Development of a Dual Powered Fish Smoking Kiln

Ajewole, P. O.*, Oluwatobi, O. B., and Oni, I. O

Department of Agricultural and Bio-Environmental Engineering, The Federal Polytechnic, Ado-Ekiti, Nigeria.
*Corresponding Author**

Abstract: **Fish is a perishable food material and it is highly susceptible to deterioration without any preservative or processing measure. Harvesting of fish, handling, processing, and distribution provide livelihood for millions of people, as well as providing foreign exchange to many countries in Africa, but about 40% of the fish caught in the rural communities get spoilt as a result of poor infrastructures for post-harvest processing and storage. In order to solve this problem, the performance evaluation of a smoking kiln that was fabricated and assembled at the engineering workshop of the Department of Agricultural and Bio-Environmental Engineering, The Federal Polytechnic, Ado-Ekiti, Nigeria, was carried out. The smoking cabinet was made from galvanized sheet metal and lagged with insulator to prevent heat loss, the smoking chamber consists of 5 set of trays of 520 x 480 x 80mm. The fish smoking kiln was tested with three different fish (Herring fish, Stock Fish and Cat Fish) using charcoal and electric heat sources. The kiln gave higher drying rate and required more energy cost for all the three fish types when powered with charcoal. However, it was discovered that the labour cost in using charcoal was less than that of the electric heat source. The stock fish had highest drying rate and least energy and labour cost when compared with other fish types.**

I. INTRODUCTION

Smoked fish is a type of fish that has been cured by smoking. Foods have been smoked by humans throughout history in a way to preserve it for a period of time. In more recent times fish is readily preserved by refrigeration and freezing and the smoking of fish is generally done for the unique taste and flavour imparted by the smoking process, or in a situation where there is erratic or no power supply.

Fish smoking is a rich source of lysine suitable for supplementing high carbohydrate diet. It is a good source of thiamine, riboflavin, vitamins A and D, phosphorous, calcium and iron. It is high in polyunsaturated fatty acids that are important in lowering blood cholesterol level (Graham, 2007). In Nigeria smoked fish products are the most readily form of fish product for consumption.

According to Fagade (2012), artisanal catch made up to about 40% of all the fish consumed in Nigeria. Today there are two main methods of smoking fish: The traditional method and the mechanical method. The traditional method involves the fish being suspended in smokehouses over slowly smouldering wood shavings. The fish are left overnight to be naturally infused with smoke (Abidemi, 2009).

Various traditional methods are employed to preserve and process fish for consumption and storage. These include smoking, drying, salting, frying, and fermenting and various combinations of these. According to Rozum (1999), the process of smoking fish occurs through the use of fire. Wood contains three major components that are broken down in the burning process to form smoke. The burning process is called pyrolysis, which is simply defined as the chemical decomposition by heat. The major wood components are cellulose, hemicellulose and lignin (Brownell, 2015).

In many rural fishing communities, the infrastructures for post-harvest processing and preservation of fish are inadequate. As a result, losses reach up to 40% of the total catch by weight. The fishing industry, in spite of its importance, suffers from enormous post-harvest losses which are estimated at 35–40% of landed weight, and it is estimated that post-harvest losses remain about 25% of the total world catch annually. These losses have a profound adverse impact on fishing communities whose status and income often depend on post-harvest activities. Such losses also have a detrimental impact on the socio-economic life of the fishing communities and reduce the amount of animal protein available to a large segment of the population. In Africa, some 5% of the population, about 35 million people, depend wholly or partly on the fisheries sector, mostly artisanal fisheries, for their livelihood.

Smoking prolongs shelf life of fishes, which permits storage in the lean season; enhances flavour and increases utilization of fishes in other diets, such as soups and sauces. It enhances the nutritive value and promotes digestibility of protein. It increases protein availability to people throughout the years and makes fish easier to pack, transport and market for reaching the consumer in relatively good state (Holman, 1998).

The traditional way of smoking fish is done by leaving the fish to be processed naturally with smoke generated by burning wood. And usually, smokehouses (smoking kiln) are built for the purpose of smoking fish. However, it is not getting a lot of prominence for export and it is gradually being replaced with modern mechanical methods of preserving fish.

Mechanically, fish are smoked with the use of a smoking kiln. It can be relied upon to produce a high-quality, uniform product that conforms to internationally acceptable standard. In this process, fish grading is done first by sorting according to the species or on their sizes. Removal of scales is done next in order to make it pleasant for consumption and after that the fish are cleaned by removing the gills in order to reduce spoilage. Slime removal is done for some fish species because slime on the fish skin creates a perfect condition for microorganism growth and have to be removed by thorough washing. The fish are herby cut either by splitting or filtering. The smoking of the fish is therefore done by utilising the mechanical fish smoking equipment to produce quality smoked.

In high ambient temperature of the tropics, fish will spoil within 12-20 hours depending on species, methods of captures etc. (Clucas, 2011). According to Rawson and Sai (2006) in the process of drying and smoking, much of the water content of the fish is extracted through heat thus inhibiting the action of microorganism and prolonging the shelf life. Smoke therefore combine three main effects drying, cooking and preservation.

II. MATERIAL AND METHOD

2.1 Description of the smoking kiln

The smoking kiln was fabricated and assembled at the engineering workshop ofthe department of Agricultural and Bio-Environmental Engineering, The Federal Polytechnic, Ado-Ekiti, Nigeria, the smoking cabinet was made from galvanized sheet metal and lagged with insulator to prevent heat loss, the smoking chamber consists of five (5) set of trays of 520 x 480 x 80mm.

The cabinet overall dimension was 1600 x 1220 x 750mm, it was a dual powered equipment of charcoal and electric heat sources, its heating elements (heaters) are connected with the aid of wire gauze made from stainless steel placed in a compartment in the heating chamber. When the smoking kiln is connected toelectricity, the heaters supply heat energy needed to heat up the available air in the smoking chamber, while the amount of heat is regulated to the required level with temperature regulator.

The smoking kiln harnessed charcoal heat source by loading required level of charcoal in the combustion chamber, while fire is supply to burn the charcoal, which will supply heat to the smoking chamber to heat up the available air in the smoking chamber to smoke the fish in the smoking chamber. The heat from charcoal heat source cannot be regulated; air circulation by convection is made possible from the plenum (combustion chamber) and carries heated air in all directions of the loaded trays.

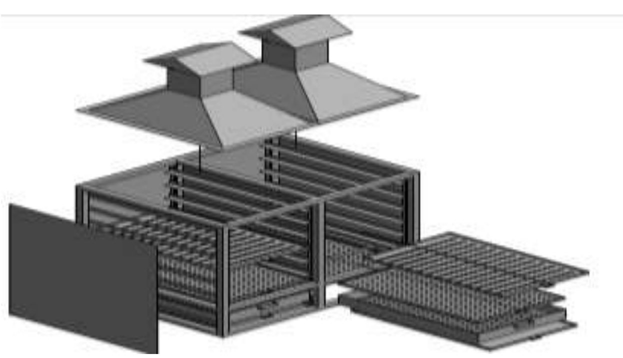

Fig. 1: Isometric view of the fish smoking kiln

A reflector was built in the chimney unit to diffuse the reflected heat back to the smoking chamber. The chimney conducts the smoke to the outdoor environment; the heated air is evenly circulated by fan incorporated in the smoking kiln. Sub units of the smoking kiln include: smoking chamber, smoking trays, rollers (mobility), combustion chamber, chimney, reflector, overhead cover. The isometric and exploded view of the smoking kiln are given in Fig. 1 and Fig. 2.

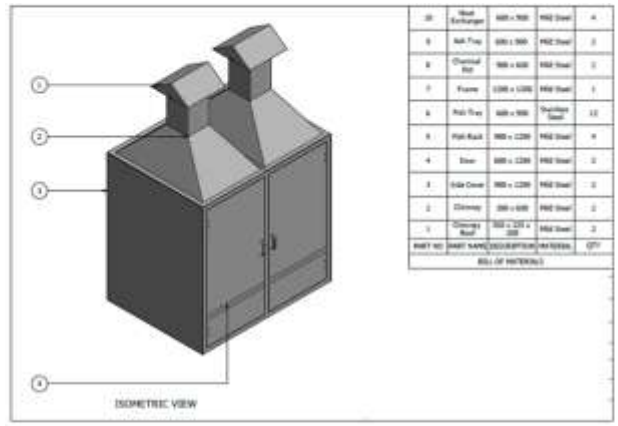

Fig. 2: Exploded view of the fish smoking kiln

2.2 Components parts of the kiln

The smoking kiln compromises of fish trays,tray roller, smoking chamber, chimney, reflector, combustion chamber, overhead cover, fan, heating elements (heaters), charcoal chamber, charcoal tray, fluid collector and temperature regulator.

2.3 Procurement and sampling of fish

Herring and stock fish were purchased from a cold room located atOdo-Ado area of Ado-Ekiti. Cat fish were obtained from AfeBabalola University Farms in Ado-Ekiti.

2.4 Initial testing of the smoking kiln

The smoking kiln was test run by loading the charcoal chamber, the temperature was measured and it was discovered to be stable at 205^0C after about 30 minutes. Also the smoking kiln was connected with electricity and test run to discover and detect faulty condition of the electrical components. It was observed that both the fan and heater were faulty and melted.

2.5 Repair and replacement of damaged components

In the processing of initially testing the kiln, it was discovered that the blower (fan) and the heater in the heating chamber had melted. This probably happened because the fan was made of plastic material and it could not withstand the heat in the heating chamber. The heaters were also found to be faulty as it was not given any heat, the fan and heaters were later replaced.

2.6 Experimental Design

The experimental design used for this project is 3 x 3 x 2. Three types of fish (herring, stock and cat) were smoked with 3 replicates and 2 sources of heat. The parameters obtained are: time of smoking, temperature of smoking, quantity of charcoal used, labour cost of smoking, energy cost of smoking and drying rate.

2.7 Experimental procedure using charcoal

The smoking kiln was fired by burning a measured quantity of charcoal in the charcoal chamber. 5kg of each species of fish was measured and loaded on the trays of the smoking kiln and the weight of the smoked fish was measured at intervals of 1 hour until a constant weight was obtained. The quantity of charcoal remaining after smoking was measured in order to obtain the energy consumed. This procedure was replicated 2 times and repeated for all the three species of fish.

2.8 Experimental procedure using electricity

Two 1000w heaters were installed in the smoking kiln, making total of 2000w. The smoking kiln was then connected with electricity. 5kg of each species of fish was measured and loaded on the trays of the smoking kiln at stable temperature and the weight of the smoked fish was measured at intervals of 1 hour until a constant weight was obtained. The overall time spent in smoking was noted and recorded. This procedure was replicated 2 times and repeated for all the three species of fish and the following parameters were obtained: Time of smoking, temperature of smoking, drying rate, labour cost of smoking,energy cost of smoking.

2.9 Determination of drying rate

The rate of drying the fish was calculated using the following relationship.

$$D_r = \frac{M_i - M_f}{T}$$

Where

D_r = Drying rate (kg/hr)

M_i= initial mass of fish (kg)

M_f =final mass of fish (kg)

T = total drying time (t)

2.10 Determination of energy expended in drying

(a) Charcoal heat source used in drying the fish using charcoal heat source is given as:

$$E_d = E_c \text{ x } M_c$$

Where E_d = Energy expended in drying.

E_c = Energy present in 1kg of charcoal = 29.3MJ (Hulsher, 2016).

M_c = Total weight of charcoal used

(b) Energy expended using electric source $E_d = P_h \text{ x } t_s$

Where E_d = Energy used in drying.

P_h = Power rating of heater.

t_s = time spent in drying.

2.11 Determination of drying cost.

The cost of drying the fish was estimated in two modes which are:

(i)Energy cost. (ii) Labour cost.

2.12 Determination of energy cost

(a) Charcoal heat source: This was estimated by multiplying the cost of 1kg of charcoal used with total mass of charcoal used (Mc). The cost of 1kg of charcoal in local market is ₦67.67

(b) Electric heat source: The cost of using electric source was estimated using the cost of 1kwh of electric energy supplied by electricity distribution company in the area 1kWh = ₦34.90

Total cost= ₦34.90 x Time spent in drying (hrs).

2.13 Determination of labour cost

Labour cost for drying the fish was calculated based on average cost of casual labour available in the study area for 8 working hours in a day.

Casual labour for 8 hours = ₦2000

Labour cost for 1hr = ₦2000/8 = ₦250.

Total labour cost for each drying operation was estimated by multiplying the cost per hour by total time of drying the fish.

III. RESULT AND DISCUSSION

3.1 Result

Tables 1-6 below shows the results obtained from smoking of the three species of fish using charcoal and electric heat sources.

Table 1: Result of drying herring fish with charcoal

Replicates	Initial Weight (kg)	Final Weight (kg)	Total Time of Drying (hr)	Average Temperature (°C)	Drying Rate (kg/hr)	Energy Used (J x 10^6)	Energy Cost (₦)	Labour Cost (₦)
1	5.0	2.0	4.0	145.5	0.75	158.20	370.98	1000.00
2	5.0	1.6	4.3	127.3	0.79	146.50	343.50	1075.00

3	5.0	2.0	5.3	113.3	0.57	208.00	487.77	1325.00
Average	5.00	1.87	4.53	128.70	0.70	170.90	400.75	1133.33

Table 2: Result of drying cat fish with charcoal

Replicates	Initial Weight (kg)	Final Weight (kg)	Total Time of Drying (hr)	Average Temperature (^oC)	Drying Rate (kg/hr)	Energy Used (J x 10^6)	Energy Cost (₦)	Labour Cost (₦)
1	5.0	1.1	4.3	192.2	0.91	263.70	618.30	1075.00
2	5.0	1.4	3.3	117.6	1.09	140.60	329.76	825.00
3	5.0	1.8	4.0	147.7	0.80	149.43	350.37	1000.00
Average	5.00	1.43	3.87	152.50	0.93	184.58	432.81	966.67

Table 3: Result of drying stock fish with charcoal

Replicates	Initial Weight (kg)	Final Weight (kg)	Total Time of Drying (hr)	Average Temperature (^oC)	Drying Rate (kg/hr)	Energy Used (J x 10^6)	Energy Cost (₦)	Labour Cost (₦)
1	5.0	1.1	2.0	128.8	1.95	70.32	164.88	500.00
2	5.0	1.0	2.0	101.2	2.00	64.46	151.14	500.00
3	5.0	1.0	2.0	118.4	2.00	73.25	171.75	500.00
Average	5.00	1.03	2.00	116.13	1.98	69.34	162.59	500.00

Table 4: Result of drying stock fish with electric heat source

Replicates	Initial Weight (kg)	Final Weight (kg)	Total Time of Drying (hr)	Average Temperature (^oC)	Drying Rate (kg/hr)	Energy Used (J x 10^6)	Labour Cost (₦)	Energy Cost (₦)
1	5.0	0.6	4.00	155.6	1.10	72000	1000.00	139.60
2	5.0	0.6	4.15	122.2	1.06	74700	1037.50	144.90
3	5.0	0.6	4.19	125.5	1.05	75420	1047.50	146.23
Average	5.00	0.60	4.11	134.43	1.07	74040	1028.33	143.58

Table 5: Result of drying cat fish with electric heat source

Replicates	Initial Weight (kg)	Final Weight (kg)	Total Time of Drying (hr)	Average Temperature (^oC)	Drying Rate (kg/hr)	Energy Used (J x 10^6)	Energy Cost (₦)	Labour Cost (₦)
1	5.0	1.7	6.0	123.0	0.55	108000	209.40	1500.00
2	5.0	2.0	7.0	131.4	0.43	126000	244.30	1750.00
3	5.0	2.9	9.0	104.6	0.23	162000	314.10	2250.00
Average	5.00	2.20	7.33	119.67	0.40	132000	255.93	1833.33

Table 6: Result of drying herring fish with electric heat source

Replicates	Initial Weight (kg)	Final Weight (kg)	Total Time of Drying (hr)	Average Temperature (^oC)	Drying Rate (kg/hr)	Energy Used (J x 10^6)	Energy Cost (₦)	Labour Cost (₦)
1	5.0	1.5	5.2	134.6	0.67	93600	181.48	1300.00
2	5.0	1.1	6.1	143.7	0.64	109800	121.89	1525.00
3	5.0	1.4	5.8	129.9	0.62	104400	202.24	1450.00
Average	5.00	1.33	5.70	136.07	0.64	102600	168.54	1425.00

3.2 Discussions

3.2.1 Variation in drying rate

Fig. 1 shows the variation in drying rate among the three species of the fish. Stock fish appears to have the highest drying rates of 1.98kg/hr and 1.07kg/hr respectively for both charcoal and heat sources. Observations from the figure shows that the smoking kiln has higher drying rate when charcoal heat is used than electric heat. Lowest drying rate of 0.23kg/hr was recorded for cat fish when charcoal heat source was used. This may be due to higher water and fat content of cat fish.

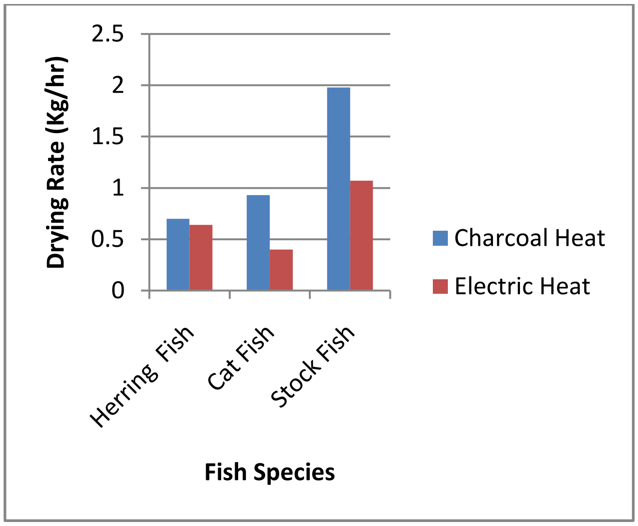

Fig. 3: Drying rates of the three different fish species

3.2.2 Comparison of energy cost in drying the three fish species using different heat sources

Fig. 2: shows the graph of energy cost of drying the three types of fish using electric and charcoal heat sources. The energy cost using charcoal is higher than that of electricity. Cat fish consumes more energy and more cost in drying than all other fish types. This is probably due to the higher moisture content of the fish.

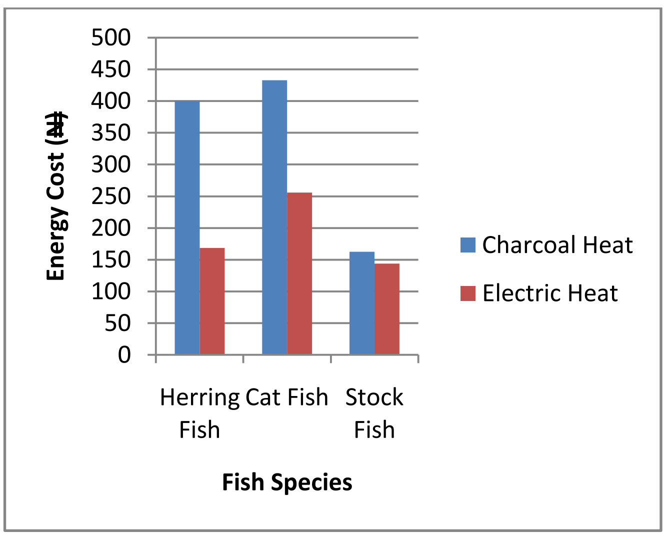

Fig. 4: Comparison of energy cost in drying the fish species

3.2.3 Comparison of labour cost in drying the three fish species using different heat sources

From Fig. 3, the electric heat source of drying the fish incurred higher labour cost than using charcoal heat. This is due to longer hours of electric heating required before the fish could be dried. However the stock fish cost the least in drying for both heat sources.

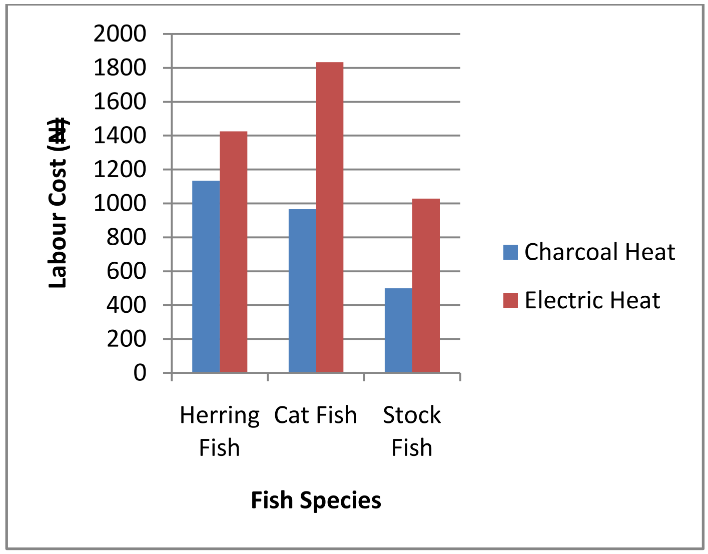

Fig. 5: Comparison of labour cost in drying the fish species

IV. CONCLUSION

The smoking kiln was evaluated to determine drying rate of three different fish species. The fish smoking kiln was tested with three different fish (Herring fish, Stock Fish and Cat Fish) using charcoal and electric heat sources. The kiln gave higher drying rate and required more energy cost for all the three fish types when powered with charcoal. However, it was discovered that the labour cost in using charcoal is less than that of the electric heat source. The stock fish has highest drying rate and least energy and labour cost when compared with other fish types.

V. RECOMMENDATION

The smoking kiln should be made available locally for fish farmers at a relatively low cost and energy. The kiln can also be powered with low alternate source of power for example, solar energy. The kiln should be fabricated with stainless steel to withstand heat better than mild steel that was used and also to ensure there is no contamination of the fish due to rusting. Heat loss should be avoided by increasing the quantity of lagging material of the kiln. The capacity of the electric heating element should be increased to boost the temperature.

REFERENCES

[1] Abidemi O. A. (2009): Quality Changes of Nigeria Traditionally Processed Freshwater Species and Fish Smoking J. Food Technol. 18:17-29.

[2] Brownell, F. L. (2015): Quality Function Deployment: Integrating Customer Requirements Into Product Design (Translated By Glenn H. Mazur). Cambridge, MA: Productivity Press. ISBN 0-915299-41-0 (Originally Published 1988 by Japan Standards Association), 374Pp AOAC. 1995.

[3] Clucas, I.J. (2011): The Influence of Traditional Handling Methods on the Quality of Processed Fish In Nigeria. In*: Proceedings Of The Conference on the* Handling, Processing And Marketing Of Tropical Fish. *13 To L9th April, 1976*

Organized by the Tropical Product Institute, London 201 Pp.

[4] Fagade, F. (2012): The Nutritional Importance to Local Communities Of Fish Caught Off The Coast of Quatar*Nutrition and Food Science, 6:* 288-294.

[5] Graham, D. (2007):Ecology of the Fisheries Resources of Coastal Wetlands of Ondo State and Its Management Implications. *Ph.D. Thesis,Federal University Of Technology, Akure. 297pp.*

[6] Holman, J.P. (1998): Heat Transfer, 9th Edition. New York: McgrawHill. ILO – WEP. 1982. Small-Scale Processing Of Fish. Geneva, Switzerland: International Labour Office, 95Pp.Official Methods of Analysis of AOAC International, (16th Ed.), P. 42-1.

[7] Rawson, G. C. and Sai, F. A. (2006): A short guide to fish preservation.FAO, Rome.

[8] Rozum, J. J (1999): Fish Processing Technology in the Tropics. Ilorin, Nig.: University of Ilorin Press, 403Pp FAO. 1971. Equipment and Methods for Improved Smoke-Drying Of Fish in the Tropics.