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FABRICATION AND PERFORMANCE ASSESSMENT OF A LOCALLY DEVELOPED FISH SMOKING KILN

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Abstract: *A study was conducted to fabricate a new smoking kiln to improve on the existing fish smoking kiln technology and to determine its performance for recommendation for use. The parameter used to determine the smoking efficiency included the loss in weight of the fish samples, the temperature and the time it took to properly smoke the fish using charcoal as smoking fuel. The smoking kiln was tested by using three different species of fish: Clarias sp., Mormyrus spp. and Chrysichthys sp. under a period of one hour. It was discovered that it performed perfectly well. Its advantages over all the already existing fish units are that it is faster in efficiency producing well dried smoked fish of regular golden brown colour which lasted for about six weeks even without spoiling. The fish processing itself took less than one hour. The temperature of the heat supplied was quite higher than in the commonly used drum oven. The smoking kiln on the average cost approximately ₦8,000 Nigeria money. It is a perfect substitute for any of the already existing widely used technologies.*

Keywords: *drying, fabrication, fish, performance, smoking kiln.*

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1. INTRODUCTION

Fish is one of the most important foods on the planet. It's flesh is a source of top quality protein and for many in less developed parts of the world, it represents a significant proportion of the animal protein in their diet, either as fresh fish or cured in a variety of ways such as smoking, salting, drying, charring, icing and chilling. Fish can also be seen as a renewable natural resources provided that the seas, lakes, rivers reservoirs, lagoons are not over-exploited. Fish harvesting, handling, processing and distribution provide livelihood for millions of people as well as providing foreign exchange earning to many countries (Al-Jufaili and Opara, 2006). Appropriate processing of fish enables

maximal use of raw material and production of value-added products which is obviously the basis of processing profitability (Ito, 2005; Davies and Davies, 2009).

Protein of animal origin is in short supply in Nigeria due to decreasing population of cattle, arising from the prevalence of viral, parasitic disease, desert encroachment and drought which has caused reduction of forage grounds. Availability of fish, another major source of protein, to consumers has reduced due to increase in human population in Nigeria, restriction in fish importation, spoilage due to poor preservation and marketing practice in the artisan sector. These have also put tremendous pressure on the limited supply of fish (Akinola et al., 2006).

Fish is one of the most perishable of all staple commodities. Spoilage occurs as the result of the action of enzymes (autolysis) and bacteria present in the fish and also chemical oxidation of the fat which causes rancidity. At the high temperatures prevalent in tropical countries like Nigeria, bacterial and enzymic actions are enhanced. Fish invariably become putrid within a few hours of capture unless they are preserved or processed in some way to reduce this microbial and autolytic activity and, hence, retard spoilage. If the moisture content of fresh fish is reduced during drying to around 25%, bacteria cannot survive and autolytic activity will be greatly reduced, but to prevent mould growth, the moisture content must be reduced to 15%. Also the presence of salt retards bacterial action and, in addition, it aids the removal of water by osmosis (Khoshmanesh, 2006).

Freshwater fish processing, like the processing of the other food raw materials should: assure best possible market quality, provide a proper form of semi-processed final product, assure health safety of products, apply the most appropriate processing method and reduce wastes to the barest possible extent. Akinneye *et al*. (2007), Davies and Davies (2009) reported that the development of appropriate fishing machinery and techniques that employed effective production, handling, harvesting, processing and storage, cannot be over-emphasized especially in the age when aquacultural development is fastly gathering momentum in Nigeria.

Opara and Al-Jufaili (2006) reported high incidence of fish losses as a major impediment to the realization of government goal towards increasing the contribution of the sector to the overall national economy. The use of appropriate technology which is a radical approach to stem up production and processing technique, has become subordinate to social need, and is of paramount importance.

The need to mechanize fish processing techniques has drawn the attention of national agricultural research to devote utmost interest and resources to engineering research in operation, to minimize the drudgery, reduce labour operation, and unsanitary and inherent unhygienic handling that are mostly involved in the traditional manual operations. Eyo (1997) reported abundant fish catch in the dry season. During this period, ponds, lakes and streams experience reduced water level, for easy harvest. Thus, period of fish scarcity is often encountered especially during the flood and raining seasons, during which fish are in short supply. Thus, it is imperative to process and preserve some of the fish caught in the period of abundance, so as to ensure an all year round supply. This will invariably reduce post harvest losses, increase the shelf-life of fish, and guarantee a sustainable supply of fish during off season with concomitant increase in the profit of the fisher-folks (Davies and Davies, 2009).

Akinola *et al*. (2006) reported different types of preservation methods; drying, smoking, freezing, chilling and brining. But the most prominent fish preservation in Nigeria is smoke drying. This could be adduced to the fact that most of the fish communities have no access to electricity to freeze their products. Electricity itself is fast becoming a less reliable source of energy for fish processing and preservation. Bolaji (2005) reported that despite the rudimentary nature of process of traditional methods, lack of control over the drying rate, sometimes results to under-drying or over-drying, and expose the fish to unexpected winds, dust, dirt, insect infestation, and contaminants such as flies. These methods still remain predominant in Nigeria.

Tawari (2006), Davies and Davies (2009) also reported that most of the fish processing communities in Nigeria employed traditional techniques and they have been in existence for more than ten years. In order to reduce post harvest losses and to improve the quality of fish and fishery products, traditional processing technology must be improved upon in Nigeria. This includes upgrading the traditional fish processing technology and adoption of artificial dryers. Most of the modern drying technologies available are expensive and not appropriate for a developing country like Nigeria, particularly in the areas where prerequisites for these technologies, such as electricity are simply not available adequately.

Therefore, this study is focused on the fabrication of a simple, durable, portable and easily maintained smoking cabinet with air vents and heat flow system developed from the mechanisms of traditional chimney kilns (smoke house). The smoking kiln is constructed to function without any electrical or sophisticated mechanical appliances to generate heat, but with the help of natural air convection through air vents.

2. MATERIALS AND METHODS

2.1 Construction of the Smoking Kiln

Fig. 1 shows the locally developed smoking kiln. The smoking cabinet is made up of galvanized iron sheet for the body and 25 mm square galvanized pipe for the frame. The cabinet has overall length of 610 mm and breadth of 610 mm. The top of the cabinet is made in form of perforated surface where the fish is placed for smoking. A circular tray is constructed below the perforated surface which holds the smoking fuel (charcoal). Attached to the circular tray is a pipe connected to a pressure equipment sack which serves as air blower, which allows heat from the smoking fuel to move up faster to fish smoking sheet. The smoking kiln can be used to smoke up to 80 kg of fish at a time. The entire system can be placed under a shade because of sun or rain.

Fig. 1: Locally developed smoking kiln

2.2 Smoking Procedure

The three fish species used for the tests (*Clarias gariepinus*, *Mormyrus rume* and *Chrysichthys nigrodigitatus*) were obtained from two different fish farms. The species are popular delicacies among the low and middle income earners and vary in size, and relatively cheap and affordable. They are fresh water fish species commonly found locally in the inland waters of Nigeria. The fish were degutted and immediately washed thoroughly, brined and ready for smoking.

The perforated sheet surface was greased with groundnut oil to prevent the fish from sticking unto the sheet. The brined fish were arranged on the perforated sheet and red hot charcoal was placed under the smoking sheet on the fuel tray to supply heat to the fish to enhance smoking. The fish were smoked for less than 1 hour with smoking temperature ranged between 60^{o}C and 100^{o}C.

2.3 Determination of Weight Loss

The weight loss was determined using Eq. (1):

$$\textit{Weight loss} = \textit{initial weight} - \textit{final weight} \quad (1)$$

The percent weight loss was determined using Eq. (2):

$$\%\ weight\ loss = \frac{initial\ \ weight - final\ weight}{initial\ \ weight} \times 100\% \qquad (2)$$

2.4 Determination of Shelf Life

The shelf life of the smoked fish was determined by putting each of the products from the 3 fish species into aluminium foil sheet and stored for at least 7 weeks. The attributes and conditions of the stored fish were assessed regularly at one week interval.

3. RESULTS AND DISCUSSION

The smoking kiln was tested with fifteen fishes (five fishes from each of the three species) with total weight of 1350 g. All the fishes were smoked together at the same time, but five fishes of *Chrysichthys nigrodigitatus* (locally referred to as *Obokun*) were first completely well smoked within the first 35 minutes of smoking. It took 44 and 56 minutes to completely smoke *Murmyrus rume* (Long nose) and *Clarias gariepinus* (locally referred to as *Eja Aro*), respectively. The fishes were weighed before and after smoking, and the results obtained during the tests are shown in Table 1.

Table 1: Determination of weight loss from fabricated smoking sheet

Fish species	No. of fish	Initial average weight (g)	Final average weight (g)	Weight loss (%)	Smoking time (min.)
Clarias gariepinus	5	80	55	31.3	56
Mormyrus rume	5	95	60	36.8	44
Chrysichthys nigrodigitatus	5	95	50	47.4	35

Table 1 shows the results of the weight loss for the three fish species. As shown on this table, the time taken to achieve the percentage weight loss in all the species was less than one hour. This was more preferable in order to preserve the protein contents of the fish and to retain it's characteristic flavour and golden colour. According to Osuji (1977), during dehydration process in fish smoking, autolytic reactions take place in the muscle that breaks down nitrogenous compound to produce free amino acids and results in an improvement in the taste of smoked fish.

The third fish species (*Chrysichthys nigrodigitatus*) has the highest percentage weight loss compared to the other two fish species. It showed that in 35 minutes of smoking this species, water content of the fish was reduced significantly and thus increased the shelf life of the fish giving an improved golden-brown colour which will attract customers using the smoking kiln. The average percentage weight loss obtained during the test for the three fish species were 31.3, 36.8 and 47.5%, respectively.

Table 2 shows the attributes of smoked fish during the time of preservation. As shown on this table, the smoked fish from the fabricated smoking kiln for the three species shows good attributes such as flavour, colour, texture and the quality was retained for five weeks (35 days). At the end of the 5th week, it was observed that the fish was still hard

dried maintaining its colour, texture and flavour. Comparison with other products which were smoked using the old already existing kiln (drum oven), showed that the products from drum oven was just wet dried and did not even last for one week. It started growing mould on the fourth day after smoking. The presence of mould on the smoked fish showed high level of moisture content in the fish, which is a breeding ground for bacteria of all sorts, while the texture of the fishes smoked with fabricated smoking kiln were still good and dry for over 5 weeks of preservation inside Aluminium foil sheet.

The smoked fish were tested under the "Tasting Panel", and the results of the organoleptic analysis obtained are shown in Table 3. As shown in the table, the attributes (flavour, texture and colour) of the three species were appropriate and acceptable. Cost, time and products' quality are factors that were given serious consideration; since the end users could be farmers or elites that desires to smoke their own fish under hygienic conditions and stored over time for use. The smoking chamber can take about 200 pieces of fish of average weight of 90 g, which makes it a production of 200 smoked fishes for average time of 45 minutes. The cost analysis of the fabricated smoking kiln is shown in Table 4. The total cost is ₦8,000 Nigerian Naira.

Table 2: Attributes of smoked fish during the time of preservation

Week	***Clarias species***	***Murmyrus rume***	***Chrysichtys nigrodigitatu***
1st week	The fish were firm and all the attributes okay	The fish were firm and all attributes okay	Fish were firm and all attributes okay
2nd week	The fish were firm and all the attributes okay	The fish were firm and all attributes okay	Fish were firm and all attributes okay
3rd week	The fish were okay and all attributes outstanding	The fish were okay and all attributes outstanding	The fish were okay and all attributes outstanding
4th week	The fish texture, colour and smell are okay	The fish texture, colour and smell are okay	The fish texture, colour and smell are okay
5th week	The fish texture, colour and smell are okay	The fish texture, colour and smell are okay	The fish texture, colour and smell are okay
6th week	Slight change in colour but texture was okay	Slight change in colour but texture was okay	The fish texture, colour and smell are okay
7th week	Showing various Spoilage signs	Showing various Spoilage signs	Slight change in colour but texture was okay

Table 3: Results of organoleptic analysis of the smoked fish species

Attributes	***Clarias gariepinus***	***Mormyrus rume***	***Chrysichthys nigrodigitatus***
Flavour	Good	Very good	Very good
Texture	Very good	Averagely good	Good
Colour	Averagely good	Fair	Good

Table 4: Cost analysis of the fabricated smoking kiln

Item	Cost (₦)
Iron sheet (0.6 x 0.6 m)	4000
Air pump	1700
Hinges	100
Fuel tray (diameter 4.0 cm)	500
Labour	1300
Total	8,000

4. CONCLUSION

In this study, a simple, portable and easily maintained fish smoking kiln was fabricated and tested using three different fish species (*Clarias gariepinus*, *Mormyrus rume* and *Chrysichthys nigrodigitatus*), and its performance was evaluated. Weight losses observed in the experiment was due to the evaporation of water content of fish, which depends on the temperature of the heat source, the higher the temperature, the faster the drying (smoking) rate. Davies and Davies (2009) made the similar observation that the weight loss of the smoked fish was a result of the drying or dehydration effect form the burning charcoal. Dehydrating temperature can be easily controlled by the air vents by the side of the combustion chamber and by the distance of the fish from the source of heat, which control rate of weight loss. Smoked fish from the fabricated smoking sheet were easily identified from the fact that it was firmer when chewed and had a characteristic golden-brown colour.

The high heat intensity produced by the charcoal was responsible for the smoky flavour, sweet fragrance which are generally eugenol, syringaldehyde and acetosyringon. These are important for hot-smoked products. The fabricated smoking kiln can be used by both farmers and elites, because of the hygiene and aseptic way of handling the smoke products.

Preservation is very important in smoked fish because it extends the shelf-life; it changes the texture and adds more value to the products. Another observation is that smoked fish from the fabricated smoking kiln have longer shelf-life than those from the commonly used drum oven. It takes over 6 weeks for mould to appear but the texture still remains intact, which lead to the fact that the water content has reduced greatly , inhibiting the bacteria which often can cause spoilage. The time spent in smoking is also a factor that must be considered. An average of 45 minutes is enough for the species to be properly smoked so that the protein content is not denatured and the golden-brown colour is retained. The average percentage weight loss obtained during the test for the three fish species were 31.3, 36.8 and 47.5%, respectively.

5. RECOMMENDATION

Finally, it is recommended that fish must be properly smoked for the period of at least 45 minutes so as to retain the golden brown colour and have a longer shelf-life in the new smoking kiln. Since more fishes could be smoked under a very short period (at least 200 pieces) and the fish smoked stays for over 6 weeks before spoilage. The smoking kiln is recommended for farmers (large or small) scale, industrialists, institution laboratories, for domestic use and even for marketers who sell smoked fish products. It is also recommended for producers and sellers of roasted meat (locally called Suya or Kilishi) and roasted plantain (locally called Boli).

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