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The Drying Rates and Sensory Qualities of African Catfish, *Clarias gariepinus* Dried in Three NSPRI Developed Fish Kilns

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ABSTRACT
Fish drying is a popular method of processing fish in Nigeria. Three models of fish kilns namely; charcoal, electrical and gas powered were used for drying of African catfish (*Clarias gariepinus*) as well as assess the volume of oil collected during the drying process. Twenty-five kilogram (25 kg) of fish with an initial moisture content of 69.93 % (wet basis) were dried to a final moisture content of 6.87 % within 12 hrs, 15 hrs, and 18 hrs in electrical, gas and charcoal powered fish kilns respectively. The mean drying rate of the fish were 1.46 ± 0.01 kg/hr, 0.99 ± 0.04 kg/hr and 0.89 ± 0.10 kg/hr for electrical, gas and charcoal powered kilns respectively. There was a significant difference ($p<0.05$) in the drying rates values of the fish samples in the entire kilns. All the fish dried in the three kilns had high sensory attributes. The fish samples dried in the three models of the fish kilns differed significantly ($p<0.05$) in their sensory attributes. The three NSPRI fish kilns were effective in drying *C. gariepinus* to a safe moisture content with acceptable sensory quality as well as in collection of fish oil. The electrical fish kiln performed better in terms of drying rate and sensory qualities of the fish. The charcoal powered fish kiln has the highest (270ml) fish oil, followed by electrically powered kiln with 170ml/25kg of fish. To effectively utilize the charcoal powered kiln, the charcoal box be recharged every 2 hours while fish processors with access to electricity and gas should be using either of the two models.

Key words: Drying rate, NSPRI fish kilns, *C. gariepinus* sensory, quality

INTRODUCTION

Fish is one of the major animal protein foods available in the tropics. It is particularly valuable for providing proteins of high quality comparable with those of meat, milk or eggs. This has made fishery an important aspect of the study. According to Olatunde (1989), in Nigeria fish constitutes 40% of animal protein intake; unlike any other animal protein source with one problem of religious taboo or health hazard, fish is eaten across the country. Fish protein also provides vital protein constituents which enable the body to carry out certain functions such as growth. However, fish is highly susceptible to deterioration immediately after harvest. Immediately the fish dies a number of physiological and microbiological deterioration sets in which reduces the quality of the fish (Okonta and Ekelemu, 2005). Wastage of fish mainly due to spoilage has been estimated at 20-50% of domestic fish production in Nigeria (Eyo, 2001). This means that a high proportion of fish produced in this country does not get to the consumers in a wholesome state. Although the world fish production has increased tremendously over the last decade, there is still a marked imbalance in utilization due to inability to transform the freshly harvested fish into stable, acceptable products and to distribute these products to the people who need them in good quality and affordable prices (FAO, 2012). This has an adverse effect on the protein intake of developing countries that are already facing scarcity of animal protein due to shortfall in meat production. For wastage to be reduced, harvested fish should be processed in order to retain quality and increase shelf-life. A number of methods are used to preserve fish. Some of these techniques are based on temperature control using ice, refrigeration, freezer and others which involve the control of water activities which include drying, salting, smoking, freeze-drying and combination of different techniques (FAO, 2001).

Fish drying is an age long practice across the world. It is one of the methods of processing fish. Traditional fish smoking as practiced in Nigeria not only consumes lots of fuel wood, but it is also

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bedevilled by lack of control over the drying process, exposure to dirt, dust, insect infestation, contaminants and low capacity. Consequently, fish, dried using traditional methods are unstable with poor quality and very short shelf life (Davies and Davies, 2009; Kolawole *et al*., 2010). The trade in traditional fish products such as smoked fish, from West Africa to Europe has come under increasing scrutiny from authorities both in the exporting and importing countries due to the supply of poor quality products. International trade legislation designed for relatively sophisticated industrial level processing is being applied to what is essentially a traditional process. As a result, processors and exporters fail to meet the required standards set by authorities in the country of export. Formal trade is therefore being constrained in what is, at retail level in importing countries, a high value product. Many kilns meant to be fuel efficient and produce better quality fish have been developed. Their major setback is poor adoption rate by traditional fish processors due to their high cost, complexity of construction and consumption of fuel wood (Bala and Mondol, 2001; Akinola *et al*., 2006; Olayemi *et al.*, 2012).

As part of the mandate of the Nigerian Stored Products Research Institute (NSPRI) to reduce post-harvest losses in food grown and consume in the country, including fish and meat, the institute has developed various models of smoking kilns. The developed kilns have assisted fish processors in reducing postharvest losses. Olayemi *et* al. (2013) developed a smoking kiln for fish processing in a developing economy. The smoking kiln was effective in drying fish, but relies on the use of charcoal for its operation. The smoking kiln and other charcoal powered kilns are limited in efficiency and require rigorous monitoring to provide quality dried fish. Oil droplets from the fish gets into the charcoal may also cause fire hazards. Apart from this during smoking, heating and drying processes, combustion products come into direct contact with foods and PAHs contamination can occur. PAH compounds have been detected in various food and non-food substances and beverages, including fish (Anyakora and Coker, 2007).

Due to the aforementioned challenges fish farmers and processors have seen the need for improved smoking kiln with alternative source(s) of energy that can produce quality dried fish. In order to address the need of fish processors in this regard, NSPRI developed three models of fish kilns namely; electrical, gas and charcoal powered kiln. This research work, therefore, evaluated the performance of three models of fish kilns with respect to the drying rate, quality of fish dried and the quantity of fish oil collected from the kilns during operation.

MATERIALS AND METHODS

The description of the fish kilns

The electrically powered fish kiln (Plate 1) is a double walled structure having a dimension of 0.6 x 0.6 x 1.20 m (L x W x H) completely insulated all round with polyurethane of 2.54 cm thickness to conserve heat within the drying chamber as well as preventing the operator from being exposed to serious heat. The internal wall of the kiln is made from Galvanized steel (GS) to avoid corrosion while the outer wall is made of mild steel (MS) painted with gloss paint. The kilns consist of the drying chamber, combustion chamber and the vent. The drying chamber has five sets of tray on racks. The trays are made of expanded metal of 2.5 x 5.0 cm mesh size (GS) welded to a square pipe of 2.54 cm thickness. The holding capacity of the kiln is 25 kg of fresh fish. The combustion chamber, which is positioned away from the drying chamber, houses the electrical heating element, the gas burner and charcoal box for the electrical, gas, and charcoal powered kilns respectively. The kilns were mounted on a set of four wheels for ease of movement. The fish kilns can be dismantled into six parts and has a temperature gauge to monitor the drying temperature as well as an oil collecting unit through which the oil oozing out from the fish during drying is collected.

The charcoal powered kiln has a combustion chamber that houses the charcoal box and a direct current (DC) fan that is operated with a rechargeable battery powered by a solar panel. The essence of the fan is to enhance heat distribution within the kiln thereby ensuring even drying and at the same time reduce the need for change of drying trays during operation.

In the gas powered kiln, the combustion chamber houses the gas burner that is coupled with the gas cylinder through a hose.

The electrical kiln on the other hand has a combustion chamber consisting of two (2) heating elements each of 1.8 W and an alternating current (AC) fan. Also, it has a temperature regulator through which desired temperature can be set. Plate 1 is the side view of the gas powered fish kiln showing the gas cylinder, the combustion chambers and the drying chamber. Plate 2 is the front view of the charcoal powered kiln showing the temperature gauge, drying trays, oil collector and the charcoal box while Plate 3 is the front view of the electrically powered kiln.



Plate 1: Gas powered fish kiln Plate 2: Charcoal powered fish kiln Plate 3: Electrically powered fish kiln

Sample preparation and fish drying

African Mud Catfish of average weight of 330 g was purchased from a farm in Ilorin metropolis and transported in water to NSPRI headquarters. They were killed by breaking their spine, gutted (ensuring the complete removal of gills and intestines) and cleaned. The samples were subjected to osmotic pre-treatment (350 g of salt to 50 litres of water) for 30 minutes (to enhance the release of water from the fish tissues and to add taste). Thereafter the fish were drained by arranging on drying trays to ensure that surface water is removed before putting them into the dryer. Each of the trays was labelled. The fish kilns were powered and allowed to attain the maximum temperature (130 ^{0}C). After the kiln has stabilized, the drying trays with the fish arranged on them were then put into the kilns. The average weight of fish in each of the fish kilns was 25 kg. The temperature drop, the equilibrium temperature and the time taken for each of the kiln to attain the temperatures were recorded. The samples were then weighed in an interval of three (3) hours using a digital weighing balance with an accuracy of 0.01 g (Avery Berkel- Averyweigh-Tromix HL122) until the fish is dried to the desired moisture content. The drying temperatures within the kilns were recorded with the aid of a data logger (Tinytag TV-4104). At the end of drying the fish were allowed to cool then packed. The charcoal box of the charcoal powered kiln was recharged at an interval of 2hrs to prevent the temperature in the smoking kiln from dropping to ambient temperature.

As the drying progresses, oil droplets (fish oil with water) oozed out of the fish and fell on the collector plate; because the collector plate is hot the water evaporates thus leaving the oil. Fish oil draining from the oil collector was put in a plastic bottle and allowed to cool after which they were poured into measuring cylinders. The rate of moisture removal (drying rate) was calculated from the data recorded during drying. The drying rate was calculated according Ichsani and Dyah, (2002) as equation 1.

$$R = \left(\frac{dM}{dt}\right) = \frac{m_i - m_f}{t} \qquad \text{……………………………………………...………………………..1}$$

Where; R is the drying rate in g/hr, dM is the change in mass (g), dt is the change in time (hr) and t is the total time (hr), m_i and m_f are the initial and final mass of fish samples respectively in gram.

Quality assessment

The sensory analysis was carried out using the 9-point hedonic scale (SSP, 2016). The template which is a rating method allows the panellists to choose from a range of options; from 'like extremely' to 'dislike extremely'. The options include; like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much and dislike extremely; and they were allocated 9, 8, 7, 6, 5, 4, 3, 2 and 1 mark respectively. The panellists consisting of six people were given three test templates, each; one per sample. Each person in the panel analysed the dried African Mud catfish dried in the three fish kilns. After the test, the result was extracted by collating the allocated points for each option chosen by the panellists.

Statistical analysis

The data obtained from the experiment were subjected to One-way Analysis of Variance (ANOVA). Significant differences between the means were determined using the Duncan New Multiple Range Test (DMRT) with the means of SPSS version 16 at 95% confidence level (P=0.05).

RESULTS

Temperature profile and drying rate of *C. gariepinus* in the fish kilns

Figure 1 shows the Temperature profile of the three NSPRI fish kilns. The drying temperature in the smoking kilns rises from ambient (30^{0}C) to 90^{0}C, 90^{0}C and 92^{0}C after two (2) hours for all the three fish kilns. The highest temperatures obtained in the kilns during drying were; 143 ^{0}C, 127 ^{0}C and 110^{0}C for electrical, gas and charcoal powered smoke kiln respectively. Figure 2 shows the drying rate curve of the fish samples dried in the fish kilns. There was an initial constant rate drying period after three hours of drying in all the kilns during which the highest drying rate values of 1.15kg/hr, 1.78kg/hr and 2.14kg/hr were recorded for charcoal, gas and electrically powered kilns respectively. The drying rate then reduced to an average of 0.38kg/hr in the three kilns after about nine (9) hours of drying.

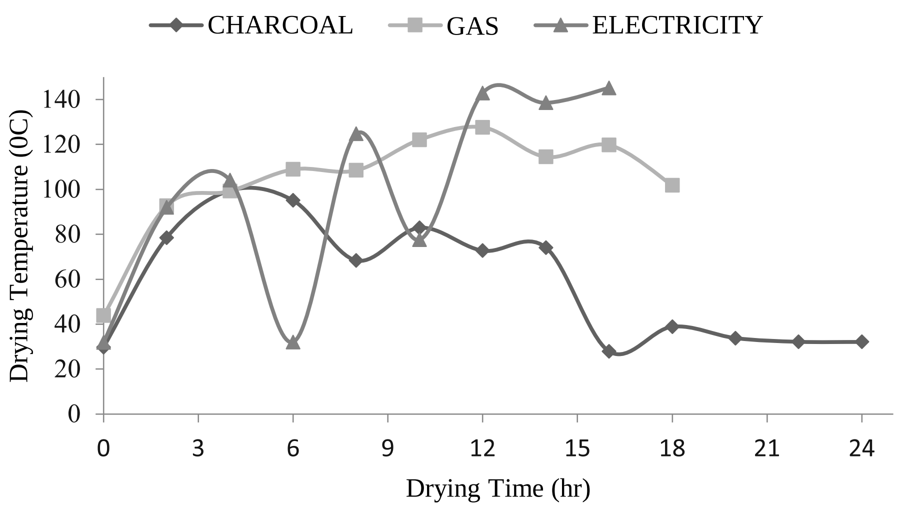

Figure 1: Temperature profiles of the NSPRI fish kilns

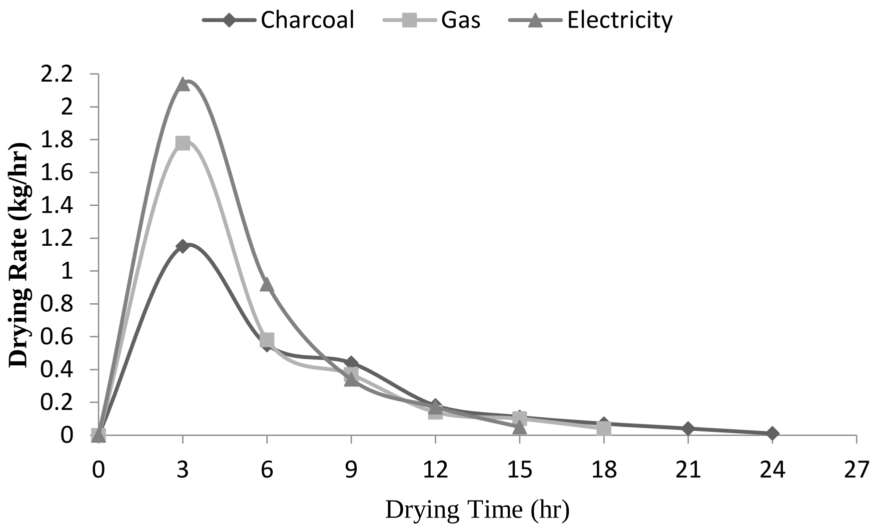

Figure 2: Drying rate curve of C. gariepinus smoked, dried in the three NSPRI fish kilns

Table1: Moisture content and weight loss of *C. gariepinus* dried using three NSPRI fish kilns

Drying time (hr)	Weight loss (kg)			Average Drying Rate (Kg/hr)		
	Charcoal Kiln	Gas Kiln	Electrical Kiln	Charcoal Kiln	Gas Kiln	Electrical Kiln
0	24.95	24.95	24.7	$0.88 \pm 0.10^{a*}$	0.99 ± 0.04^{a}	1.43 ± 0.01^{b}
3	3.45	5.35	6.42			
6	3.3	3.50	5.63			
9	3.95	3.35	3.10			
12	2.20	1.70	2.05			
15	1.70	1.47				
18	1.30					

*values with different letters are significantly different ($p<0.05$)

Table 1 shows the moisture contents and weigh loss of *C. gariepinus* dried using three models of NSPRI fish kiln. The temperature profiles of the three models of the fish kilns are shown in Figure 4. The fish kilns attained maximum drying temperatures of 105 ^0C after 6 hours, 130 ^0C and 140 ^0C after 12 hours of charcoal, gas and electric powered respectively.

Sensory properties of *C. gariepinus* samples dried in three NSPRI fish kilns

Table 2 shows the sensory qualities of *C. gariepinus* smoke dried in the three NSPRI fish kilns. The fish sample dried with electrically powered kiln had the best appearance, colour, texture, taste, flavour and aroma, followed by those dried with gas powered fish kiln. Generally, sensory quality ratings ranged between 8.5 for appearance and 6.5 for texture and taste, with the significantly ($p<0.05$) higher acceptability values ~~of~~ (7.9) in samples smoked with electrically powered kiln. Gas powered and charcoal powered fish kilns have 7.5 and 6.6 acceptability values, respectively. There was a significant ($p<0.05$) differences between the acceptability values of gas and charcoal powered fish kilns.

Table 2: Sensory parameters of *C. gariepinus* dried using three NSPRI fish kilns

Source of power	Appearance	Colour	Texture	Taste	Flavour	Aroma	Overall Acceptability
Electricity	8.5	8.3	7.1	8.2	7.8	7.4	7.9^{a}*
Gas	7.6	7.8	7.4	7.7	7.5	7.0	7.5^{b}
Charcoal	6.6	6.5	6.5	6.5	6.8	6.7	6.6^{c}

*values with different letters are significantly different ($p<0.05$)

Quantity of oil collected during drying

The average quantity of oil collected from the fish kilns loaded with fish of 25 kg each were 170, 270, and 100 ml for the electrical, gas and charcoal powered kilns respectively.

DISCUSSION

Effects of fish kiln type on the temperature profile and drying rate curve

The temperature profiles of the three fish kilns indicated that the fish kilns were able to attain the required temperature for fish drying since the temperature attained is well above the ambient temperature which allowed for evaporation of moisture from the fish. The profile showed that while the electrical and gas powered kilns were able to maintain uniform temperature over a relatively long period (which is required for effective and even drying), the temperature trend for the charcoal powered kiln on the other hand was different. This is because the temperature rose steadily as the charcoal is ignited until it fully glowed at a point which the maximum temperature of 99.5 ^{0}C was attained. However, after about two (2) hours the temperature had dropped to 60 ^{0}C which necessitated the reloading of the charcoal box. Generally, the drying temperature increases as the drying approaches the desired moisture content due to the reduction in the moisture content of the fish samples. This confirms the results of previous studies by Olayemi *et al*. (2013) and who pointed out that as the moisture content of the fish decreases, the drying temperature increases because the drying air no longer carries much moisture.

The drying curve obtained show that drying of fish like any other agricultural material occurs in the constant rate and falling rate period. The constant drying rate period was observed in the first three (3) hours due to the initial high moisture content irrespective of the type of kiln. Thereafter the drying phase progresses into the falling rate period as more moisture is removed from the fish samples. This shows that moisture is the driving force for the falling rate period as reported by Omodara and Olaniyan (2012). Although due to the variation in the temperature profile of the kilns the drying rate differs, the trend was however similar in the three kilns.

Effects of drying temperature on moisture loss and the drying rate of *C. gariepinus* dried in three NSPRI fish kiln

Generally, the three fish kilns were able to attain a temperature above 50 ^{0}C which is a precondition for effective drying. The electrically powered kiln maintained a higher temperature compared to the charcoal powered and the gas powered kilns. The electrically powered fish kiln dried fish 24.7 kg from initial moisture content of 69.85% (wet basis) to a final moisture content of 6.90 % within 12 hours with a drying rate of 1.43 kg/hr. This is as a result of regular flow of the heat coupled with rapid intensity as it moves moisture rapidly from the fish samples. Ashaolu, (2014) reported a similar result. The gas powered fish kiln on the other hand reduced the moisture content of 24.95 kg African mud catfish from 70.10 % to 6.85 % (wet basis) after 15 hours of drying with a drying rate of 0.99 kg/hr while the charcoal powered kiln dried 24.95 kg fish samples of an initial moisture content of 69.85% to a final moisture content of 6.85% (wet basis) with a drying rate of 0.88 kg/hr. This showed that the electrically powered kiln is the most effective while the gas powered kiln is more effective than the charcoal powered fish kiln. It was observed that the rate of moisture removal in all the samples was higher within the first six (hours) of drying as there was a moisture loss of 27.1%, 35.5% and 48.4% for charcoal, gas and electric powered kilns respectively. This was due to the initial high moisture content of the samples. This agrees with the findings of Idah and Nwankwo (2013), who reported that the quantity of moisture lost during smoke drying of fish is higher in the first five (5) hours of drying than the subsequent drying periods. The drying rate decreased in all the fish kilns as drying progresses irrespective of the type of kilns. This is in conformity with the findings of Modibo *et al*. (2014) who observed that drying rate decreases with reduction in moisture content of fish dried using traditional sun drying and shade drying. The drying curves obtained showed that drying of fish occurred only in the falling rate period. This further buttresses previous works done by Omodara *et al*. (2012).

In general, drying rate increased with increase in drying temperature, but decreased with time which showed that the temperature was a major factor affecting the drying rate of a product. This is in conformity with previous studies carried out on drying of agricultural commodities. (Mujaffar and Sankat, 2005, and Kilic, 2009).

The high acceptable sensory attributes recorded in this study are in line with the findings of (Govas and Kontominas, 2005; Wu and Mao, 2008 and Kumolu –Johnson *et al.*, 2010), which showed that fish dried in improved fish kilns or dryers generally have good sensory qualities (Govas and Kontominas, 2005; Wu and Mao, 2008 and Kumolu –Johnson *et al.*, 2010). The values of the overall acceptability showed the effectiveness of the fish kilns in producing good quality dried fish.

The effects of the fish kiln type on quantity of oil collected

The quantity of oil collected from the fish samples during the drying test is an indication that oil that would have dropped into the drying cabinet, or into the combustion chamber in some other design thus causing fire outbreaks can be effectively collected and use for other purposes. Although the highest quantity of oil was collected in gas powered kiln with the charcoal powered kiln having the least quantity of oil, this can be traced to some other factors inherent in the fish samples used rather than the type of kiln used.

Conclusions and recommendations

The performance evaluation showed that the three models of fish kilns developed were effective in drying *C. gariepinus* to safe moisture content. All the fish samples had high acceptance value irrespective of the type of fish kiln. The study has established that the electrically powered kiln is the most effective with respect to drying rate and sensory attributes of the dried fish. The gas powered kiln is more effective than the charcoal powered smoke kiln. Also the electric and gas powered kilns required less monitoring than the charcoal powered kiln. The performance of the charcoal powered fish kiln can be improved by regular charging of the charcoal box.

It is recommended that for effective use of the charcoal smoking kiln, the charcoal box should be charged at an interval of 2 hours. There is need to carry out further research on the clarification and characterization of oil collected and established appropriate use of the fish oil. Although the quantity of oil collected varied in quantity more research needs to be carried out to establish the basis for the variations observed.

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