DEVELOPMENT AND ASSESSMENT OF A LOCALLY DESIGNED FISH SMOKING KILN USING INSULATING REFRACTORY MATERIALS

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Abstract
Smoke drying among other traditional methods has remained a choice means of preserving fish products, one of the cheapest sources of animal protein in Nigeria. Among the locals, the most commonly found fish smoking facility is the open top/barrel type while few people have sought for an enclosed structure to achieve more effective heating. Often, the shelf life quality and hygienic value of the smoked fish is largely dependent on the handling and processing facility. While inadequacies in the process which often lead to wastage had been generally noticed, the existing local facility/techniques certainly call for improvement. This paper reports on an experimental smoking kiln project developed based on a novel design and built using insulating refractory materials; towards improving the existing fish smoking kiln techniques in Nigeria with performance evaluation for recommendation. The result showed a significant improvement over the existing fish smoking kiln solutions.
Keywords: fish preservation, smoking kiln design, refractory materials

Introduction

As renewable natural resources, fish is known to be a rich source of protein and other essential nutrients required for a balanced human diet. Silva, Adetunde, Oluseyi, Olayinka and Alo (2011) noted that fish, in addition to being a good source of vitamins and minerals, contains lysine, an essential amino acid found in proteins suitable for supplementing high carbohydrate diet. Al-Jedah et al., 1999 also found that it is high in polyunsaturated fatty acids that are important in lowering blood cholesterol level. In Nigeria, fish products are one of the cheapest, commonest and staple food supplements available to the teeming population. Besides, fish culture, handling, processing, storage and distribution have also provided livelihood for millions of its people including subsistent means.

In view of the highly-perishable nature of fish worsened by the hot weather conditions in Nigeria, harvested fish quickly get prone to spoilage due to action of enzymes and bacteria said to be present in the fish (Omojowo and Sogbesan, 2003; Ikenweiwe, Bolaji, and Bolaji 2010). In particular, Abolagba and Akise (2011) noted that fish with a high fat content is the most susceptible to rapid deterioration and hence losses are encountered from harvest to post-harvest stages. Appropriate processing of fish is thus expedient to enables maximal use of the raw material, to obviate wastage and enhance production of value-added products for more profitability (Ito 2005; Davies and Davies 2009; Davies, Davies and Abowei 2009; Abowei and Tawari 2011). Traditionally, several means of fish handling and preservative methods have been developed to in attempt to extend the shelf life of harvested fish and commonly

known are smoking, salting, sun-drying, freezing, chilling and brining further expatiated in Tawari and Abowei (2011).

Having observed that fish spoilage is one of the greatest challenges beclouding the fishing industry world over, continual efforts has been made to reduce fish spoilage to the minimum through improved preservation techniques. Ikenweiwe et al (2010) observed that the excessive supply of fish at harvest time always tends to lead to lower market price and fish spoilage except storage facilities are adequately provided. According to Silva et al (2011), food smoking belongs to one of the aged technologies of food preservation which mankind has used in fish processing. Among the various processed forms in Nigeria, smoked fish could be assessed to be the most readily form of fish products accessible for local consumption. Gómez et al. (2009) buttressed that fish smoking has become a means of offering diversified, high value added products as an additional marketing option for certain fish species where fresh consumption becomes limited. Smoke drying among other traditional methods therefore has remained a choice means of preserving fish products, one of the cheapest sources of animal protein in Nigeria. Recent report shows that out of the total of 194,000 metric tons of dry fish produced in Nigeria, about 61% was smoked (Silva et al, 2011).

The shelf life quality and hygienic value of the smoked fish is largely dependent on the handling and processing facility. Among the locals, the most commonly found fish smoking facility for small-scale fish processing is the open top/barrel type while few people have sought for an enclosed structure to achieve more effective heat work. Also of widespread use at the extent of West Africa is the open-closed *Chorkor* kiln which seems to be an improvement over the traditional open fish smoking system (see Figure 2). Ajang, Ndome and Ingwe (2010) in their study also appraised the *Chorkor* kiln over traditional smoking kilns in terms of the cost benefit and smoked fish quality. While inadequacies in the process which often lead to wastage had been generally noticed, the existing local facilities/techniques certainly call for improvement. It was observed that most of the local efforts on developing viable smoking kilns do not consider heating efficiency and conservation which could in no little means can reduce the firing cost and enhance profitability for the artisanal fisheries sector. Therefore, this study therefore focused on the design and development of a novel fish kiln borrowing from ceramic kiln construction technology. The project was executed by utilizing insulating bricks and other locally available resources. The evaluation of the kiln design suggested that the applied knowledge of ceramic kiln thermal technologies could be a pragmatic way towards improving fish preservation for effective fish drying-smoking techniques. For a semi-permanent kiln structure, a potential advantage realized besides good thermal insulation was the genuineness of ceramic brick materials over the commonly used iron materials which are more likely to get defaced and deteriorate after long exposure to atmospheric conditions. The following figures refer to various existing kiln design surveyed for the study.

Material and Method

Sourcing of Raw Materials & Brick Making

An insulating dense firebrick was chosen as the main building block using a standard brick size of 9inby3inby2.5in. The bricks were made manually with a slop-mould (wooden frames) with composition of 30% sawdust, 60% kaolin and 10% ball clay (see Figure 6). Kaolinite clay, the main refractory material used in the brick making was sourced from a neighboring material site in Akure, Ondo State. Meanwhile some bags of processed kaolin from Auchi, Edo state were also used to enhance the quality of the raw kaolin and making of mortar. The combustible material, sawdust, was collected from the nearby sawmill. The raw kaolin was screened with the builder's mesh to have a consistent particle grain. About five hundred brick were moulded within a month while they were exposed immediately after moulding for drying. Having attaining a good drying time, the brick were set for firing.

Firing and Sorting of Bricks

Dried bricks were fired with a 45 cubic foot wood kiln using wood as fuel and following a standing rule of one finger apart in the arrangement of the bricks for firing. The temperature attained for the firing was 900^{o}C, after which the kiln was allowed to cool down for brick offloading. Fired bricks were sorted out and set in a dry place from where they were transferred to the building site.

The Kiln Design

The kiln building was preceded by developing a kiln design considering the following factors:

- The limitation of the existing local kilns.
- The need to maximize the provided space for fish smoking.
- The firing system which can utilize coal effectively and wood if preferred.
- Easy access and operation.

Figure 8 shows the computer generated models for the kiln which shows a downdraft system with a 2-wing fire ports and other main kiln structure excluding the chimney.

Kiln Building

For the kiln masonry, about 500 bricks were earlier estimated for the construction of about 61cubicfoot (3.9ft by 4.75ft by 3.3ft) capacity kiln. Basically the kiln building adopted the header course arrangement for a single-walled kiln chamber. Angular iron was used to keep the framework of the kiln while the door structure and firebox ports utilized an iron sheet recycled from a scrap water tank. According to the kiln design, the interior of the kiln should house a retractable iron grate set in three layers and a perforated base slab acting as a firewall to prevent the fish on the grate from direct impact of heat. An elongated iron tube was temporarily connected to the kiln from behind to serve as a chimney for supporting the heat draft. The kiln grate was made from iron net of 0.3mm thickness and framed by 15mm thick iron rods. Some key construction stages were outlaid in Figure 9.

Result and Discussion

Adelabu et al (2007) noted that insulating firebricks have several advantages over ordinary firebricks or dense mud bricks which include:

- Less heat escape through the kiln walls
- Less fuel is needed to heat an insulating inner wall because it is less dense
- The surface of an insulating inner wall is hotter during firing and the increased glow increases the radiance of heat to the wares.
- They are cheap to make by using less clay and needing no grog

For the fish smoke kiln design, improvement on the existing facilities were seen in terms of

- Capacity for complete enclosure which enable efficient heat circulation and conservation.
- The enclosure perverse the fish from exposure to flies and other insects which could serve as source of contamination for the food.
- The firebox design provides easy operation of firing and control using a covering lid.
- The insulating brick significantly support heat conservation and minimise heat loss.

Ikenweiwe et al (2010) agreed that 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. 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.

Beside gas, solar and electricity, this study considered charcoal most convenient and clean source of heat for small-scale or courtyard fish smoking. Silva (et. al) in their study on the effects of the smoking methods on the quality of locally consumed fishes in Nigeria found that the sawdust smoked fishes consistently has the highest level of polycyclic aromatic hydrocarbons (PAHs) of all the smoked fished from various methods of processing investigated followed by the fire wood and the charcoal. PAHs are described as ubiquitous environmental pollutants, resulting from the incomplete combustion or pyrolysis of organic matter during industrial processing and various human activities. Due to their carcinogenic activity, PAHs have been included in the European Union (EU) and the United States Environmental Protection Agency (USEPA) priority pollutant lists. Human exposure to PAHs occurs in three ways, inhalation, dermal contact and consumption of contaminated foods. Often more smoke is produced by smouldering wood and shavings or sawdust in the oven, directly below the hanging fish or fillets, laid out on mesh trays. The oil content of the fish and the temperature of the smoking process were also found to affect the PAHs level.

Considering precision in the building of kiln with ceramic bricks is usually admired to make a kiln structure to have a lovely presence and add aesthetic value to the environment. Apart from seeing the kiln as a tool, it could also be handled as a work of art.
Due to lack of suitable temperature measuring tool, the complete firing cycle from time and temperature readings has not been recorded at the time of this report. However, based on direct observation, it took 18 hours for a hard dry fish smoking. The quality of the fish sample as shown in figure 12 indicated that the output is clean and out-rightly ready for consumption. The fish can be salted and peppered to make it more palatable for eating.

The firing of the kiln as compared to other local existing one proved to be more effective, spacious and convenient in firing by utilizing coal while its demand less monitoring time to operate after carefully observed the behavior of the kiln. The operation of the kiln is cost effective with an estimate of ₦1800 worth of charcoal (one and half bag) to smoke about 100kg of fresh fish.

The Smoking Procedure
The general steps involved in the processing of smoked fish are displayed in figure 11.

- For a hard dried fish, 18 hours is required to complete the fish smoking. This could be spanned over 3 days as deemed fit by the operator.
- For a complete smoking cycle, one and half bag of charcoal is used by loading intermittently through the 2 wings of firebox. It could be ignited with kerosene or other local combustible material.
- For a long spanned 3 days fish smoking session, the oven was loaded around 2pm of day one with the charcoal burning brightly while it was later checked around 7pm of the same day to observe the progress of the smoking. In the morning of the second day, the firebox is refilled from the remaining half bag of charcoal, and smoking progress manually checked to again observe the progress. In the evening of the second day, fish is checked again while the firebox is also refilled with charcoal to fire overnight.
- Depending on the required output, smoked fish can be retrieved the second day's evening, after the charcoal had been added in the morning.
- The smoked fish's output is manually observed by visualizing the colour and texture.
- Wood and charcoal can be equally combined once. It was however noted that if this is noted properly controlled, using excessive wood for the oven's combustion might not yield so very desirable output because of smoke.
- The smoked fish exhibits a golden brown colour, as opposed to a black coloration obtained with other existing local oven (figure 12); suggesting that the smoking quality looks fit for international standards.

Conclusion
Fish preservation and processing methods explore means by which spoilage is stopped or reduced to give fish product a longer shelf life. The study thus explored a novel kiln design for local artisanal fish farmers that could be reliably used to sustain fish processing over a long period of time without compromising the smoking quality. The adoption of ceramic insulating brick formulation and an enclosed structure provided a new vista to heat conservation which in turn can help reduce smoking cost for maximum profit.

Traditional smoking techniques involve treating of pre-salted, whole or filleted fish with smoky heat from wood, charcoal, or sawdust. The composition of the smoke and the conditions of processing affect the sensory quality, shelf life, and wholesomeness of the product. Silva et al thus informed that potential health hazards associated with smoked foods may be caused by carcinogenic components of wood smoke; hence charcoal or cleaner sources of heat is recommended by the study. For the construction of kiln, a single wall structure is expected to be sufficiently enough to provide a good thermal heat-work for the dry-smoking of fish.

Finally, fish smoking has become a delightful tradition and smoked fish recognized as delicacy in Nigerian cuisines. The study considered it well deserved to promote its means of provision for a healthy, productive and virile nation.

Figure 1: The drum oven is a common local fish processing facility
(*photograph by Philip Dada*)

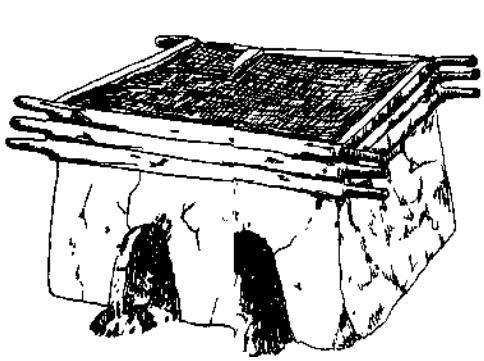

Figure 2: Traditional *Chorkor* kiln design and use.
(Right- Retrieved via http://www.nzdl.org/cgi-bin/library.cgi; Left- *Photograph by Philip Dada*)

Figure 3: Enclosed smoking kilns developed by Bello M. O. using mud bricks and iron sheet
(Photograph by Oluwafemi Adelabu)

Figure 4: A fish smoking kiln developed by Ikenweiwe N. B., Bolaji B. O. and Bolaji G.A. using galvanized iron sheet and frame. Source: Ikenweiwe et al. (2011)

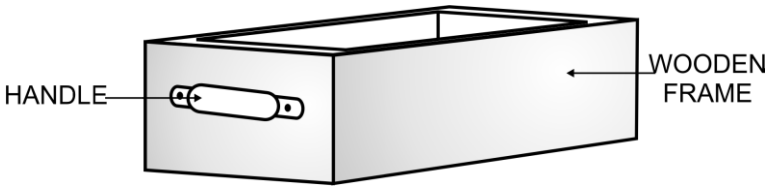

Figure 6: A wooden frame used brick moulding (Adelabu et al. 2007)

Figure 7: The bricks before and after firing *(Photograph by Oluwafemi Adelabu)*

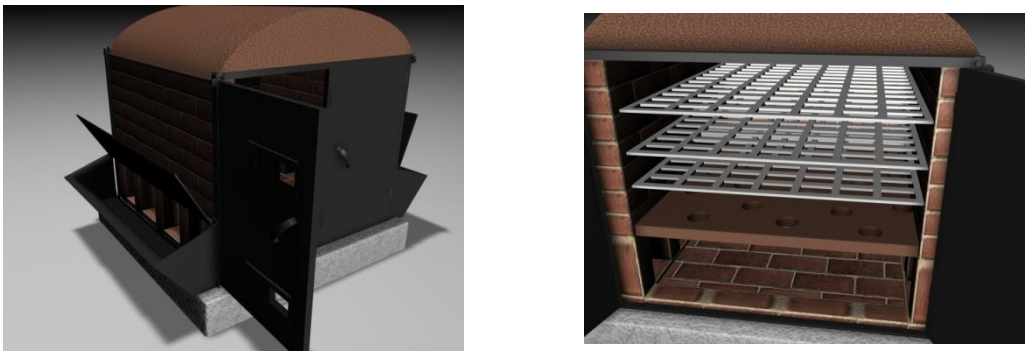

Figure 8: Developed computer aided prototype for the kiln design
(CAD models by Lydia Shoretire)

Figure 9: The kiln construction stages *(Photograph by Oluwafemi Adelabu)*

Figure 10: The kiln after first test smoking
(Photograph by Adelabu)

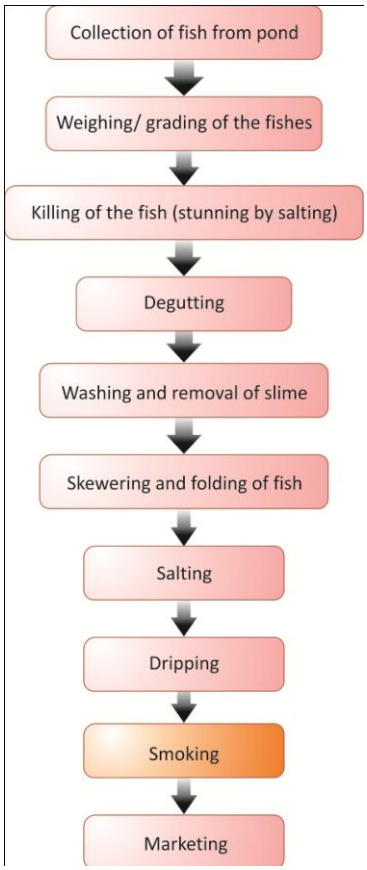

Figure 11: A chart flow of activities involving fish smoking from fish harvest to marketing


Figure 12: The smoking result *Clarias gariepinus* (locally referred to as Eja Aro) obtained from the new kiln (right) in contrast with fish smoked with a local drum oven (left). *(Photograph by Philip Dada)*

Table 4: Cost analysis of the fabricated smoking

	Kiln Items	**Cost (₦)**
1.	Raw material sourcing (basically covering transportation cost)	15,000
2.	Angular Iron frame	5,000
3.	Hinges	500
4.	Iron sheet	From recycled material
5.	Iron rods (15mm thick)	3000
6.	Iron grate (5mm thick)	5000
7.	Labour	10,000
8.	Miscellaneous	2,500
9.	Total	40,000

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