Development and Evaluation of NCAM Fish Smoking Kiln

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Abstract
A fish kiln that derives its heat energy from dual heat sources (charcoal and sawdust) with an overall dimension of 62cm x102cm x 134cm was designed, fabricated and tested. The basic features of the kiln are the frame, smoking chamber, heat chamber and a chimney. The inner and outer wall of the smoker/kiln is coated with silver paint and fully lagged with fiber glass to prevent possible loss of heat through conduction, convention and radiation. The fish smoking kiln has a capacity of 25kg per batch and requires six smoking trays. It was observed from the performance evaluation that the highest smoking efficiency of 90% was obtained when charcoal was used at 0.21% smoking rate and the lowest smoking efficiency obtained was 47.6% at 0.11% smoking rate when sawdust was used. The cost of producing a unit of the fish kiln was estimated to be eighty thousand naira (₦80,000)

Keywords: Fish Kiln, smoking chamber, smoking trays, and heat loss

Introduction
The relevance of fish as food has been recognized by man in time past. The flesh of fish is rich in protein and minerals like calcium, phosphorous and iron (Luven 1982, Akosile, 2004 and Ologunlagba et al 2010). It is an important component of the diet of most Nigerians, as fish is a major source of protein in the nation. Fish is highly susceptible to deterioration when it is without any preservatives or processing measures (Clucas and Sutcliff, 1981; Okonta and Ekelemu 2005, Ologunagba et al 2010). Report revealed that local farmers in different part of the world account for about 50 to 70 percent of the national catch in most countries, out of which 30 to 40 percent are usually lost due to poor handling and inadequate processing (UNIFEM 1993, Akande 1996, Ologunagba et al 2010). A tour to some of the riverside areas where fish processing takes place were sights of evidence of these losses due to spoilage.

Though, there are modern fish preservation techniques such as drying, canning, use of additives, pasteurization, freezing and refrigeration and so on (Hall1992; Ologunagba et al 2010). Smoking of fish still remain predominant in most communities where fish processing is carried out in Nigeria (Davies and Davies 2009; Ologunagba et al 2010) , most of these techniques are expensive and are outside the reach of the rural farmers and processors. Also, smoking is prefered for the flavor, taste and color it gives the fish (Kumolu- Johnson et al, 2001). In developed countries where refrigeration and integrated logistical infrastructure for efficient transportation of perishables is in place, fish smoking for flavor is popular while in developing countries smoking of fish for preservation is common.

Generally, the advantages of smoking fish are manifold, smoking extends/prolongs shelf life, enhances flavor in soups and sauces. It reduces waste in times of large and successful catches and permit storage for the lean season (FAO, 2001, Ologunagba et al 2010). Therefore, in order to remove the drudgery and other problems associated with the traditional smoking techniques and also provide an effective alternative to the ice storage facility such as refrigerators and cold rooms that have been jeopardize by irregular electricity supply in these processing communities, there is need to develop an improved fish smoking machine that would meet the current challenges in the sector (Ologunagba et al 2010).

Materials and Methods
Design consideration
For efficient and reliability of the performance of its various components in the design of the kiln, the following were considered;
- Selection of materials that are resistant to corrosion, durable, water proof, non toxic and non absorbent were used so as to eliminate the possibility of contaminating the fish and also to be able to withstand repeated cleaning and disinfecions
- In order to prevent accumulation of smoke as well as regulate the level of dangerous smoke that is inhaled by the processor, a provision of chimney that allows smoke to escape freely from smoking chamber is put in place.
- The inner and outer walls of the kiln were coated and fully lagged with fibre glass in order to prevent possible heat loss by conduction, convection or radiation.
- Provisions were made for the wire racks to be adjustable or detachable so as to facilitate thorough cleaning and disinfection.
For affordability of the kiln, locally available materials were used.

**Design Features**
The major components used in fabricating the fish kiln were locally sourced and cheap. It consists of the supporting frame, smoking chamber, heat chamber and a chimney.

**Supporting Frame**
It was constructed with 25mm by 25mm angle iron as frame and a double metal sheet wall lagged in between with fiber glass. The lagging insulates the smoking chamber thus preventing heat loss.

**Smoking Chamber**
The smoking chamber is a six row compartment with rails for square racks. Five of the racks have wire mesh as tray for easy flow of heat. The last tray at the bottom has a perforated corrugated iron sheet tray to keep the fish oil from dripping into the heat source. The fish is smoked lying on the wire racks.

**Heat Chamber**
The heat chamber is fabricated in such a way that it can derive its heat from charcoal or sawdust. This chamber is demarcated with perforated mild steel tray which allows penetration of heat and also designed in such a way that it will serve as collector for melted fat from the smoke fish. Heat is generated by placing a coal pot, whose source of heat could either be coal or sawdust.

**Chimney**
The kiln also consists of two chimneys of 85mm diameter and 120mm height located at the top of the smoking chamber to allow effective exit of smoke and excess heat from the kiln.

**Performance Test**
After smoking the following machine parameters were determined for the fish kiln.
- Smoking rate
- Machine capacity
- Smoking efficiency
- Quantity of heat used
- Smoking house temperature

\[
Smoking \ rate (Rs) = \frac{Weight \ of \ smoked \ fish}{Time \ of \ smoking} \ Kg/h
\]

\[
Smoking \ Efficiency (Es) = \frac{Weight \ of \ smoked \ fish}{Initial \ weight \ of \ fish} \times 100
\]

\[
Quantity \ of \ heat \ used = M_1C_1(\theta_2 - \theta_1)
\]

Where;
- \(C\) = Specific heat capacity of the material (kJ/Kg/k)
- \(M\) = Quantity of moist material before smoking (Kg)
- \(\theta_1\) and \(\theta_2\) = Temperature of the material before and after smoking (K)

\[
D_1 = \frac{M_i - M_f}{M_t}
\]

Where;
- \(M_i\) = Initial mass of fish before smoking
- \(M_f\) = Final mass of fish after smoking

**Source:** Guide to industrial Dryness – A.S. Mujundar
Table 1: Summary of Data on Machine Performance, Using charcoal as source of heat

<table>
<thead>
<tr>
<th>Type</th>
<th>Initial weight of fish (kg)</th>
<th>Time of smoking (hrs)</th>
<th>Final weight of fish (kg)</th>
<th>Initial Temp. $\theta_1$ ($^\circ$C)</th>
<th>Final Temp. $\theta_2$ ($^\circ$C)</th>
<th>Quantity of heat used (kg)</th>
<th>Smoking rate kg/hr</th>
<th>Smoking efficiency%</th>
<th>Qty of fish/rack kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>21</td>
<td>4.00</td>
<td>3</td>
<td>70</td>
<td>6.00</td>
<td>0.19</td>
<td>80.0</td>
<td>4 big sizes</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>21</td>
<td>4.50</td>
<td>3</td>
<td>70</td>
<td>6.00</td>
<td>0.21</td>
<td>90.0</td>
<td>5 medium</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>21</td>
<td>3.00</td>
<td>3</td>
<td>70</td>
<td>6.00</td>
<td>0.14</td>
<td>60.0</td>
<td>8 medium</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>21</td>
<td>3.60</td>
<td>3</td>
<td>70</td>
<td>6.00</td>
<td>0.17</td>
<td>72.0</td>
<td>8 medium</td>
</tr>
<tr>
<td>E</td>
<td>5</td>
<td>21</td>
<td>3.50</td>
<td>3</td>
<td>70</td>
<td>6.00</td>
<td>0.17</td>
<td>70.0</td>
<td>10 medium</td>
</tr>
<tr>
<td>F</td>
<td>5</td>
<td>10</td>
<td>3.00</td>
<td>3</td>
<td>70</td>
<td>6.00</td>
<td>0.30</td>
<td>60.0</td>
<td>15 small</td>
</tr>
<tr>
<td>G</td>
<td>5</td>
<td>20</td>
<td>4.00</td>
<td>3</td>
<td>70</td>
<td>6.00</td>
<td>0.20</td>
<td>80.0</td>
<td>8 medium</td>
</tr>
</tbody>
</table>

Highest smoking efficiency ranged between 70% and 90% as recorded for samples A, B, D, E and G and reduced efficiency of 60% for samples C and F.

Using sawdust as the source of heat, the highest smoking efficiency was 60% while a lowest efficiency of 47.6% was obtained as shown in figure 2. The smoking time for sawdust as source of heat was higher with average of 20.86hrs than charcoal as source of heat with an average of 19.3hrs.

Table 2: Summary of Data on Machine Performance, Using Sawdust as source of heat

<table>
<thead>
<tr>
<th>Type</th>
<th>Initial weight of fish (kg)</th>
<th>Time of smoking (hrs)</th>
<th>Final weight of fish (kg)</th>
<th>Initial Temp. $\theta_1$ ($^\circ$C)</th>
<th>Final Temp. $\theta_2$ ($^\circ$C)</th>
<th>Quantity of heat used (kg)</th>
<th>Smoking rate kg/hr</th>
<th>Smoking efficiency%</th>
<th>Qty of fish/rack kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>22</td>
<td>3.00</td>
<td>7</td>
<td>63</td>
<td>3.90</td>
<td>0.14</td>
<td>60.0</td>
<td>4 big sizes</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>22</td>
<td>2.38</td>
<td>7</td>
<td>63</td>
<td>3.90</td>
<td>0.11</td>
<td>47.6</td>
<td>8 medium</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>22</td>
<td>2.80</td>
<td>7</td>
<td>63</td>
<td>3.90</td>
<td>0.13</td>
<td>56.0</td>
<td>8 medium</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>22</td>
<td>2.72</td>
<td>7</td>
<td>63</td>
<td>3.90</td>
<td>0.12</td>
<td>54.0</td>
<td>8 medium</td>
</tr>
<tr>
<td>E</td>
<td>5</td>
<td>22</td>
<td>2.89</td>
<td>7</td>
<td>63</td>
<td>3.90</td>
<td>0.13</td>
<td>58.0</td>
<td>10 medium</td>
</tr>
<tr>
<td>F</td>
<td>5</td>
<td>14</td>
<td>2.81</td>
<td>7</td>
<td>63</td>
<td>3.90</td>
<td>0.20</td>
<td>56.0</td>
<td>15 small</td>
</tr>
<tr>
<td>G</td>
<td>5</td>
<td>22</td>
<td>2.50</td>
<td>7</td>
<td>63</td>
<td>3.90</td>
<td>0.11</td>
<td>50.0</td>
<td>8 medium</td>
</tr>
</tbody>
</table>

A – Croaker; B – Cat Fish; C – Titus (Alaran); D – Kote; E – Sawa; F – Panla; G- Tilapia

Conclusion
The NCAM fish smoking kiln performed satisfactorily with charcoal as the source of heat than sawdust. It is cheap, user friendly, easy to operate and maintain. Compared to the traditional smoking oven, the kiln produces better quality smoked fish. This helps to eliminate the limitations posed by the traditional method of smoking fish.It is therefore recommended for commercial fish processors and other end users.

References
5. Frank, P
7. Luven, P. 1982. The role of fish in human nutrition. FAO food and nutrition 8(2) pp9-18

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APPENDIX

Fig.1: Pictorial view of the kiln

Fig.2: Isometric view of the kiln

Fig.3: Exploded view of the kiln.

Fig. 4: Orthographic projection of the kiln.