after every 2 hours, to reduce the effect of heat loss when taking the readings.

VI. DISCUSSIONS

A charcoal (or wood) fired fish drier was designed and produced. Trial shows that the drier is environmentally friendly, due to the energy sustenance technology introduced. The drier is safe to use and all the content of the drier (product) can be replaced at the same time because the temperature distribution inside the chamber is uniform. The oil from the fish does not drop on to the flame, reducing cancerous element from depositing on the smoked products [16, 17].

A visual observation of processed fishes showed light brown colour indicating the attraction of a good selling price. The weight loss, 62%, after 19 hours of processing showed an improvement over the weight loss reported by some researchers [18]. The recorded weight loss implies a longer shelf life of the finished products as reported by other researchers [19]. The duration of the operation can be regulated according to the customers demand, since record shows that weight loss can be 60% after 6 hours of processing.

The temperature variation is significant, considering employing unforced heat convection. The temperature rose to above 80^0C within the first 2 hours and continued even after fueling has been stopped through the night. The sustenance of the temperature in the smoke chamber is due to the lagging of the equipment. The average temperature was 80^0C which tallies with report by other findings [19]

The coal consumption analysed from the test, running at low capacity, is about N105/kg of fresh fish sample.

VII. CONCLUSIONS

The main advantage of this drier is its safety of use at anytime and anywhere. The drier can be fabricated in any size and test indicated that the increase in size does not reduce the effectiveness of the equipment.

Operation of the drier is safe since operators do not need to open the drying chamber often and there is no need to change the position of the content as temperature distribution is uniform inside the smoking kiln. Due to the lagging, the external body temperature is equal to the surrounding temperature, thus, operators are safe to be close to unit when on operation. 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 duration of processing can be reduced by increasing the volume of the coal pot. However, an electric fan can be incorporated if equipment is operated where there is

electricity, which will also reduce the duration of the smoking process.

ACKNOWLEGDMENT

The authors acknowledge the Department of Fisheries and Aquatic Studies/Animal Science, Faculty of Agricultural Technology, Niger Delta University Bayelsa State, Nigeria for the use of the facilities.

REFERENCE:

[1] **S. A. Adewuyi, B. B. Phillip, I. A. Ayinde and D. Akerele,(2010),** Analysis of Profitability of Fish Farming in Ogun State, Nigeria, J Hum Ecol, 31(3): pp 179-184

[2] **E. Ele, O. W. Ibok, E. A. Antia-Obong, I. E. Okon and E. S. Udoh** (2013), Economic Analysis of Fish Farming in Calabar, Cross River State, Nigeria, Greener Journal of Agricultural Sciences, Vol. 3(7), pp. 542-549, ISSN: 2276-7770

[3] T. M. Kudi, F. P. Bako and T. K. Atala (2008) Economics of Fish Production In Kaduna State Nigeria, ARPN Journal of Agricultural and Biological Science, Vol. 3, No. 5&6, pp 17-21, ISSN 1990-6145

[4] **A. A. Eyo** (2001), Fish Processing Technology in the Tropics, University of Ilorin Press, pp 153-192

[5] **C.C. Tawari** (2006), "Effectiveness of Agricultural Agencies in Fisheries Management and Production in the Niger Delta", PhD Thesis, Rivers State College of Science and Technology, Nigeria

[6] **R.M. Davies and O. A. Davies and J. F. N. Abowei** (2009), Traditional and Improved Fish Processing Technologies in Bayelsa State, Nigeria, European Journal of Scientific Research, Vol. 26 No. 4, pp 539-548

[7] **C.C. Tawari and J.F.N. Abowei, (**2011), Traditional Fish Handling and Preservation in Nigeria, Asian Journal of Agricultural Sciences 3(6): pp 427-436, , ISSN: 2041-3890

[8] **G. Ames, I. Clucas and S.S. Paul** (1999), Post Harvest Losses of Fish in the Tropics, Natural Resource Institute, Overseas Development Administration, pp11

[9] **P.I. Bolorunduro, A.O.K. Adesehinwa and J.O. Ayanda (**2005), Adoption of Improved Fish Preservation Technologies in Northwestern Nigeria, TROPICULTURA, , Vol. 23, No. 3, pp117-123

[10] **S. H. Sengar*, Y. P. Khandetod and A. G. Mohod (**2009),Low cost solar dryer for fish, African Journal of Environmental Science and Technology Vol. 3 (9), pp. 265-271, ISSN 1991-637X

[11] **Sh. Khoshmanesh (**2006), Design of Solar Dehydrator, Coupled with Energy, Storage in Rock Bed Reservoir for Fish Drying Process, International Conference on Energy and Environment

[12] **C.A. Komolafe, I.O. Ogunleye, and A.O.D. Adejumo**, (2011), Design and Fabrication of a Convective Fish Dryer, the Pacific Journal of Science and Technology Vol. 12 No. 1. pp 89-97 http://www.akamaiuniversity.us/PJST.htm

[13] **N.B. Ikenweiwe, B.O. Bolaji, and G.A Bolaji**, (2010), Fabrication And Performance Assessment of A Locally Developed Fish Smoking Kiln, Ozean Journal of Applied Sciences 3(4), pp 363-369, ISSN 1943-2429

[14] **B. Maas-van Berkel B. van den Boogaard and C. Heijnen (**2004), Preservation of fish and meat Agromisa Foundation, Wageningen, 3rd edition: ISBN: 90-72746-01-9

[15] **Thermal insulator Handbook(2001),** www.tiasa.org.za pp 17-19 (site visited 22/10/2013)

[16] **Dana-Farber Cancer Institute** (2006), Safe Summer Grilling http://www.dana-farber.org/uploadedFiles/Library/adult-care/treatment-and-support/support/nutrition-services/safe-summer-grilling.pdf (site visited 29/12/2013)

[17] **O.A. Akinola, A. A. Akinyemi and B. O. Bolaji** (2006), Evaluation of Traditional and Solar Drying Systems Towards Enhancing Fish Storage and preservation in Nigeria (Abeokuta Loacal Government as a Case Study), Journal of Fisheries International, Vol. 1 (2-4) pp 44-49

[18] **N.B. Ikenweiwe, B.O. Bolaji and G.A. Bolaji** (2010), Fabrication And Performance Assessment of a Locally Developed Fish Smoking Kiln, Ocean Journal of Applied Sciences Vol. 3, No. 4 ISSN 1943-2429

[19] **P.A. Idah and I. Nwankwo (**2013), Effects of Smoke Drying Temperature and Time on Physical Nutritional Quality Parameters of Tilapia (*Oreochromis niloticus*), International Journal of Fisheries and Aquaculturer, Vol. 5, No. 3, pp 29-34