Effective Fish Smoking Kiln for Developing Country

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Abstract- An effective fish smoking kiln powered with sawdust (to generate the smoke) and charcoal which provides the heat for drying incorporated with three axial fans powered by 15 volt D.C. battery was developed. The kiln was constructed of local materials for cost effectiveness and ease of reproducibility by local farmers. It was evaluated using catfish. The kiln was able to attain the remcommended drying conditions of 70 ^{0}C for 3 hours. The heat distributions within the drying chamber were fairly uniform which led to uniform drying of the fish. The kiln was able to reduce a total weight of fresh catfish of 19.284 kg to 5.076 kg after 9 hours 30 minutes with an operating cost of ₦ 550. The provision of the chimney and the close operation of the kiln eliminate smoke inhaling, and burns usually experienced by the operator. The kiln also prevents soot deposition or charring of the smoked fish during smoking. The proximate analysis of the smoke-dried catfish was conducted and the results proved the suitability and effectiveness of the smoking kiln for use among fish handlers and processors in developing countries due to good nutritional quality recorded.

Keywords: Smoke-drying, fish processors, quality, smoke-dried fish

1 INTRODUCTION

ONE of the major ways of adding values to fish in the Tropics is by smoking and drying. Drying is the process of removing moisture contained in a product inoder to reduce considerably the reactions which lead to the product's deterioration. The water is elimated by evaporation into the surrounding air by activated energy. Various equipment has been developed for dehydration of food products. Such equipment include dryers, ovens and kilns.

Food has been preserved by smoke-curing since before the dawn of recorded history. People in all cultures in the world have relied on the smoke curing of fish and meat products for long term storage. Smoking apart reducing the moisture content of the product also impacts a desirable flavour, appearance and texture to the products [1]. In developed countries where refrigeration and integrated infrastructures for efficient transportation of perishables are in place, smoking is not a means of fish preservation but used to enhance the flavour of the fish. But in developing countries, hot smoking is still a very important method of fish preservation. In this process, drying is of paramount importance for preservation because level of moisture in the flesh of fish contributes to bacterial activity and spoilage [2], [3]. Fish smoking has two basic procedures which are cold and hot smoking.

The hot smoking which is common in developing countries cooks the fish product by the application of heat and smoke. The fish product centre is subjected to a temperature of 145 ºF for a long period which will enable the protein to coagulate. The cold smoke used in the developed country only applies smoke to the product at temperature less than 90 ºF. The protein content in this fish will not coagulate at this condition [4].

A combination of smoke, salt and drying is one of the earliest recorded methods of food preservation. These procedures loosely known as smoking or smoke preservation are successful because they kill food poisoning and spoilage bacteria or render them harmless by altering the chemistry of the environment required by these organisms to thrive [5], [6] .

In an effort to develop an effective method of fish smoking, different models of improved ovens and kilns were developed in various parts of Africa [7], [8]. Until the end of 1960, the oven most used for smoking fish was cylindrical or rectangular and made of mud or metal. These ovens had considerable disadvantages. The disadvantages are low capacity, inefficient fuel usage (firewood) thereby contributing more to forest depletion and the health hazard which its operation entails as a result of the smoke which affects eyes and lungs of operator. In addition, fingers are burnt due to undue exposure to direct heat, the procedure is very laborious and poor quality smoked fish are usually produced [9]. These associated problems have not only

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limited fish smoking to the rural artisanal fisher folks but has also hindered the trade of smoke fish (especially importations from African countries to Europe) due to insistent mould attacks resulting from poorly smoked products[10], [11]. The objective of this study was therefore to develop an effective fish smoking kiln that will reduce if not eliminate all challenges in the use of smoking kiln in the developing country.

2. MATERIALS AND METHODS

2.1 Description of the smoking kiln

The smoking kiln (Figure 1) was designed and constructed based on materials availability. It is rectangular in shape with dimension of 600 x 600 x 1200 mm. It has an inner lining made of galvanized iron sheet. The galvanized iron sheet was lagged with 25.4 mm asbestos particles and covered with 12.7 mm thick plywood. The double wall structure with the insulating material was provided to conserve the heat energy by reducing heat loss and also to keep the working environment conducive for the user. The kiln has four (4) tray shelves made of wire gauge of dimension 590 x 590 mm. The trays were constructed of durable and light weight frame and properly finished edge fine wire mesh which prevents the dried fish products from falling through. The trays were placed on 25 x 25 mm square pipe which allow them to be pulled out without tipping and can easily be slide in and out. The total surface area available for drying is 1.44 m^2. The drying capacity varies with species and thickness of fish. The kiln has a double wing door which can be opened and closed easily. The doors fit smoothly when in a closed position. The kiln was incorporated with three (3) axial fans connected in series and powered by five (5) pairs of 1.5 volt battery with an 'ON' and 'OFF' control switch. This helps to improve the air and heat circulation within the kiln chamber and removal of moisture out of the dried product. It also has six air-inlets at the base made of 25.4 mm Φ pipe to permit fresh airflow for combustion and drying of the fish product and air-outlets at the top made of 25.4 mm Φ pipe which serve as the exhaust for the moisture laden air. The kiln was powered with saw dust for smoking and charcoal for heating/drying operations. The saw dust and charcoal were placed inside a combustion pot of dimension of 450 x 450 x 450 mm dimension. A forklike hanger was made for combustion pot handling.

2.2 The Smoke-Drying Procedure

The performance test of the kiln at no load were performed using saw dust at constant weight of 0.5 Kg of sawdust and varying weight of charcoal at 0.5, 1.0 and 1.5 kg with fan and without fan. The temperatures attained by the kiln at an interval of 15 minutes were recorded using mercury in glass thermometer. The test was terminated when the sawdust and charcoal were completely burnt. This was done to determine the ideal operating condition of saw dust and charcoal for smoke-drying in terms of the quantity of fuel that can supply the needed energy over a know period.

When the kiln was loaded with fish (loading condition), the charcoal container was loaded with 1 kg charcoal, properly fired and placed inside the fish smoking kiln to attain a temperature of 120 ^{0}C. The fish were then arranged on the shelves on which red oil has been rubbed. The red oil was applied to avoid the fish getting stick to the rack. When the fish were placed in the shelves, 0.5 kg of saw dust was introduced into the saw dust chamber to produce smoke. The fish was cooked until dryness was achieved and the axial fans were on for proper air circulation. 1 Kg charcoal was added continuously at an interval of two hours during the smoking process and the temperature of the drying chamber was continuously monitored using mercury in glass thermometer installed at the top, middle and bottom parts of the chamber.

The smoking/drying was stopped when the fish were properly dried to safe moisture content (below 12.5 % wb) after which the heating chambers (charcoal pot) was removed while the fans were still in operation to cool the dried fish to the ambient temperature before they were packed. The proximate analysis (moisture, ash, protein, crude fiber and fat contents) were then determined.

3. Results and Discussion

The results of the performance of the smoking kiln conducted at 'NO Load' and Loading conditions were presented in this section.

3.1 Thermal Evaluation of the Smoking Kiln at 'No Load' Condition

The temperatures obtained in the smoking kiln at six different conditions of operation at 'No-Load' with fan and without fan are shown in Figure 2. The initial temperatures of the kiln at 'No-load' at charcoal loading of 0.5 kg with fan and without fan respectively were 110 ^{0}C and 104 ^{0}C and the temperatures declined to 41.33 and 34 0C after 225 and 165 minutes respectively. Increasing the weight of charcoal to 1.0 kg, the temperature also increases to 164 and 150 ^{0}C with fan and without fan respectively declining to 52 and 39 0C after 315 and 300 minutes respectively. Using 1.5 kg of charcoal with fan and without fan the average temperature recorded was 168.67 and 152.17 ^{0}C respectively, and reduced to 40.67 and 39.33 ^{0}C respectively after 435 minutes. The temperature deviations in the different conditions were 1.12 and 6.05 ^{0}C for charcoal of 0.5 kg with fan and without fan respectively. For charcoal weight of 1.0 kg, the temperature deviations were 1.4 and 3.21 ^{0}C for with fan and without fan respectively. For charcoal loading of 1.5 kg, the temperature deviations were 1.65 and 4.15 ^{0}C for with fan and without fan respectively. Furthermore, the costs for running the kilns at these conditions were N 280.00 and ₦ 240.00 for 0.5 kg of charcoal loading for with fan and without fan respectively. For charcoal loading of 1.0 kg, the costs of running the kiln were ₦ 550.00 and N 460.00 respectively for with fan and without fan. The running cost for the kiln at 'No-Load' with fan and without fan were ₦ 720.00 and N 680.00 as shown in Table 1.

The evaluation was necessary to know if the designed kiln is able to meet the required drying conditions for fish as recommended by [12]. Fish are required to be heated to an internal temperature of 70 ^{0}C for 3 hours so as to eliminate the harmful pathogens; while the smoking kiln must be able to provide temperature between 95 and 110 ^{0}C.

From the results obtained it was observed that charcoal do not supply steady power to the kiln but at decreasing level with increase in time. Hence, the charcoal needed to be loaded regularly to achieve the power requirement for fish smoking. The kiln when operated with 1.0 kg charcoal with fan (WF), 1.5 kg without fan (WOF) and 1.5 kg with fan(WF) met the require standard of 70 ^{0}C in 3 hours in the six operations examined (12;13). Furthermore, the temperature attained by 1.5 kg with fan (WF) was too high and could caused denaturing of the fish, but the operations of the kiln with charcoal of 1.0 kg with fan (WF) and 1.5 kg without fan (WOF) were ideal for the fish smoke-dried conditions. Nevertheless, the temperature deviation of 4.15 0C within the kiln chamber at 1.5 kg charcoal loading without fan (WOF) and the cost (₦ 680.00) of operation, as compared to 1.0 kg charcoal loading with fan (WF) of 1.4 ^{0}C and cost of ₦ 460.00 gave it a better choice over 1.5 kg charcoal loading (WOF) and the best operating condition out of the six. Operating the smoking kiln at 1.0 kg of charcoal is able to give the required energy for 4 hours, temperature fluctuation of 1.4 ^{0}C and cost of operation of ₦ 460.00 as compared to 4.5 hours for 1.5 kg without fan (WOF) at temperature fluctuation of 4.15 ^{0}C and operating cost of N 680.00 as shown in Table 1.

From this analysis it is proposed that the operating condition for the developed kiln should be 1.0 kg charcoal with fan (WF) which is able to give the required drying requirement, low temperature fluctuation within the drying chamber, thereby guarantee uniform drying and low cost of operation.

3.2 Thermal Evaluation of the Smoking Kiln Loaded with Catfish

The thermal performance of the kiln for saw dust at 0.5 kg and charcoal at 1.0 kg with fan in operation when loaded is shown in Figure 1. Comparing the same operation at 'No Load', it was observed that there was a temperature drop from 130 to 70 ^{0}C at the start of operation. This sharp drop in the kiln temperature might be due to the wetness of the fresh catfish which pick-up the heat energy to equilibrate with the drying chamber of the smoking kiln. Hence, there was a heat transfer between the fresh catfish and the smoking kiln, while the catfish was gaining heat energy, the smoking kiln was losing.

Furthermore, it was also observed from Figure 3 that the drying process of the catfish followed three phases. Phase I from time 0 to 110 minutes corresponds to the rise in temperature of the catfish until it reaches equilibrium with the kiln temperature. What happened at this phase was that the heat energy was used to raise the low temperature of the catfish to attain the high temperature of the smoking kiln. The phase II took place between 110 to 340 minutes of the drying process which corresponds to the evaporation of the free moisture on the surface of the catfish which are permanently renewed by the moisture coming from the inside of the catfish. This phase is the stage for proper drying of the catfish where moisture were removed from the catfish and transported to the atmosphere through the chimney. The uneven stability of the Phase II might be due to the non-uniformity of the heat energy from the charcoal which was not able to give constant air temperature and velocity during operation. The Phase III was from time 340 to 570 minutes of the drying which corresponds to the stage at which the free water in the catfish has been fully evaporated and evaporated to the outside environment as water vapour. At this stage, the water evaporated at the surface was not seen, but the bound water in the fish was affected.

3.3 Quality Composition of Smoke-Dried Catfish

The smoke-dried catfish are shown in Plate 1. Figure 4 shows the proximate compositions of the fresh and dried catfish. The total weight of fresh catfish of 19.284 kg was reduced to 5.076 kg of dried weight after 9 hours 30 minutes. It is evident from Figure 3 that fresh catfish constitutes 75 % of water and there is a need to cold treat or dehydrate immediately after harvest so as not to expose it to microbial attack and chemical decomposition.

The proximate composition of the smoke-dried fish samples show that the smoking and drying of the catfish brings about changes in quality parameters and its composition. This is in line with previous work reported by [14], [15]. There is an inverse relationship between the protein content of the fresh and dried smoked catfish on one hand and the moisture content, and fat on the other hand as shown in Figure 3. The dried catfish protein is 68.4 % compared to initial fresh catfish of 16.24 %. This clearly shows that drying of catfish condenses the protein after the removal of water from the fish tussles. Likewise the 68.4 % of protein content corresponded to 7.3 % of moisture content in the dried fish; and vice versa. The 16.24 % of protein content of the fresh catfish corresponds to 78.7 % moisture.

In like manner the 12.5 % fat in the dried fish corresponds to 7.3 % moisture content of dried fish and vice versa. Moisture content of 78.7 % corresponds to 0.5 % of fat. Ash content and carbohydrates 6.4 % and 1.8 % respectively for dried fish and 1.33 % and 0.92 % for fresh fish was much higher in the dried fish because of the loss of moisture through drying. Generally, the values of the parameters analyzed showed that the smoking kiln was able to preserve the nutritional quality of the smoke-dried fish. This is an achievement over the traditional smoking kilns which have low productivity as well as poor qualities as reported by [16].

4. CONCLUSION

The developed fish smoking kiln was able to attain the recommended temperature and time needed for fish smoking. The incorporation of the fans gave fairly uniform distribution of heat within the drying chamber and ensures uniform smoking and drying of the fish. The use of batteries to power the fans makes the kiln useable in any remote area of the world. The operating condition for the developed kiln is 1.0 kg charcoal with fan (WF) which was able to give the required drying requirement, low temperature fluctuation within the drying chamber, thereby guarantee uniform drying and low cost of operation of ₦ 550:00. The chimney, incorporation and the close operation of the kiln eliminate smoke inhaling, burns and prevent deposition of soot or charring of the smoked fish. The quality of the smoked catfish was high and the challenges experienced by the kiln operators were eliminated.

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TABLE 1: TEMPERATURE DEVIATION AND POWER COST OF OPERATING THE SMOKING KILN

Operation Condition	Temperature Deviation (^{0}C)	Cost (N:K)
1.5 kg charcoal with fan	1.65	720:00
1.5 kg charcoal without fan	4.15	680:00
1.0 kg charcoal with fan	1.40	550:00
1.0 kg charcoal without fan	3.21	460:00
0.5 kg charcoal with fan	1.12	280:00
0.5 kg charcoal without fan	6.05	240:00

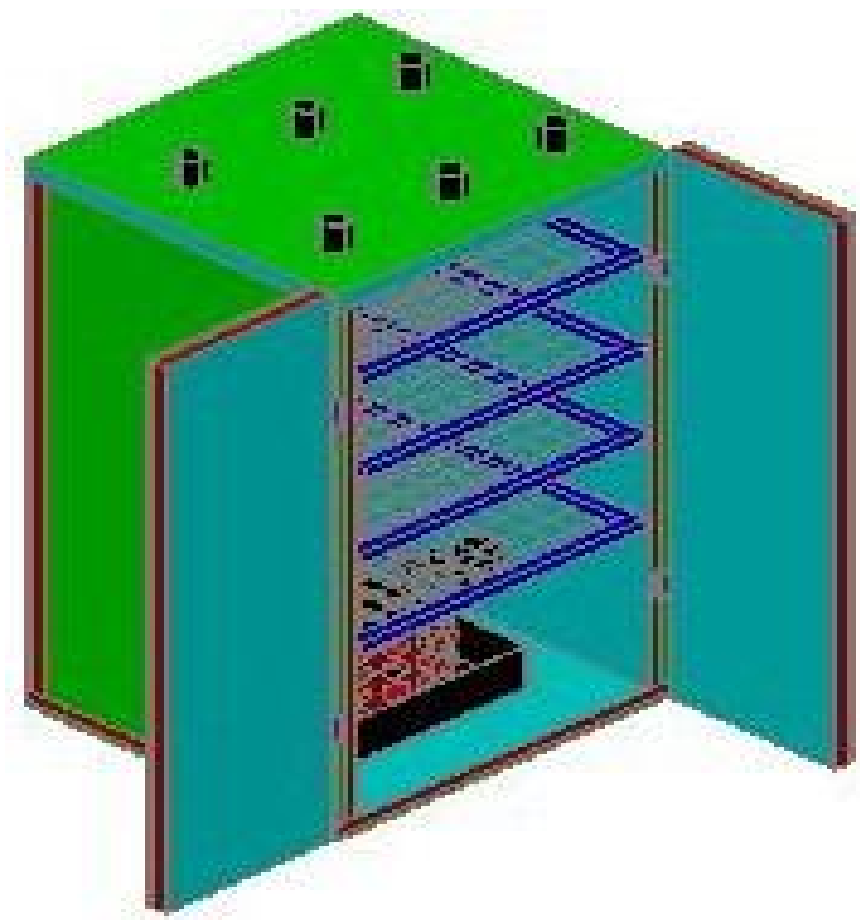

Figure 1: Isometric View of Smoking Kiln

ISSN 2229-5518

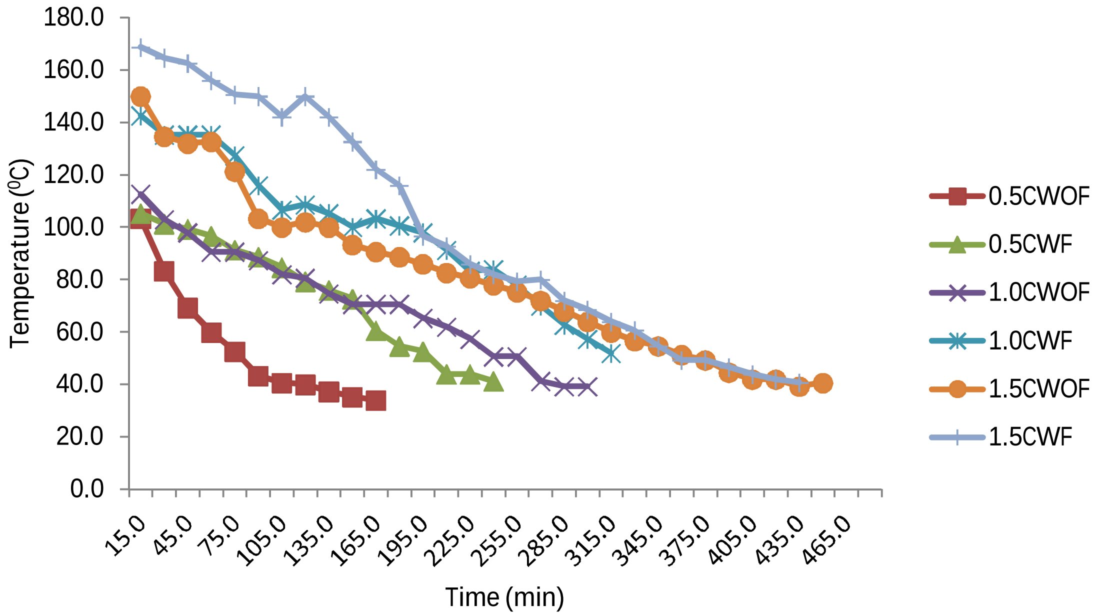

Figure 2: Temperature Distribution in Smoking Kiln at No Load

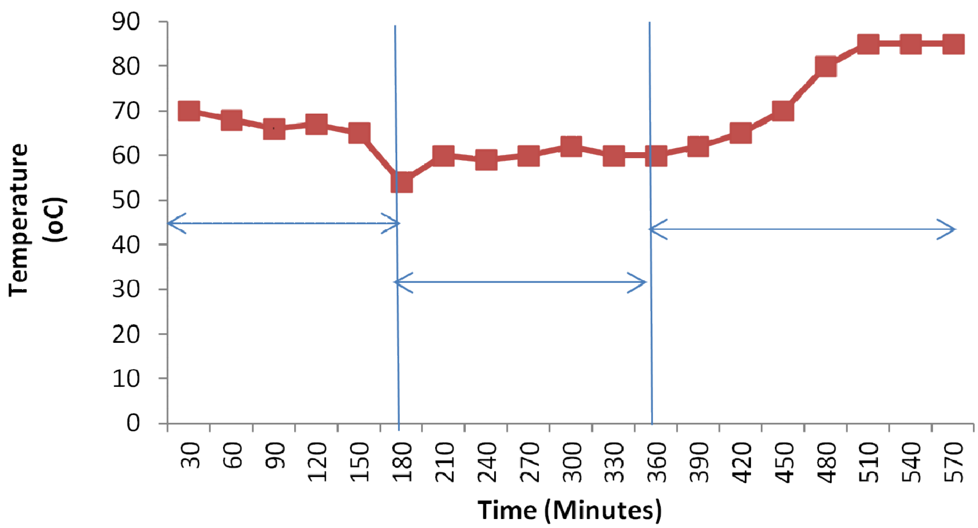

Figure 3: Temperature of the Smoking Kiln at Loading Condition with 1.0 kg Charcoal.

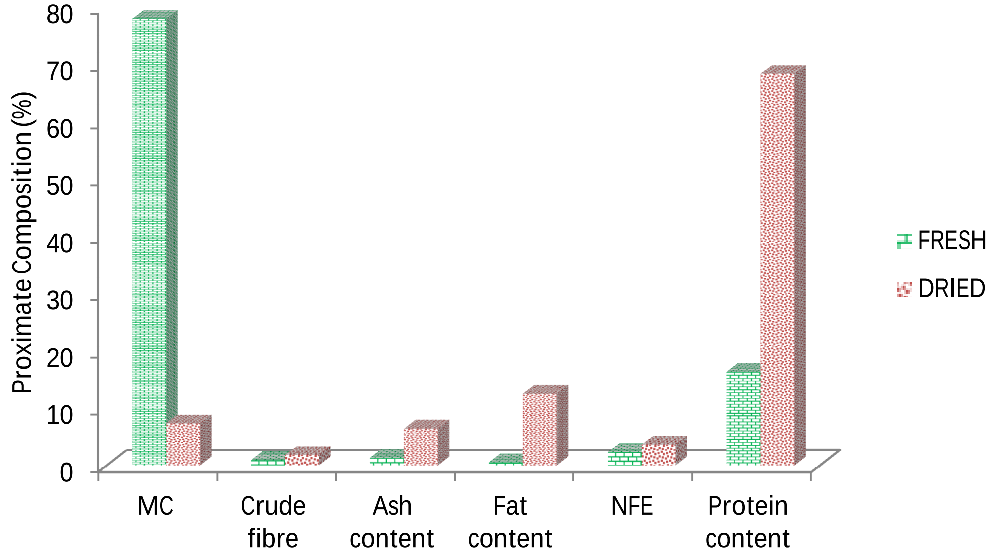

Figure 4: Initial Proximate Compositions of the Fresh and Dried Catfish

Plate 1: Smoke-Dried Catfish Product of the Study