THE CONSTRUCTION AND OPERATION OF
A NEW MECHANICAL GAS SMOKING KILN
(KAINJI GAS KILN)

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INTRODUCTION

The origin of fish smoking dates back to antiquity. It is thought that the process was started by hanging the product over a fire which was used for heating purposes. So the ancient traditional hearth was simply an open fire place. Further advancement was made traditionally by the erection of mud, bricks or corrugated Iron sheet enclosures, fish being suspended on a single rack of chicken wire or criss-crossed iron bars with fire and smoke rising from burning wood below. Modifications of the traditional methods have given rise to the Altona type kiln where fish are placed on two or more racks and the Watanabe kiln which is similar to the Altona type kiln but having an external hearth. Detailed description of various traditional kilns are shown elsewhere (Anon 1970).

A deviation from the traditional method of fish smoking was enhanced by the development of the Torry kiln in 1939. This kiln has an external hearth and fire is provided by smouldering sawdust on top of wood shavings or mush. The temperature is maintained by either electric or steam heaters which are thermostatically controlled. This kiln has the advantage of producing a uniform and clean product with less labour (than the traditional kiln) and to a considerable extent independent of the weather. The kiln has been adopted commercially in Britain for producing many products including finnans, kippers, sprats for canning and smoked salmon (Burgess et al 1965).

Eyo (1980) observed that a very important single structure for effective fish smoking is the smoke house or the smoking kiln. For a long time, the design of smoking kiln in Nigeria has been traditional or quasi-traditional. Eyo (1980) recommended that new designs and construction of better kilns with gadgets for controlling interaction between smoke and fish components should be looked into. Such smoking kilns should allow uniformity of air velocity, temperature and humidity and also offer environmental protection, economy of operation and high sanitation standards. Smoke should be generated externally to reduce carcinogenic compounds in the smoked fish. Sanni, (1980) also noticed that mechanical smoking kilns expected to give products acceptable to the consumers were still to be designed in Nigeria. Such an apparatus should be adaptable for use in rural areas where electric power is not yet commonly used. It is expected that the newly constructed mechanical gas smoking kiln will meet these requirements.
2. **OBJECTIVE**

The mechanical gas smoking kiln has been developed using locally available materials with the objective of improving the quality of smoked fish in Nigeria at minimum production cost.

3. **DESCRIPTION OF THE KILN**

The kiln is made from mild steel with structural dimension of 0.92 x 0.76 x 1.24m. panelled with angle bars. (Figs. 1 and 2). The smoking chamber dimension 0.66 x 0.76 x 0.94m. is separated from chest of drawers by a perforated mild steel partition. Below the smoking chamber is the furnace covered with a sheet of perforated steel which allows dispersion of heat to the smoking chamber while at the same time acting as a receptacle for the collection of melted fat.

There are provisions for six rails of wire mesh trays in the chamber each 0.13m. apart. Each wire mesh rests on angle bars and measures 0.71 x 0.62m.

Three drawers are present in this model each of dimension 0.74 x 0.23 x 0.18m. Below the last drawer is a regulator connected internally to a thermostat and a pipe which terminates with a nozzle inside the furnace (Fig. 4). The liquid petroleum (L.P.) cylinder is stoppered with a regulator which connects to the pipe by means of a rubber hose.

4. **THE SMOKING PROCESS**

4.1 Fish Preparation

Trials so far conducted have indicated that fish prepared in the normal way could be smoked using this kiln but for best results of the finished product the following approach is recommended.

4.1.1 Cleaning

Clean the fish by descaling, eviscerating and thorough washing in tap water. Large fish e.g. *Lates niloticus* should be headed and split, then cut into small chunks to leave a large surface area for smoke absorption. Large fish should not be smoked whole or skewered into pointed sticks as this will delay smoke and heat penetration into the inner tissues thereby unduly lengthening the duration of smoking.

4.1.2 Immersion in Brine

Immerse the dressed fish into a clean solution of brine for one hour. 60% saturated brine has been observed to give the smoked product a glossy appearance and good taste. The brine also helps in the osmotic removal of free water from the tissues thereby assisting the drying process. Standard measurement of brine strength using various hydrometer scales is shown in Appendix II.
4.1.3 Hanging

Remove the fish from the brine solution and allow moisture to drip by leaving the fish in a perforated basket or hanging them in the open well protected from flies and other dipteran insects. The fish are now ready for smoking. In all cases good quality raw materials should be used. Poor quality fresh fish become soft and flabby breaking easily on handling after smoking though the surface colour may appear normal.

4.2.1 Kiln Operation

After fish have been dressed for smoking they are placed on wire meshes inside the chamber which has a capacity of handling 60 to 80 kilogrammes of fresh fish. Inside the drawers are placed sawdust on top of wood shavings. Smoke is produced by igniting the wood shavings which burst into flame and smoulders the sawdust. Smoke produced by the smouldering sawdust enters the smoking chamber through ducks on the steel partition.

The heating system below the smoking chamber is thermostatically controlled. The regulator could be set at minimum, medium, and maximum positions to control the amount of heat entering the smoking chamber. Heat gradually rises as soon as the furnace is ignited and with the regulator at the minimum position, heat in the smoking chamber will not exceed 60°C within one hour of operation. The regulator should then be shifted to the medium position for another one hour after which the regulator should remain at maximum position until the smoking is complete. At this point temperature in the kiln will remain essentially between 100 – 120°C. Excess heat and smoke in the smoking chamber leave the kiln by the way of the chimney. Heat and smoke are uniformly distributed in the smoking chamber hence it is not necessary to alter the position of the fish on the racks until the process is complete. This also saves the product from mechanical damage. The kiln is fitted with rollers to ease mobility on smooth surfaces (fig. 3).

4.2.2 Hot Smoking

The heat produced in the furnace by leaving the regulator at the maximum position will cook the fish within 2 – 3 hours. The hot smoked fish so produced could keep for two months at ambient temperature if properly stored in a sealed pack. Though hot smoking is the commonest smoking process normally encountered in traditional smoking in Nigeria due to the extended shelf life of the product, reports have shown that there is a fall in the nutritive value resulting from losses of arginine, histidine, total lysine along with low Net Protein Utilization (NPU), (Hoffman et al 1977). The latter tend to decrease with increase in the thickness of the fish (Clifford et al 1980).
4.2.3 Cold Smoking

By using the Kainji Gas Kiln, it is now possible to embark on "Cold" smoking of fish, a process in which the temperature of the fish does not exceed 30°C whereby the fish flesh remains uncooked after smoking. This is rendered possible by setting the regulator at the minimum position throughout the operation. Though cold smoking is not practiced in Africa because of the need for an alternative method of preserving the smoked fish (e.g. refrigeration), cold smoked fish are known to possess higher nutritive value than hot smoked fish which become cooked in the process. However because of the suitability of this kiln in areas where there may be no refrigeration, the duration of smoking established in Table 1 were arrived at after hot smoking of the species.

5. MERITS OF THE KILN

Using the mechanical gas smoking kiln it is now possible to smoke filleted *Lates niloticus* to 50% moisture loss within 4 - 6 hours depending on the thickness of the fillets. Whole *Tilapia sp.* is completely smoked in 4 hours. This is faster than the conventional smoking methods.

The smoked fish have a savoury flavour and a desirable brownish colour which is more acceptable to consumers than the dark tan or black (sooty) colour commonly encountered with traditionally smoked fish.

Because the fish is not exposed to tar, dust and soot, while in the chamber, the smoked fish are cleaner than those smoked traditionally.

This method of smoking is less labour intensive and does not require much supervision, there is no need to strip the kiln - a process which involves shifting the fish from one rail to another to prevent them from burning. A single operator can thus take charge of the entire operation. Because of the reliance on liquid petroleum for heat production instead of electricity, the kiln is suitable for use in rural areas where electricity may not be available.

Since Steinig (1976) reported that smoked fish from kiln with external smoke generators contained less than 1 ppb benzo[a]pyrene in their edible parts whereas much more than 1 ppb has often been found in products from traditional kilns, it follows that smoked fish from the Kainji Gas Kiln which uses external smoke generators will be expected to contain less of these carcinogenic polycyclic aromatic hydrocarbons (PAH) than those smoked traditionally.
Deposition of aerosol particles on surface is thought to arise as a result of Brownian motion, by the action of radiometer i.e. increase in velocity of rebound molecules in relation to temperature (Epstein 1929), centrifugal and gravitational forces (Foster and Simpson 1961). Using the Torry kiln these authors observed that the upper and lower surfaces of fillets are exposed to the same temperature (i.e. radiometer forces would be equal) and are exposed to similar aerodynamic conditions (i.e. centrifugal forces would be equal) and since Brownian diffusion is equal in all directions, therefore 90% of the deposit on the upper surface arose from the action of gravitation forces.

This observation is very interesting because like the Torry Kiln, smoking in the Kainji Gas Kiln takes place in a closed chamber. Unlike the Torry Kiln there is no fan to aid the circulation of smoke and the heating furnace is dependent upon burning butane gas. Deposition of smoke on the upper and lower surfaces of fillets in the Kainji Gas Kiln is therefore dependent on the gravitational forces acting on the smoke particles in the smoking chamber. These forces have been used to an advantage in the design of this kiln which produces acceptable smoked products in the absence of motorised fan.

6. **ECONOMY OF THE OPERATION:**

The mechanical gas smoking kiln has so far proved very economical. A full liquid petroleum (L.P.) cylinder weighing 15kg. and costing ₦3.80 (liquid content only) is able to complete three batches of smoked fish successfully. Woodshavings and sawdust are usually discarded at the carpentry workshop and could be collected free of charge. The only expensive item is the smoking kiln which is built complete with furnace at a cost of ₦500.00 for the model described above. Details on the requirements and estimated cost for constructing the kiln is shown in Appendix I. Duration of construction of the medium size kiln is approximately one week.

7. **CONCLUSION**

The Kainji Gas kiln has been developed using locally available materials. The performance of the kiln has been tested using various inland fishes (Table I). The result obtained shows that the kiln is less labour intensive and can handle different sizes of fish faster with better appearance of the end product than the conventional smoking methods. The kiln relies on the commonly available liquid petroleum (cooking gas) for heat production instead of electric heaters which makes it suitable for use in rural areas where electricity is limiting. With the reliance on smoke production by smouldering sawdust and wood shavings instead of firewood, the extent of deforestation for fish
smoking could be minimised. This also renders the kiln suitable in the Northern (arid) states of the country where firewood may not be easily available.

In view of the merits of this kiln it is highly recommended for use by Ministries, River Basin Authorities, Industries and individuals involved in production and sale of good quality smoked fish.

8. **Acknowledgement**

   It is with pleasure that I acknowledge the useful co-operation of Mr. Daniel Ojemudia who assembled the smoking Kiln. I am also grateful to the Director, Kainji Lake Research Institute, Dr. H.M. Yesufu and the Head of Fisheries Division, Mr. E.O. Ita for their invaluable suggestions during the design of the Kiln.
TABLE I: FISH SMOKING IN THE MECHANICAL GAS SMOKING KILN
(KAINJI GAS KILN)

AT THE OPERATION TEMPERATURE

<table>
<thead>
<tr>
<th>SPECIE</th>
<th>Common Name</th>
<th>Duration of Smoking (Hours)</th>
<th>No. of Fires</th>
<th>Wt. Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synodontis sp.</td>
<td>Cat fish</td>
<td>4 - 5</td>
<td>2/3</td>
<td>48</td>
</tr>
<tr>
<td>Distichodus sp.</td>
<td>Moon fish</td>
<td>3 - 5</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Citharinus sp.</td>
<td>Moon fish</td>
<td>3 - 5</td>
<td>2</td>
<td>42</td>
</tr>
<tr>
<td>Labeo sp.</td>
<td>African Carp</td>
<td>3 - 4</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Alestes macrolepodois</td>
<td>Characin</td>
<td>3 - 4</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>Lates niloticus</td>
<td>Niger perch</td>
<td>4 - 6</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Bagrus sp.</td>
<td>Cat fish</td>
<td>4 - 5</td>
<td>3</td>
<td>46</td>
</tr>
<tr>
<td>Tilapia sp.</td>
<td>Cichlid</td>
<td>4 - 5</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Hydrocynus sp.</td>
<td>Tiger fish</td>
<td>4 - 6</td>
<td>3</td>
<td>46</td>
</tr>
</tbody>
</table>

* Indicate the number of drawers in which sawdust and woodshavings were burnt.

** Includes loss in Wt. after immersion in brine.
APPENDIX I

REQUIREMENTS AND ESTIMATED COST OF MATERIALS FOR CONSTRUCTING ONE UNIT OF THE KAINJI GAS KILN

1. Requirements For The Welding Workshop

(i) One guillotine
(ii) One vice
(iii) One electric drilling machine
(iv) One electric grinding machine
(v) One hack-saw
(vi) One wire brush
(vii) One electric arc.

2. Cost Of Materials (Local Purchase)

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>UNIT COST</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Three metal sheets</td>
<td>₦55.00</td>
<td>₦165.00</td>
</tr>
<tr>
<td>(ii) Eight angle bars</td>
<td>9.00</td>
<td>72.00</td>
</tr>
<tr>
<td>(iii) One set of rollers</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>(iv) Two standard lengths of hollow pipes</td>
<td>4.00</td>
<td>8.00</td>
</tr>
<tr>
<td>(v) Two hinges</td>
<td>2.00</td>
<td>4.00</td>
</tr>
<tr>
<td>(vi) One packet of electrode</td>
<td>12.00</td>
<td>12.00</td>
</tr>
<tr>
<td>(vii) One lock</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>(viii) One nozzle</td>
<td>4.00</td>
<td>4.00</td>
</tr>
<tr>
<td>(ix) One roll of copper tube</td>
<td>65.00</td>
<td>65.00</td>
</tr>
</tbody>
</table>

= ₦342.80

LABOUR COST

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SALARY PER WEEK</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Craftsman (welding)</td>
<td>₦31.25</td>
</tr>
<tr>
<td>One Labourer</td>
<td>25.00</td>
</tr>
<tr>
<td>Plus 25% of Salary for Overtime</td>
<td>14.06</td>
</tr>
</tbody>
</table>

= ₦70.31

GRAND TOTAL = ₦402.81

*This estimate reflects the cost of constructing the medium size Kiln. The cost of materials for the small size Kiln is slightly lower.*
### Appendix II

**BRINE STRENGTH AS MEASURED ON VARIOUS HYDROMETER SCALES AT 60°F (16°C)**

<table>
<thead>
<tr>
<th>Salinometer Degrees</th>
<th>Specific Gravity</th>
<th>Baume Degrees</th>
<th>Twaddell Degrees</th>
<th>Per Cent Salt By Wt. lb.</th>
<th>Lbs. Salt per Imp. Gal. of Water lb. oz</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.000</td>
<td>0.0</td>
<td>0.0</td>
<td>0.000</td>
<td>0 - C</td>
</tr>
<tr>
<td>10</td>
<td>1.019</td>
<td>2.7</td>
<td>3.8</td>
<td>2.640</td>
<td>0 - 4½</td>
</tr>
<tr>
<td>20</td>
<td>1.038</td>
<td>5.3</td>
<td>7.6</td>
<td>5.279</td>
<td>0 - 9</td>
</tr>
<tr>
<td>30</td>
<td>1.058</td>
<td>7.9</td>
<td>11.6</td>
<td>7.919</td>
<td>0 - 13½</td>
</tr>
<tr>
<td>40</td>
<td>1.078</td>
<td>10.5</td>
<td>15.6</td>
<td>10.558</td>
<td>1 - 180</td>
</tr>
<tr>
<td>50</td>
<td>1.098</td>
<td>12.9</td>
<td>19.6</td>
<td>13.198</td>
<td>1 - 8½</td>
</tr>
<tr>
<td>60</td>
<td>1.118</td>
<td>15.3</td>
<td>23.6</td>
<td>15.837</td>
<td>1 - 14</td>
</tr>
<tr>
<td>65</td>
<td>1.128</td>
<td>16.5</td>
<td>25.6</td>
<td>17.157</td>
<td>2 - 1</td>
</tr>
<tr>
<td>70</td>
<td>1.139</td>
<td>17.7</td>
<td>27.8</td>
<td>18.477</td>
<td>2 - 4½</td>
</tr>
<tr>
<td>75</td>
<td>1.149</td>
<td>18.8</td>
<td>29.8</td>
<td>19.796</td>
<td>2 - 7½</td>
</tr>
<tr>
<td>80</td>
<td>1.160</td>
<td>20.0</td>
<td>32.0</td>
<td>21.116</td>
<td>2 - 10½</td>
</tr>
<tr>
<td>85</td>
<td>1.171</td>
<td>21.2</td>
<td>34.2</td>
<td>22.436</td>
<td>2 - 14½</td>
</tr>
<tr>
<td>90</td>
<td>1.182</td>
<td>22.3</td>
<td>36.4</td>
<td>23.755</td>
<td>3 - 1½</td>
</tr>
<tr>
<td>95</td>
<td>1.193</td>
<td>23.5</td>
<td>38.6</td>
<td>25.075</td>
<td>3 - 5½</td>
</tr>
<tr>
<td>100</td>
<td>1.204</td>
<td>24.6</td>
<td>40.8</td>
<td>26.395</td>
<td>3 - 9½</td>
</tr>
</tbody>
</table>
References


Fig. 1. Structural Framework of the Small size Kainji Gas Kiln.

Fig. 2. Structural Framework of the medium size Kainji Gas Kiln.

*Made of Angle Bars and Hollow Pipes.
Fig. 3. Diagram of the completed medium size Kainji Gas Kiln

Chimney

Fish Tray

Hearth

Gas Regulator

Heat Regulator

Roller

Furnace

Receptacle

Door Lock

DRAWER

WIRE MESH TRAY

Tray Handle
Fig. 4: Diagram of the Kainji gas kiln showing details of the furnace