DEVELOPMENT OF A MODEL ROTATORY FISH SMOKING KILN USING AGRO-WASTES AS SOURCE OF FUEL

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ABSTRACT

A model fish smoking kiln was designed and fabricated to use agro-wastes (sawdust, palm kernel shell and rice bran) as alternative to conventionally used charcoal (control) as fuel energy source for smoking fish. *Clarias gariepinus* was washed, brined and smoked in chunks or whole in the kiln. The smoking kiln has an estimated capacity of 40kg of fish/batch with six fish trays and 36 fish hooks. Heat transfer is by conduction and convection. The rotatory wheel and axle on which the fish drying trays were anchored ensured even distribution of heat. The kiln has 69.4% energy efficiency and drying period of 10 hours at an average temperature range of 60 – 120°C, depending on the type of agro-waste used as source of fuel energy. The fuel conversion ratio, drying rates and calorific values of the different agro-waste products were also determined. Calorific value of the four agro-wastes ranged between 16.2MJ/Kg in palm kernel to 30MJ/Kg in charcoal. The drying rates of sawdust and rice bran compare favourably with charcoal and they produced smoked fish similar in dryness and quality with fish smoked with charcoal. Palm kernel had the least drying rate of smoked fish (weight/hour) during the 10-hour smoking duration.

INTRODUCTION

Fish wastage occurs in large quantum in the artisanal fishery of Nigera due to poor infrastructural and storage facilities. It has been estimated that fish wastage due to spoilage is between 30 and 50 percent of the total domestic fish production in the sector (Tobor, 1990). This trend is actively checked by smoking, an ancient food preservation practice. In Nigeria, the most common technologies being utilised are the indigenous smoking kilns, which include, the traditional mud or drum oven, rectangular oven, Magbon-Alade kiln, Chorkor smoker and recently, the Altona oven (Balogun, 1992). Most modern smoking kilns already developed in Nigeria or elsewhere in Africa, such as the Nigeria Institute of Oceanography and Marine Research (NIOMR's), Lagos (Talabi and Igbinosun, 1975), Kainji Gas Kiln (Eyo, 1981) and Altona Kiln (Clucas, 1982) are rather too expensive and depend exclusively on scare and competitive energy sources for their effective operation. It is noteworthy that all these kilns have no provision for the control of smoke and temperature. However, the recently developed FUTA model fish smoking machine has a unique characteristic in terms of design and operation. It has comparative overall advantage of producing evenly smoked fish products. The smoked fish products can compare favourably in the international markets. Use of agricultural wastes by the kiln portends a viable option and cost effective approach to fish smoking in commercial quantity in Nigeria. The study evaluated the efficiency of the fish smoking kiln using agro-wastes as sources of fuel energy. Currently, the FUTA model fish smoking kiln is being popularised for general acceptance by the entire fisherfolks and processors in Ondo State and beyond.

MATERIALS AND METHODS

The model FUTA fish smoking kiln (Figure 1) was developed through a collaborative research efforts between the Departments of Agricultural Engineering (AGE) and Fisheries and Aquaculture Technology of the Federal University of Technology, Akure, Ondo State. Nigeria. The kiln was designed and constructed to use different agro-wastes. The smoking kiln consists mainly of two sections: the combustion and smoking chambers. Prior to smoking, fresh *Clarias gariepinus* were washed, degutted, washed again to remove the blood stain, drained for 20 minutes, soaked in 15% brine solution for 30 minutes and drained. Big fish were cut into chunks (125±1.05g) to create large surface area for heat and smoke transfer. Prepared fish were arranged on trays and made ready for smoking in the kiln. Four agro-waste products- rice bran, palm kernel shell, sawdust, and charcoal were procured and used in smoking the fish separately for 10 hours. Fuel sources were fed from the combustion chamber, and the heat generated moved by convection to the fish in the trays at the smoking chamber. Three dial thermometers were attached to the roof, smoking and combustion chambers respectively to monitor the changes in temperature at each unit. At intervals of one hour, the fish hangers were turned through the manual hand crank to allow for even distribution of heat. Temperature of the smoking chamber was regulated between 80 and 100°C. This was achieved by controlling the opening of the lid to the temperature regulator and moderating the air inlet to the combustion chamber, through the sliding slits. Mercury thermometer was used to measure ambient temperature, the mean daily temperature during the 10-hour of smoking was recorded and represented as T_0. Three dial thermometers were affixed to the roof, smoking and combustion chamber respectively. The mean daily temperature within the combustion chamber was calculated and denoted as T_1 while the mean temperature in the smoking chamber was depicted as T_2.

Table 1: Specification of the Model Smoking Kiln

Parameters	**Specifications**
Height of kiln	1.6 metres
Width of kiln	0.8 metres
Depth of kiln	0.8 metres
Lowest distance of fish tray to combustion chamber	0.3 metres
Lenght of the wheel and axle	0.7 metres
Depth of the wheel and axle	0.5 metres
Lagging material	Fibre glass
Sources of heat	Agrowastes e.g sawdust, rice bran
Means of heat transfer	Convection/Conduction
Length of the smoking chamber	0.7 metres
Length of the combustion chamber	0.3 metres
Number of fish trays	6
Number of fish hooks	36 (6 per row)
Estimated capacity of the kiln	40 kg of fish/batch
Weight of the kiln	~ 300 kg

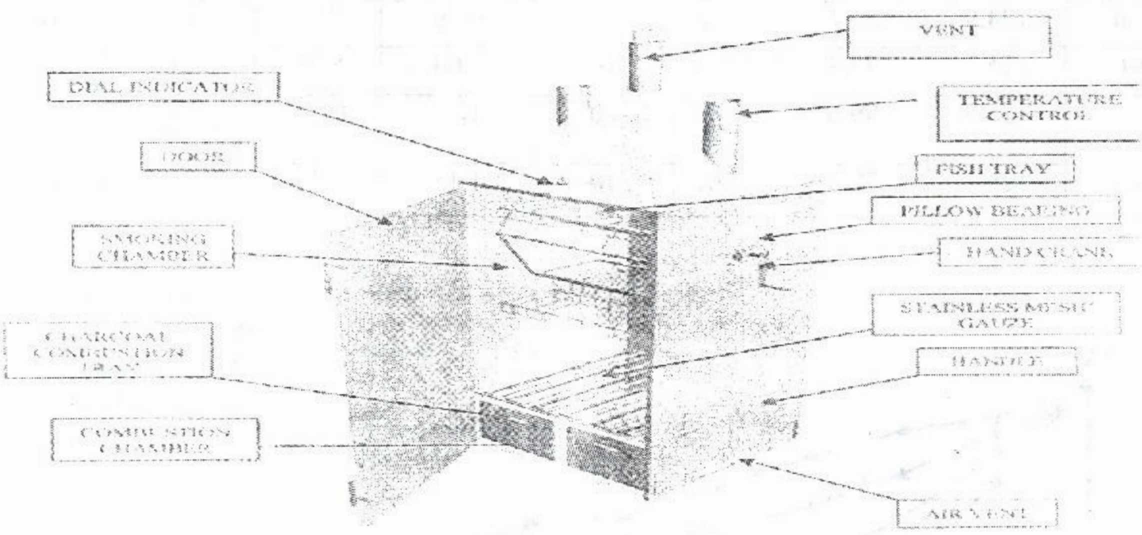

Figure 1: Details of the FUTA Model Fish Smoking Kiln

RESULTS AND DISCUSSION

Fish sample smoked with charcoal had the least water activity (A_w) at the end of the 10 hours of smoking. This was followed by fish smoked with sawdust and rice bran, while palm kernel had the highest water activity. The mean moisture content of *Clarias gariepinus* smoked with charcoal was 10.41%, sawdust (11.54%), rice bran (12.27%) and palm kernel shell (16.43%).The drying rate curve (Figure 2) of charcoal and sawdust were similar, followed by that of rice bran and on top is the palm kernel's. This implies that charcoal smoked best, followed by sawdust and rice bran, while fish smoked with palm kernel shell was the poorest. Evaluation of the calorific value (burning temperature range) of the four agro-wastes (Table 2) showed that charcoal produced the most stable and highest heat energy value of 30.0 MJ/Kg at 90-120°C while palm kernel produced the least value of heat energy of 16.2 MJ/Kg between 60-80°C. It is noteworthy that the palm kernel shell burnt poorly, requiring frequent fanning and giving of the least heat energy (temperature).

Energy Efficiency:

$$\eta = \frac{E_1}{E_2} = \frac{T_1 - T_2}{T_1 - T_0} \quad \text{(Mujumdar, 1995)}$$

Where: T_0 = Mean Ambient Temperature (Outside the kiln) = 28.8 ^{0}C

T_1 = Mean inlet air Temperature (Combustion chamber) = 87.6 ^{0}C

T_2 = Mean outlet air Temperature (Smoking chamber) = 46.8 ^{0}C

$$\eta = \frac{87.6 - 46.8}{87.6 - 28.8} = \frac{40.8}{58.8} = 0.6939$$

% energy efficiency = η x 100 = 0.6939 x 100 = 69.4%

Table 2: Calorific Values of the Agro-Wastes

Agrowastes	Source	Calorific Value (MJ/kg)	Burning Temperature Range (^{0}C)
Charcoal	Wood	30.0	90 – 120
Sawdust	Mixed wood	19.5	80 – 110
Rice bran	Rice	16.6	90 - 100
Palm kernel	Oil Palm	16.2	60 – 80

Table 3: Drying and Fuel Consumption Analysis

Treatment	Wt of fresh fish (g)	Wt of smoked fish (g)	% Wt loss	Smoking time (hours)	Fuel consumed (kg)	Kg of fuel/kg fresh fish	Kg of fuel/kg smoked fish	Cost of fuel/kg fish (Naira)
Rice bran	124.9	89.2	28.58	10	0.99	7.98	11.18	0.12
Sawdust	125.3	73.2	41.58	10	1.03	8.21	14.05	0.08
Palm kernel	125.9	99.6	20.89	10	1.36	10.79	13.63	0.16
Charcoal	126.1	72.3	42.67	10	1.15	9.11	15.88	0.13

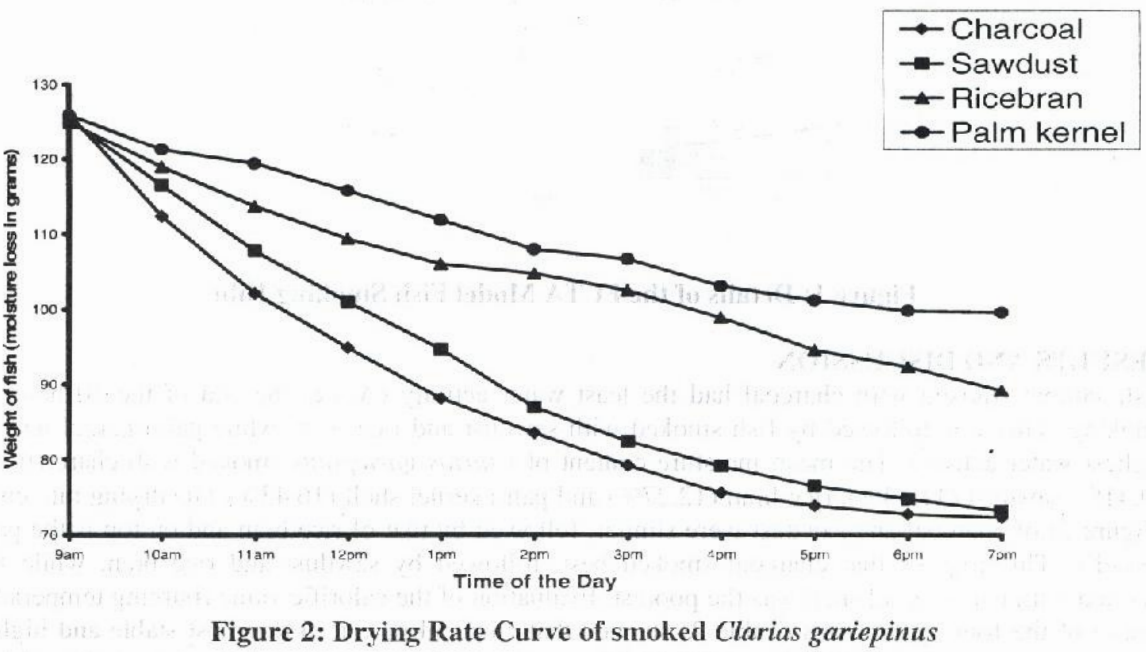

Figure 2: Drying Rate Curve of smoked *Clarias gariepinus*

In this study, the model smoking kiln was found to be fuel efficient either in the use of charcoal, sawdust and rice bran (Table 3). The kiln produced evenly smoked fish products, better than traditionally smoked fish. It has been reported (Roger, 1970) that excessive heat treatment impairs nutritional value of fish protein. In addition, less exposure to direct fire reduces the impact of phenol, which from public health angle is carcinogenic and damage human kidneys (Coan *et al*, 1982). Control of temperatures in the model kiln also reduces physical loss caused by charring (CTA, 1986). Agro-wastes such as sawdust and rice bran are good substitutes for the convectionally used charcoal in terms of heat generation and cost effectiveness. Palm kernel shell is not recommended because of the drudgery associated with fanning and slow burning process.

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