DESIGN, CONSTRUCT AND PERFORMANCE EVALUATION OF A FISH SMOKING OVEN

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Abstract— *A study was conducted to develop and fabricate a new fish smoking oven to improve on the existing fish smoking kiln technology. The fish smoking oven has an overall dimension of 900x600x360mm and uses charcoal as the main source of energy. The average capacity of the smoking tray is 9kg. Catfish and tilapia samples were smoked using charcoal. Variation in temperature with time, weight loss and sensory quality of the smoked fishes samples were evaluated. The temperature due to combustion of constant weight of charcoal ranged from 60^0C to 100^0C in 3h.30minutes. The mean moisture content of both catfish and tilapia is 8.88% and 11.11%, mean smoking rate of 1.17kg/h and 0.80kg/h and mean smoking efficiency is 91.11% and 88.88%. The organoleptically analysis (sensory quality) of smoked fish with the developed smoking oven in terms of colour difference, texture and flavor of the Catfish and tilapia were highly significantly (p≤0.05) different. The Oven would be used for drying fish which will lead to reduction of post harvest fish losses.*

Index Terms Smoking oven, development and performance evaluation.

1 INTRODUCTION

According to Food and Agricultural Organization, FAO (1996), the world fish production from capture, fisheries and aquaculture reached 121 million tones. A breakdown shows that 72 percent of the total fish production comes from marine aquaculture, 6 percent from inland catches and 13 percent from inland aquaculture. Aquaculture began by man making small modification to natural habitats so as to improve the survival and growth of his target species, some of the oldest examples are in the rearing of freshwater fish in ponds, something that has been practiced for thousands of year in Asia and at least for many centuries in Europe.

The systems and technology used in aquaculture have developed rapidly in the last fifty years. They vary from very simple facilities (e.g) family ponds for domestic consumption in tropical countries to high technology system (e.g) intensive closed system for export production. Much of the technology used in aquaculture is relatively simple, often based on small modifications that improve the growth and survival rates of the target species. That is, improving food, seeds, oxygen levels and protection from predators. Simple systems of small freshwater ponds, used for raising herbivorous and filter feeding fish, account for about half of global aquaculture production (FAO, 2012).

A decline in fish availability will have a detrimental effect on the nutritional status of the citizenry particularly in place where fish contributes significantly to the protein intake of the people. Fish is one of the most important animal protein foods available in the tropics. The less developed countries capture 50% of the world harvest and a large proportion of the catch isconsumed internally (FAO, 1985). In many Asian countries over 50% of the animal protein intake comes from fish while in Africa the proportion is 17.5%. In Nigeria fish constitutes 40% of animal protein intake, (Eyo, 2001).

As fish supplies from open water and lagoons continue to fall and human populations rises, fish farming offers an effective way of food production and income from dwindling land spaces. According to Atanda (2007) fish farming has been recognized as a viable means of increasing domestic fish production. Most recent investment in aquaculture has been targeted towards catfish farming (Abdullah, 2007). Currently, about 90% of farmed fish in Nigeria is catfish which is now a major attraction to private section investors in Nigeria (Kamthorn and Miller, 2006)

Eyo (2001), reported that poor handling, preservation and processing practices adopted by the artisanal fishermen, fish farmers and fisheries entrepreneurs, these losses are therefore significant when considered on national scale. In most developed countries, canning or freezing methods are used for fish preservation to improve fish quality and extend the shelf life of fish. However, in less developed countries, traditional fish smoking is still being practiced especially in the tropics. This is because the equipment developed for postharvest processing and handling fish are too sophisticated for the farmers to operate and are not affordable. Some of thexe equipment requires electricity or fuel such as gas for their operation. In Nigeria electricity supply in the rural areas is unstable and cost of fuel continues to rise. These have made many people to opt for less sophisticated methods of food preservation (Ihekoronye and Ngoddy, 1985). There is therefore the need to develop efficient and cheaper equipment that can be used for fish processing in order to reduce the drudgery of using traditional methods for processing fish by our local fishermen.

MATERIALS AND METHOD

2.1 Preliminary Investigations

For the purpose of the design of the developed fish smoking oven, testing of the existing smoking kiln was carried out while some physico-mechanical properties of fish were determined. The properties of the fish investigated include; length, width, weight, moisture content, curled diameter, volume and bulk density of the fish. The test was carried out on Tilapia and Cat fish (Clariasspp) obtained from Ganye main market.

3.2 Construction Materials and Method of construction of the smoking oven

In the design of smoking oven, steel materials were chosen as the principal materials. Steel is most widely used material for machine element because of it properties. It possesses high strength, high stiffness, durability and ease of fabrication. Steel are supplied in bars, flats, angles, sheet or round which can be welded and machine with ease because of its low carbon content ranging from (0-0.3%) for mild steels up to (1.5%) for higher carbon steel (of up to 1.5%) (Khurmi and Gupta,2003).
The metal sheet was used for the construction of charcoal tray and fish tray. The angle iron was used for the construction of the frame and resting support of charcoal tray and fish tray.
The method of construction refers to the process by which the component of the smoking kiln were formed before assembling into a complete functional units

2.2.1 The important components of the smoking oven constructed are;

2.2.1.1. Frame

The frame is made up of angle irons 37.5x37.5 mm, the angle irons were welded together to form the mounting support for the smoking oven. The dimension is 900 mm x 600 mm x 360 mm as shown in figure 4. The charcoal tray was fixed 200 mm from the ground; fish tray closed to the charcoal tray was 460 mm from the ground, then the second fish tray was 730 mm. Lastly chimney 900 mm from the ground surface.

2.2.1.2 Fish tray

This is the container into which the fish is loaded and smoked. It is constructed from metal sheet and wire mesh and has a dimension of 520 mm x 310 mm x 200 mm. Figure 5. The metal sheets were measured using measuring tape and cut to desired size and length to construct the fish tray.

2.2.1.3 Charcoal tray

This is the container for the burning charcoal. It is constructed from metal sheets of thickness 1mm. The tray has the dimension of 520 mm x 310 mm x 200 mm as shown in Figure 6. Charcoal tray was also constructed using the same dimension as in fish tray.

2.2.1.4 Chimney

The smoking oven consists of chimney of length and width (250 mm x 100 mm) located at the top of the smoking oven to allow effective exit of smoke and excess heat from the oven. The chimney is shown in Figure 7.

2.2.1.5. Resting support

This is constructed from 37.5 mm x 37.5 mm angle iron to make the fish tray to rest on it when offloading the smoke fish and when recharging the charcoal in the tray.

2.2.1.6. Ply wood

The plywood with thickness of 12.5 mm is fixed at all sides for finishing purpose and for safety to prevent accident burn of passerby or women.

2.2.1.7. Net

The net attached to the chimney will prevent flies from entering the oven to spoil the fish. Having considered the most important parameters in the design, the materials in Table 1 were selected for the construction. The table also contains the prices of the materials based on Ganye market price as at December, 2015.

2.3. Machine assembly

Plate I and II show the existing smoking kiln and the developed smoking oven. Appropriate bolts and nuts were used for tight construction. In the construction of the smoking oven. The height of the smoking oven (frame) was 900 mm the length was 600 mm and width was 360 mm with angle iron 37.5 mm. The metal sheets were measured using measuring tape and cut to desired size and length to construct the fish trays. The fish tray of length 520 mm, width 310 mm and height of 200 mm was constructed and put into the smoking chamber; the charcoal tray was also constructed using the same dimension as in fish tray. The rear side of the oven was insulated with ply wood, the fish trays were also insulated with ply wood. This is done to reduce heat while smoking is in progress.

Table 2.1:Cost estimate

S/No:	MATERIALS	QUANTITY SPECIFICATION	UNIT PRICE (₦)	AMOUNT(₦)
1.	Angle Iron	4 37.5mm	1200	4800
2.	Metal Sheet	2 2mm	4000	8000
3	Roller	4	500	2000
4	Flat Bar	2	500	1000
5	Cutting Stone	1	500	500
6	CPU Fan	1	6000	6000
7.	Quarter rod	1Ø2mm	2000	2000
8.	Welding Electrode	1 packet	1400	1400
9.	Paint and thinner	3 tin	1000	3000
10.	Bolts and Nuts	20 M12	30	360
11	Plywood	1sheet 12mm	4000	4000
12.	Labour			8120
13.	Total Cost			41,180

Source of the Table: Ganye Market Survey, 2015.

Plate I: AssembledDevelopedSmoking Oven

2.3.1. Operational techniques

The smoking oven operates in such a way that when the charcoal as a source of heat in the charcoal tray is lit and starts burning, it is placed beneath the fish tray. Fish to be smoke are fed into the fish tray and allowed to smoke. The switch con-

trols the speed of
the fan which provides air for the lighted charcoal. The heat from the fire dries the fish while the smoke envelopes the fish which serves as a preservative. The smoked fish is offloaded by pulling out the fish tray to rest on a support. Plate III shows fish being loaded on the tray in the oven. Plate IV shows smoked fish in the smoking oven. The weight of the fish is usually taken after every one hour of smoking until the final weight is obtained.

2.3.2. Care and maintenance

The machine is made up of metallic materials, corrosion is apparent therefore subsequent repainting with oil paint is necessary. The fish tray should be removed, cleaned and oiled after using. Charcoal tray should be removed and cleaned after using. For long time of non-usage the smoking oven should be keep under dry shed or inside store for storing.

2.4 Performance Evaluation

Two set of fish samples catfish and tilapia were procure from Ganye main Market. The samples were thoroughly washed and spread salt on the fish, then allow the water to drip and dried for 30 minutes in the sun. Then the charcoal in the developed smoking oven and the traditional smoking kiln were ignited using kerosene and marches. The ignited charcoal was allowed to burn for 10 to 15 minutes to allow kerosene ordour to be exhausted, then more charcoal was added to the burning charcoal. The catfish after drip was weighed (initial weight) as well as the weight of tilapia. The fish samples were arranged on both the fish tray of developed smoking oven and the traditional smoking kiln (oil drum types). As the charcoal was burning the fan is fanning the charcoal to supply a constant heat. While the traditional smoking kiln is expose to natural air blow to maintain it heat which is not constant. During the smoking process the side of the fish facing the burning charcoal was change routinely by turning the fish upside down. The time taken for the smoking was the total time taken. After smoking the fish were allow to cold and kept in a polythene bag to determine the shelf life. The storage life lasted for eight weeks starting from June 2016 to July 2016.

2.5 Determination of Shelf Life

The shelf life of the smoked fish was determined by putting each of the products from the two fish species into polythene bag and stored for at least eight (8) weeks. The attributes such colour, texture and flavour and conditions for the stored fish were assessed regularly at one week interval. The panel of 10 members familiar with scoring fish were given the products scores at weekly basis. After cooking, the two fish sample were serve in dishes to the panelist, the panelist were asked to taste the two fish sample and score on the score sheet as suggested by poste *et al.,* (1991). The products were scored on a scale of 5 – very good, 4 – good, 3 – averagely good, 2 – fair, and 1 – bad.

Results and Discussions

3.1. Design Results

Based on the preliminary investigation of the physico-mechanical properties of the fish, the design of various component of the machine was carried out.

3.2. Performance Evaluation Results

Fish were smoked using develop smoking oven incorporated with fan and a traditional smoking kiln. The smoking oven and the traditional smoking kiln were tested with two set of fish species catfish and tilapia. Considering smoking as one of the most popular method of processing fish in the tropics reported by Eyo (2001). The speed of the fan (1 – 5) was varied using fan regulator and speed 5 was observed to be the highest speed Table 4 shows raw result of performance evaluation of catfish smoked using develop smoking oven, while Table 5 shows raw result of performance evaluation of tilapia smoked using develop smoking oven. Table 6 shows raw result of performance evaluation of catfish and tilapia smoked using traditional smoking kiln.

The total weight of fresh catfish and tilapia of 7.00kg, and 2.00kg was reduced to 2.30kg and 0.65kg of dried weight after 4hrs 30min, and 3hrs 30min for speed one (1) and two (2). Speed three (3) total weight of 7.00kg and 2.00kg was reduced to 2.00kg and 0.60kg of dried weight after 3hrs 30min and 2hrs 23min for catfish and tilapia. Speed four (4) total weight of 7.00kg and 2.00kg was reduced to 2.10kg and 0.60kg after 3hrs and 2hrs 10min. Speed five (5) the highest speed total weight of 7.00kg and 2.00kg was reduced to 2.00kg and 0.50kg for catfish and tilapia of dried weight after 2hrs 25min and 1hr 45min. The average value for catfish and tilapia was 7.00kg and 2.00kg was reduced to 2.14kg and 0.60kg of dried weight after 3hrs 55min and 2hrs 56min within the dried chamber this result agrees with Olayemi *et al.,* (2013) and Ikenweiwe *et al.,* (2010) Total weight of 5.50kg and 2.00kg was reduced to 2.10kg and 0.70kg of dried weight for catfish and tilapia after 5hrs and 3hrs for traditional smoking kiln. When compare to traditional smoking kiln that takes almost 5hrs and 3hrs to dried catfish and tilapia in addition to the other labour stresses and drudgery.

The moisture content of catfish and tilapia for speed one (1) and two (2) was 66.00% and 67.50%, smoking rate of 0.51kg/hr and 0.19kg/hr and smoking efficiency of 34.00% and 32.50%. Speed three (3) moisture content of 71.00% and 70.00%, smoking rate of 0.57kg/hr and 0.30kg/hr and smoking efficiency of 28.57% and 30.00%. Speed four (4) moisture content of 70.00% for both catfish and tilapia, smoking rate of 0.70kg/hr and 0.30kg/hr smoking efficiency of 30%. Speed 5 the moisture content of catfish and tilapia was 71.00% and 75.00% smoking rate of 0.93kg/hr and 0.35kg/hr, smoking efficiency of 28.57% and 25.00% was observed. The mean moisture content of 69.25% and 70%, smoking rate of 0.64kg/hr and 0.27kg/hr and smoking efficiency of 30.56% and 30.00% for develop smoking oven. While the traditional smoking kiln moisture content was 70.00% and 65%, smoking rate of 0.42kg/hr and 0.23kg/hr, smoking efficiency of 30.00% and 35.00% was recorded.

Table 3.1: Summary result of the performance evaluation of catfish and tilapia smoked using develop smoking oven

S/N	Initial Weight (kg)	Final Weight (kg)	Time (Min)	Moisture Content (%)	Smoking rate (kg/h)	Smoking Efficiency (%)
Catfish	7.00	2.14	3.55	69.25	0.64	30.56
Tilapia	2.00	0.60	2.56	70.00	0.27	30.00

3.3 Data Analysis

Data generated was subjected to statistical analysis using computer software (SPSS version 14, 2016) the result were presented as a mean average, differences between mean values were analyse using paired t-test and the level of significant were considered at ($P<0.05$) test.

Table 3.2:Mean sensory evaluation of catfish smoked using developed smoking oven and traditional smoking

	Develop smoked Catfish	Traditional Smoked Catfish
Colour	4.10	3.40
Texture	4.10	3.30
Flavour	4.10	3.70
Overall acceptability	4.00	3.60

Table 3.3: Mean sensory evaluation of tilapia smoked using developed smoking oven and traditional smoking kiln

	Develop smoked Tilapia	Traditional Smoked Tilapia
Colour	2.90	3.90
Texture	4.10	4.30
Flavour	3.70	2.90
Overall acceptability	3.70	2.90

Figure 1 shows graph of weight loss in fish drying with developed smoking oven. The graph showed that the weight of fish drops with increase in smoking time signifying drying Figure 2 shows graph of weight loss in fish drying with developed smoking oven. Figure 10 shows graph of regression between weight of fish drying and smoking time. Regression analysis of processed fish with the developed smoking oven was carried out to find a relationship or correlation between the weight of fish and smoking time. The regression line is represented by an equation, in this case the equation is $y = -0.0302x+6.6357$, $R^2=0.9295$ for cat fish and $y = -0.013x+1.86$, $R^2=0.9343$ for tilapia.

The values of the computed output in terms of weight loss by the equation where plotted against the measured weight loss are shown in the Figure 10 and 11 with $R^2=0.929$ for catfish and for tilapia $R^2 = 0.999$.The regression coefficient expresses the dependence predicted value on the measured output $y_P= 0.922x+325.2$, $R^2 = 0.929$ for catfish and for tilapia $y_P = 0.984x+23.17$, $R^2 = 0.999$. A paired t-test conducted for the means value for catfish and tilapia Table 17 and 18 shows that the calculated value of (-0.1015) and (-0.8433) is less than the t-critical value of (2.4469) and (2.7764) at 0.05 significant level.

Hence there is no significant difference between the predicted and the measured, considering the overall means the predicted output data was (2.25%) greater than the measured output. However the likely discrepancies noted in the measured weight value could due to assumptions regarding the homogeneity of the moisture loss and the unsteadily interaction between the fish weight interface arising from the instability of fish movement from the oven to the weighing balance. In all the sensory qualities examined, all the smoked fishes scored above average, which indicate that the products were still, be acceptable in seven weeks time after smoking. This indicates that shorter storage duration maintain the quality of the fishes in contrast to longer storage period.

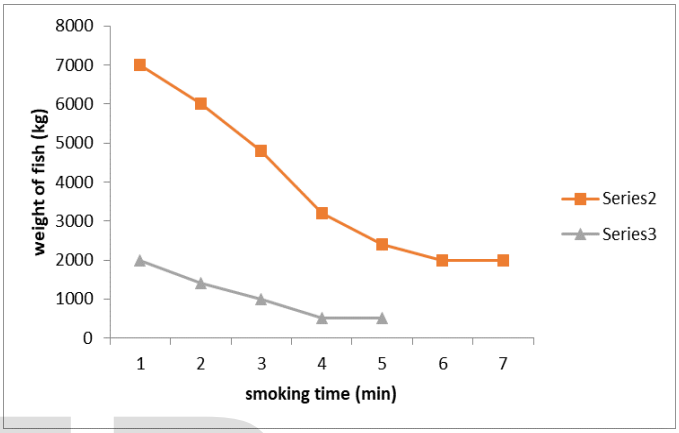

Figure 1:A graph of Weight Loss in Fish Drying Process with Developed Smoking Oven

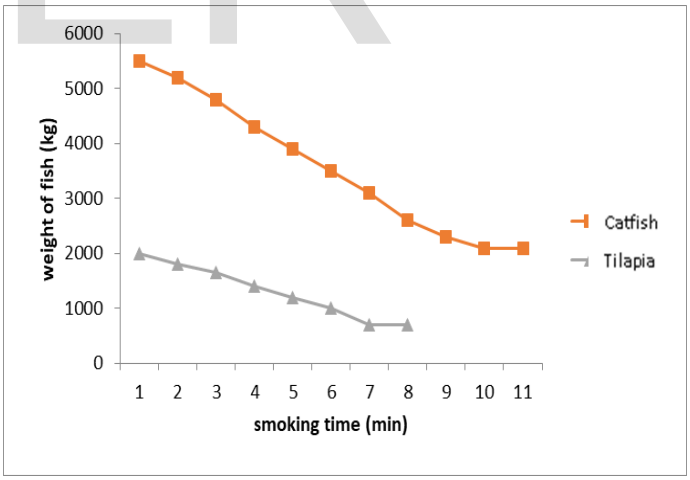

Figure 2: A graph of Weight Loss in Fish Drying Process with Traditional Smoking Kiln

Plate II: Smoked Fish in the Smoking Oven

3.4 Conclusion

The construction of smoking oven was carried out with the aim of increasing the capacity of the existing kiln and smoking time. The machine was designed and constructed based on the physico-mechanical properties. The machine was tested and the results obtained gives the mean moisture content of 69.25 and 70% dried bases, mean smoking efficiency of 30.56% and 30.00% the mean smoking rate of 0.64kg/hr and 0.27kg/hr for catfish and tilapia compared to traditional smoking kiln that is time consuming labour intensive. The develop smoking oven performed efficiently by drying the fish to a safe moisture content within 2hrs 25minutes and1hr 45 minutes while traditional took 5hrs and3hrs for catfish and tilapia. The storability was found to be 7weeks. From this result it can be inferred that smoked drying as method of processing ca be adopted in extending the shelf life of fish especially in developing countries where the sophisticated processing equipment are not affordable. This result proves that the aim is achieved.

3.5 Recommendations

Base on the study the following recommendations were made.

1. Power source should be make renewable instead of use of dry cell battery.
2. The smoking oven should be evaluated on different sizes and variety of fish in the smoking process.
3. The oven should also be evaluated on meat and other aquatic animals to make it more versatile, thereby increasing it acceptability among end users.
4. To handle large quantities in one cycle a bigger oven will be required.

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