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MASTER TRAINERS MANUAL

ON FISH POST-HARVEST TECHNOLOGIES IN AFRICA

BY

DR. MARGARET OTTAH ATIKPO AND DR. EDDIE KOFI ABBAN

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Current methods of fish post-harvest addition, approaches in the Region

Fish post-harvest technologies are undertaken at the level of the homestead, subsistence, local small and medium scale and at commercial industrial scale.

Current methods of post harvest addition to the value of fresh harvested fish are:

- Smoking
- Sun drying
- Salting
- Combination of salting and sun drying
- Fermentation
- Frying
- Grilling
- Icing
- freezing

Products of approaches, their shelf lives, utilization and processes involved in product deterioration

The corresponding products of approaches are:

a. Smoked fish
b. Sundried fish
c. Salted fish
d. Salted-sundried fish
e. Fermented fish
f. Fried fish
g. Grilled fish
h. Iced fish
i. Frozen fish

Shelf lives, utilization and process involved in product deterioration

The life span of any fish product may be dependent on the freshness indices of the product just after harvest, how it is handled, how and where it is stored and ways in which it is marketed. Determination of the freshness is however problematic due to the complex processes involved in fish spoilage due to a whole range of changes brought about initially in the fish tissues by its own enzymes, resident and acquired bacteria and also chemical reactions within the fish. Thus freshness determination may be analysed taking into consideration the appearance, texture, odour and flavour parameters. The following factors may therefore be considered to contribute to fish freshness:

- Estimation of the time within which the fish was caught and landed
- Measurement of loss of normal flavour
- Measurement of development of off flavour and odour
- Measurement of texture changes
- Estimation of keeping quality
- The holding temperature

During the time interval between when the fish has been harvested from the water and the onset of microbiological changes, the fish begins to lose its flavour due to the changes that cause spoilage of the fish. There has been no single chemical test to accurately describe the complexity of changes in spoilage in all fish species so as to be able to determine consistently accurate the level of freshness. This is because of the variability of composition of fresh fish among the species, and from catch to catch. For freshness measurements therefore, measurement of major physical and chemical alterations from the original fish condition will be meaningful. Consequently no single objective test consistently correlates with taste panel results; but rather a combination of chemical and microbiological tests that

will determine spoilage bacteria in the fish. Good fresh fish when processed will result in good attractive, palatable fish with required texture characteristics. Therefore sensory or organoleptic factors such as appearance, odour and texture of the fish to be processed are important. When assessing freshness of fish to be used for processed end products, it is important therefore to examine the following:

- appearance of the eyes, gills and body cavity (if gutted); and also the flesh along the back bone
- odour of the gills and body cavity if gutted and also
- texture

For bony fish, the following must be examined:

- The eyes must be clear, dark in appearance, and convex in shape
- The gills must be usually bright red (herrings and mackerel have brown colour)
- The slime on the body surface must be transparent and evenly distributed.
- The anus must be closed
- The fish odour must be sea fresh odour; with no trimethylamine or offensive smell
- The fish flesh must be elastic, with stiff and intact scales.

Sensory evaluation of the flesh of the processed fish products is the most widespread means to determine the edibility or quality of the fish. The advantages of this are that no special equipment is needed; tests can be carried out quickly and can be done on the spot. The disadvantages lie in the use of the senses as a subjective procedure that may give just rough quantitative indices. Also the issue of limitation of non-reproducibility and many human errors due to personal prejudices, preferences and interest, state of health, environmental, psychological factors, among others.

Factors influencing spoilage patterns are enzymatic changes; bacterial spoilage or oxidation of flavour constituents. These reactions result in such changes in fish as loss of flavour, development of off-flavour and odours, alteration in texture, and diminishing of keeping quality. Due to so many complex changes occurring, the spoilage pattern varies widely from one batch of fish to another. For example, rigor mortis changes (post-mortem biological changes) are governed partly by the method used in catching the fish (owing to the different degrees of struggling of the fish in the nets), and also the rapidity with which the fish are handled after being caught. This treatment of the fish in turn is reflected by the quantity of lactic acid accumulating in the fish and the length of time that the accompanying lowered pH persists in the tissue resulting in retarded bacteria action. Another example is the different spoilage microflora that occur in the different types of fish coupled with different enzymatic action coming from the visceral tract, since this action may be less or greater, depending upon the quality and type of feed in the fish. With all these reactions and factors varying in widespread manner, the pattern of spoilage from one type of fish to another also varies widely.

Generally quantities of Trimethylamine (TMA) measured as mg N/g of fish muscle has been found to correspond to degree of freshness. TMA occurs widely in marine fish and practically absent from freshwater fish species. The breakdown of TMAO to TMA has been found to parallel the spoilage of fish. Total volatile bases nitrogen (TVBN) content is made up of Ammonia and Trimethylamine.

Volatile reducing substances (VRS) have been implicated in being responsible for volatile off-odours.

All these changes therefore reflect on the quality of the processed fish.

Fish Smoking

Methods of fish smoking, their advantages and disadvantages

The smoking process:

The smoking of fish has the objectives of preservation basically due to dehydration during the high temperature of smoking during traditional processing (50 ºC – 180 ºC, sometimes 80 ºC – 120 ºC), the preservative effects of smoke components (phenols, aldehydes, ketones, organic acids, etc.), and for purposes of product development due to changes in organoleptic, nutritional, chemical and physical properties. These are in three phases as follows:

- Pre-drying (40 – 50 ºC for 60 minutes).
- Gelatinization of proteins and consequent reduction in protein damage (60 ºC for 60 minutes)
- Final drying and cooking of the fish, completion of desired colour formation and texture

In Ghana, about 70 % of total fish catch is smoked for preservation and value addition.

Why is fish smoked?

- To remove moisture
- Reduce spoilage
- Provide longer shelf life
- Enhance nutritional value
- Improve palatability/taste

Fresh harvested fish must be washed (Fig. 1), drained of excess water and spread as uniformly as possible on the smoking trays of the oven. Firewood for the smoking process is arranged in each of the stoke holes of the oven and lit to heat up. The fish on trays is placed in the oven. At the end of the smoking process, the firewood is removed to allow the fish to gradually cool to room temperature.

Fig. 1 Washing of fish prior to smoking

Implications of Fish smoking: Introduction and construction of two 'new' fish smoking ovens and their attributes and comparative analysis with local fish smoking ovens

Traditional fish smoking ovens and their functioning differences

a. The traditional round oven

In Ghana, traditional round or rectangular ovens with either one round (Fig. 2a) or square (Fig. 2b) stokehole were in use before the introduction of the Chorkor smoker in Ghana in 1969. Four main types of traditional smoking ovens used were the cylindrical (round) mud oven (called the Fanti oven); the cylindrical metal or oil-drum oven; the rectangular mud oven; the rectangular/square metal oven.

These ovens were constructed from moulded mud dug from the site of construction. Initially, sticks laid across the top of the oven served as the grill on which fish was smoked. An innovation of this was the introduction of the use of metal grill cut to fit the top of the oven. Since there was no cover to retain heat and smoke, fish products were not uniformly smoked and sometimes heavily charred.

a. Round oven with single round stokehole

b. Round oven with single square stokehole

Fig. 2 Ghanaian traditional round ovens

The Cylindrical mud oven or Fanti oven

The Cylindrical mud oven or Fanti oven is round and made of mud. It is widely used in the Central and Western regions of Ghana where the inhabitants are from the Fanti tribe. A typical oven has an external diameter of about 132 cm, internal diameter of about 105 cm and a height of about 80 cm. A ledge is made in the wall at about 50 cm from the bottom of the oven, on which sticks or wire mesh can rest to support the layers of fish to be smoked. The layers of fish are separated by sticks. A 42 - 48 cm hole at the bottom of the wall serves as a stokehole for feeding firewood into the oven. Disadvantages associated with this oven are the excessive handling of fish during smoking since there is frequent reshuffling and damage to the fish by the sticks used to separate the layers. This problem is especially serious when smoking small species of fish such as anchovies *(Engraulis encrasicholus)* than in the smoking of larger species such as grouper *(Epinephelu* spp.). Other problems include the wearing out of the oven after one or two seasons; it has limited capacity and time-consuming, fuel inefficient; and smoky to operate resulting in unevenly smoked products (www. tcdc.undp.org).

The Cylindrical metal oven

The Cylindrical metal oven is constructed by joining together two opened 44-gallon steel oil drums and cutting a stokehole at the base. The average diameter of the metal oven is about 115 cm, with a height of about 90 cm and a stokehole of approximately 40 x 40 cm. Iron rods are fitted about 60 cm above the base of the drum to serve as a support for the layers of fish. The oven is light and portable but has a disadvantage being prone to rust and corrosion. Also are the excessive handling of fish during smoking, wearing out of the oven after one or two seasons; limited capacity, time-consuming, fuel inefficiency; and smoky to operate (www. tcdc.undp.org). In addition, since it is made of metal, it gives off considerable heat during the smoking process, to the discomfort of the processor.

The Rectangular mud oven

The Rectangular mud oven (mostly used in the Greater Accra and Volta regions) is rectangular in shape and constructed from mud, and with thick iron bars placed across the top of the base to support the layers of fish to be smoked. A stokehole is made on one of the longer sides of the oven. The fish are arranged on pieces of wire mesh placed on the supporting iron rods. Alternate layers of fish are separated by sticks. Disadvantages of the oven include difficulty in handling the hot wire mesh loaded with fish during smoking, low capacity, loss of heat and smoke through the stokehole and around the layers of fish thus resulting in inefficient fuel use, damage of fish caused by the sticks between layers of fish, excessive handling of fish during smoking, defragmentation of fish and falling into the fire to cause charring, and difficulty in controlling the heat (www. tcdc.undp.org).

The Rectangular/square metal oven

The Rectangular/square metal oven is constructed from 44-gallon steel oil drums, which are opened and joined to give a rectangular or square shape. Wooden battens are sometimes used for reinforcement. Thick iron rods are placed on top of the base and pieces of wire mesh are arranged to support the fish. A large stokehole is cut at the base of the side wall (www. tcdc.undp.org). In addition to radiating a great deal of heat, the disadvantages of this oven are similar to those of the rectangular mud model.

The Chorkor smoker/oven

The Chorkor smoker was developed and has been in use for the past two decades. It was developed by the Food Research Institute of the Council for Scientific and Industrial Research (CSIR) of Ghana. The oven was initiated at a fishing village called Chorkor in the Greater Accra region of Ghana; hence its name. This technology is currently in use in several sub-Saharan African countries. Major advantages of the Chorkor smoker over the original traditional round/rectangular ovens include the following:

- capacity to smoke larger quantities of fish in one batch
- more efficient fuel wood management
- lack of contact between layers of fish during smoking
- the elimination of manually turning each fish to effect smoking both sides
- reduction in time of exposure to smoke by processors with attendant health implications.

Dimensions and functional characteristics of the Chorkor smoker

The plan of the Chorkor oven (Fig. 3) is rectangular in shape, measuring 88 inches long by 38 inches wide on the outer with walls of 4.5 inches thick on all sides. The inner section is divided into two equal compartments by a transverse wall of 4.5 inches thick. At the centre of the front wall of each compartment an entrance (stokehole) measuring 13 inches wide and 15 inches high is constructed by inserting a mould of the specified dimension. Red bricks are then laid all around from front to back to a total height of 45 inches from the ground to complete the structure. The constructed Chorkor oven is as shown in Fig. 3.

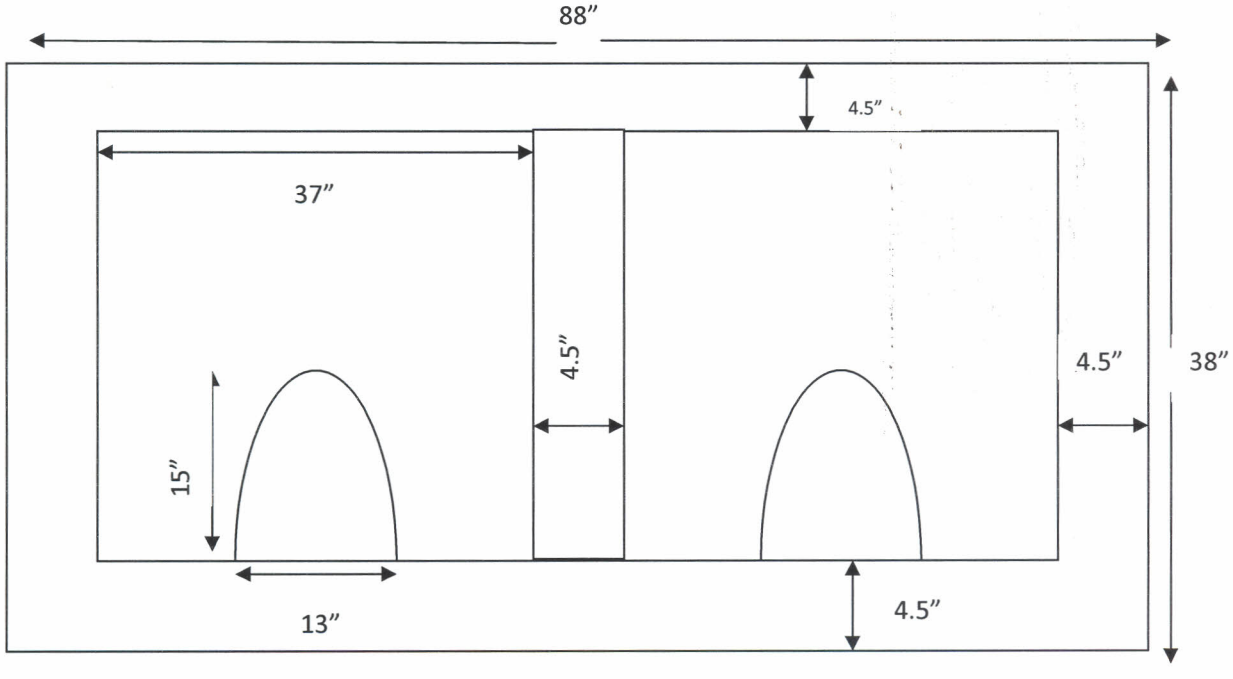


Fig. 3 Structural drawing of ground plan and wall measurements of Chorkor oven

Construction of wooden trays for Chorkor oven

The frame of the trays is made from boards of *wawa* (*Tryplochyton scleroxylon*) and measured 95 inches long (including handle of 5 inches on each side), i.e. with 85 inches length resting on the wall of the Chorkor oven (Fig 4). The width of the tray (Fig. 5) is 34 inches, while the depth is 4 to 5 inches. Wire mesh with small netting is then stretched over and nailed on the bottom part of the frame; which is then fortified with wooden battens. Ten of such trays are constructed and stacked for each Chorkor oven. A thick one-inch plywood (Fig. 6) is used to cover the uppermost tray and act to conserve the heat and smoke within the compartment during the smoking process.

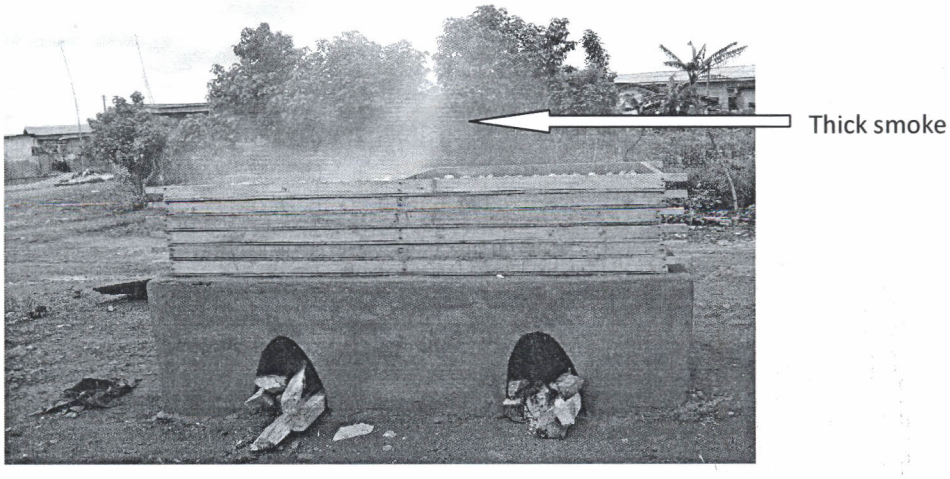


Fig. 4 Chorkor smoker showing stoke holes

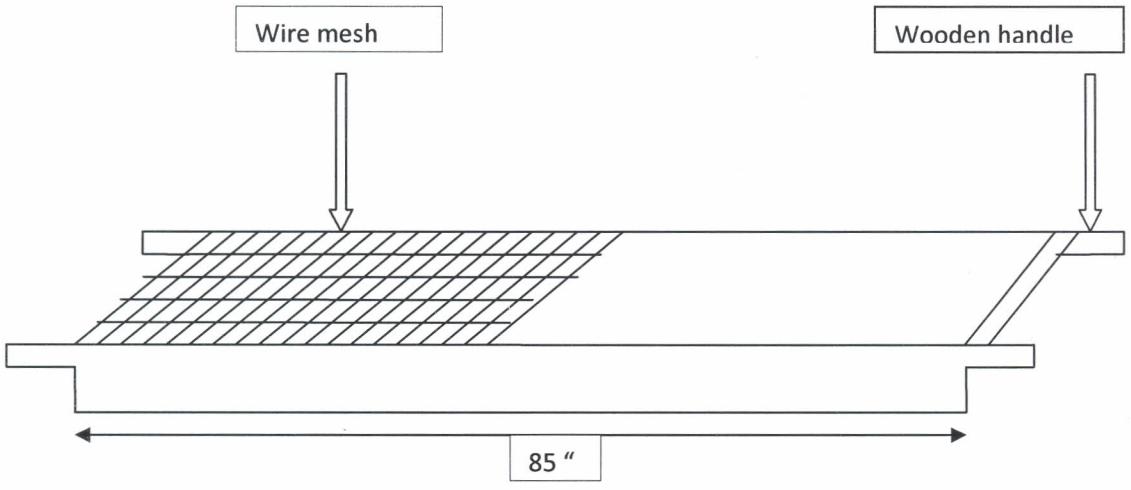


Fig. 5 Structural drawing of tray for Chorkor oven

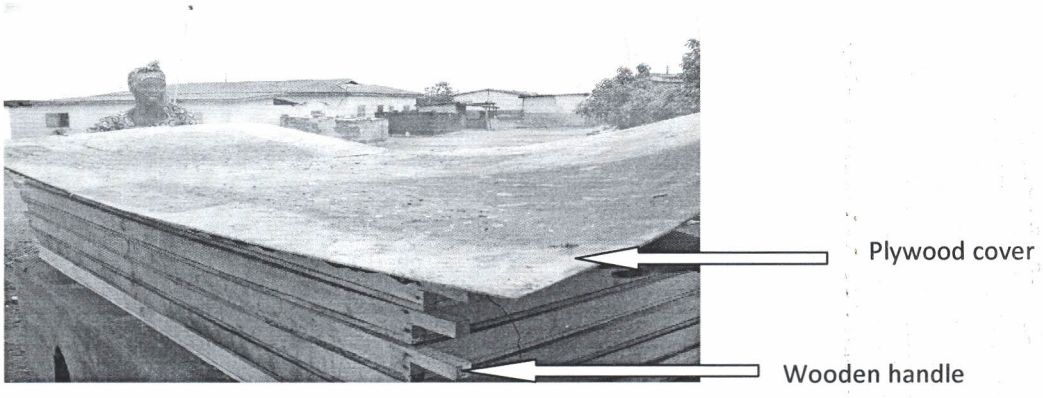


Fig. 6 A stack of wooden trays and plywood cover for Chorkor oven

Figures 7a, 7b and 7c show the disadvantage of rigorous interchanging of trays during smoking fish on the Chorkor oven. Another disadvantage in the use of the oven is the profuse smoke (Figs. 4, 7a, 7b and 7c) generated during the smoking process. Sample smoked fish using the oven is as shown in Fig. 8.

Fig. 7a Interchanging of trays during smoking

Fig. 7b Interchanging of trays

Fig. 7c Interchanging of trays

Fig. 8 Fish smoked using Chorkor oven

Pictorial presentation of the stages in the construction of chorkor oven

Figures 9 (a – d), 10 (a – b) and 11 (a – b) show the pictorial presentation of the different stages involved in the construction of the Chorkor oven. Figure 9 (a – d) shows the demarcation and

construction of the foundation of the chorkor oven. Fig. 10 (a – b) shows the raising up of bricks with mortar from the foundation level. Fig. 11 (a – b) shows the completed block work and wood work involved in constructing the Chorkor oven.

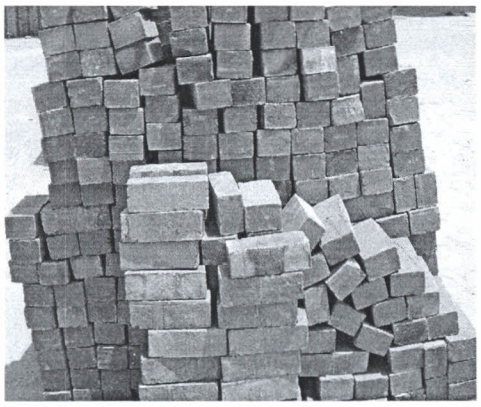


Fig 9a Bricks

Fig. 9b Laying of the foundation

Fig. 9c Partition of foundation into two compartments

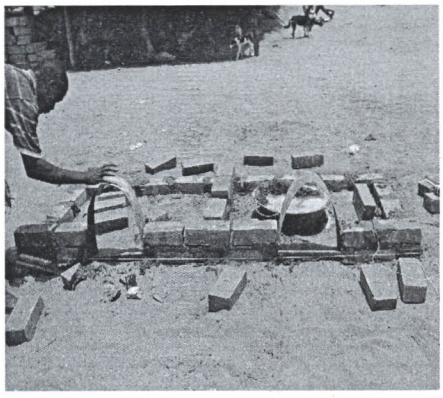


Fig. 9d Setting of frame for stokeholes

Fig. 10a Adding bricks to raise the foundation

Fig. 10b Leveling of layers of bricks

Fig. 11a The completed brick work of the chorkor oven

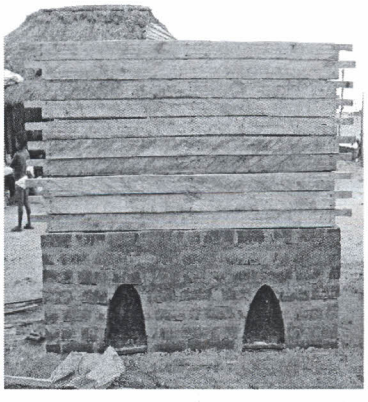


Fig. 11b The chorkor oven with its ten wooden trays

The Food Research Institute Improved Smoking Oven (FRIISMO)

The Food Research Institute (FRI) Improved Smoking Oven (FRIISMO) was developed in 2005 in Accra, Ghana under the Agro-Processing Programme of the Agricultural Services Subsector Investment Project (Blay *et al.*, 2005). The oven design was based on the concept of eliminating the laborious process of interchanging tray positions during smoking and its associated heat loss; as well as the elimination of tar deposits during smoking. The main body structure of the oven was made from burnt bricks and mortar (cement, sand and water mixture). The firing chambers are located at the two sides of the smoking chamber that holds the fixed metal frame for the trays. The curved nature of the side walls of the oven, coupled with the central positions of the shelf structure that carries the trays and the exhaust guarantee uniform smoking in the oven. The height of the

exhaust/chimney is such that smoke is always directed above the shed and also beyond the immediate surroundings of the smoking area, thus preventing the processors from smoke pollution. The base of the chimney is layered with burnt bricks. The chimney which sits on this is constructed with wood and wrapped with aluminium plate. The shelves of the oven are made from ¾" steel square pipes and designed to allow easy sliding in and out of the trays during smoking. The frames of the trays are also made from ¾" steel square pipes to which 3mm chicken mesh is welded. Different mesh sizes of the trays can be used to suit the differing fish sizes, ranging from small anchovies to large fishes like tuna or *Lates niloticus*. The door of the oven is made of wood with the inner part lined with aluminium sheet. Figure 12 shows a FRIISMO in use. The standard oven has capacity of smoking 150 kg of mackerel in 3 hours and 350 kg of tuna in 4 hours, with firewood consumption of 13.2 kg/h.

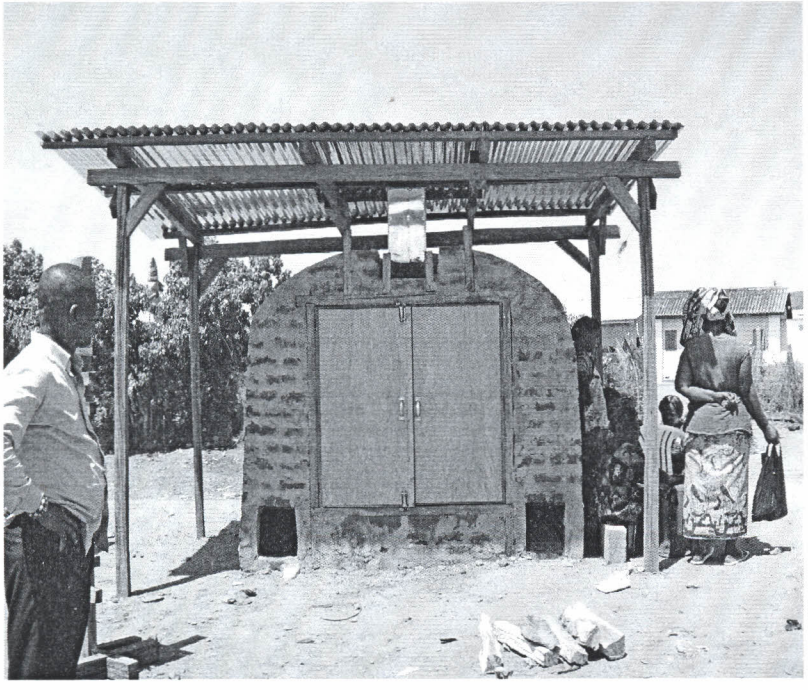


Fig. 12 FRI Improved Smoking Oven (FRIISMO)

Dimensions and Technical measurements of components of FRIISMO

The FRIISMO is an oven which is shaped as a dome-like structure (Fig. 12). The stoke holes are not situated directly under the body of the fish, but rather at the sides (Fig. 12). The trays, made of angle

iron and chicken mesh are not stacked but rather slide in and out along the metal frame. The chimney which situated above the oven directs the smoke upwards.

The floor plan has dimension 127" long by 62½" wide (Fig. 12). The structural frame of the oven (Fig. 13) comprise of chicken mesh fixed in place with binding wire in a dome shape to give shape and fortitude to the oven. At the top of the dome, a flat base is constructed with chicken mesh to support the chimney (Fig. 14) which measures 30" long and 14" wide with a cover attached to the main frame by hinges. Other chimney types may be used.

The dimensions of the shelf frame for the trays (Fig. 15) and the trays with the handles which are fixed together are as shown in Fig. 16. The square wooden door (Fig. 17) of the oven which measures 48" by 48" is lined inside with aluminium strips of plate.

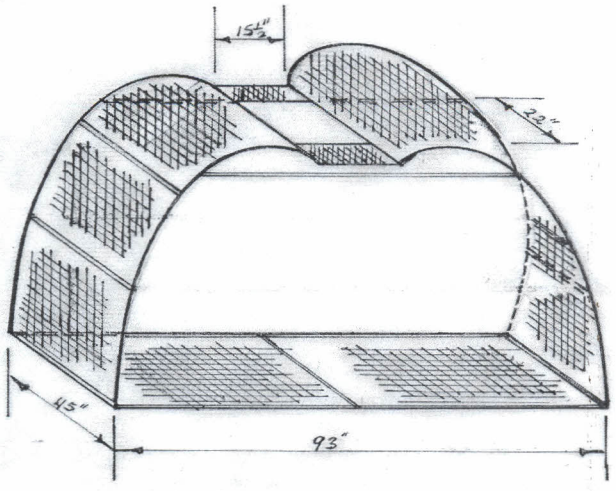


Fig. 13 Structural frame of oven

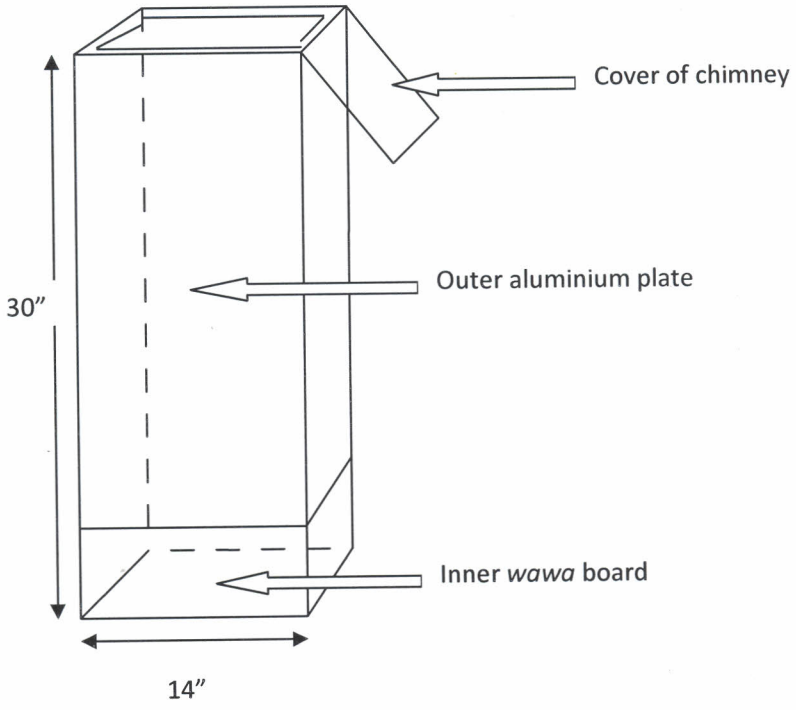


Fig. 14 Structure of chimney

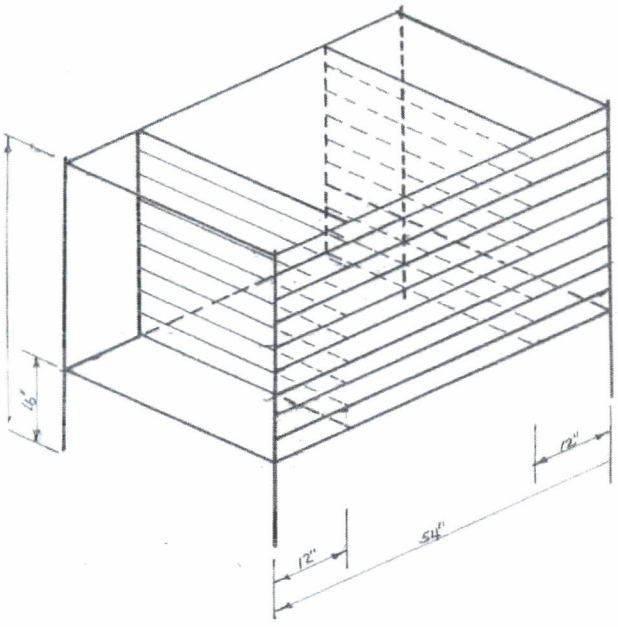
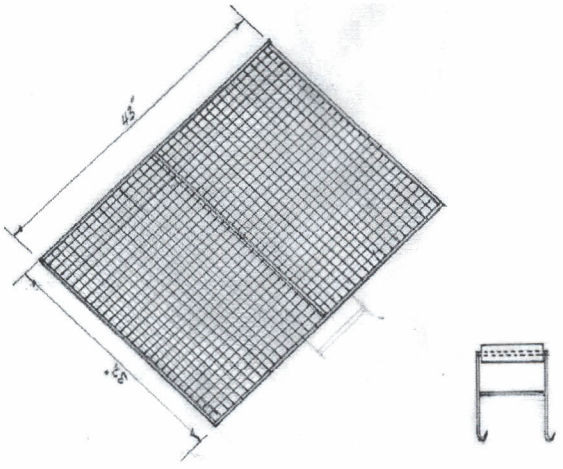


Fig. 15 Dimensions of shelf frame for trays



a. Tray **b. Tray handle**

Fig. 16 Dimensions of tray and handle

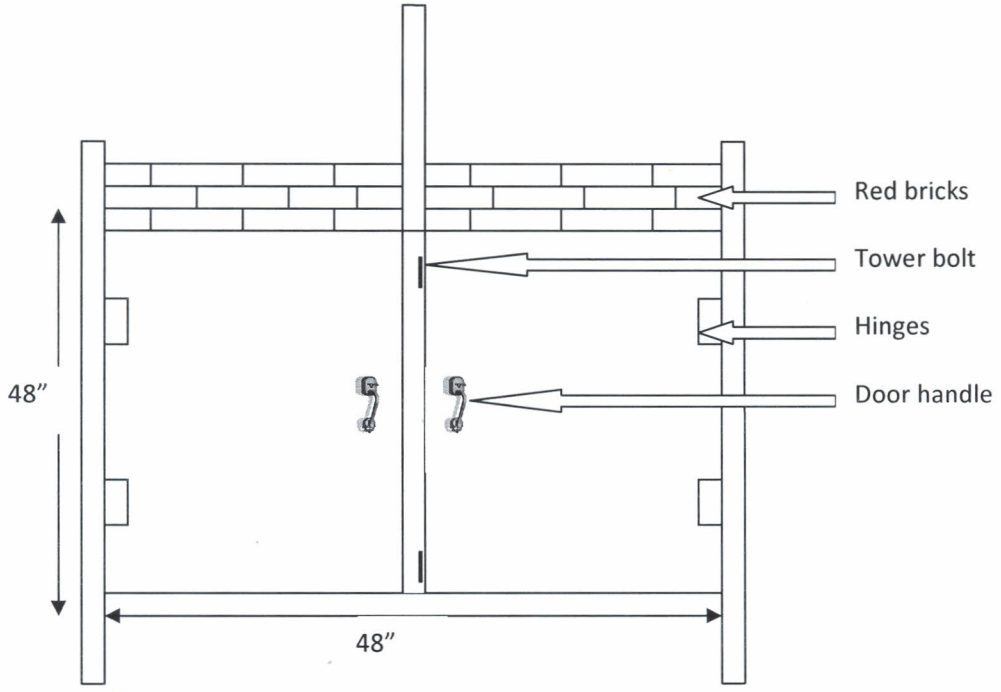


Fig. 17 Structure and dimensions of FRIISMO door

It was observed that fish smoked in FRIISMO looked glossy (Fig. 18) and more attractive than that smoked with the Chorkor smoker. The display of the arrangement of trays (with handles), the inner part of the oven door and smoked fish inside FRIISMO is as shown in Fig. 19; while Fig. 20 shows the positioning of the metal frame with trays and fish inside the FRIISMO. After the fish is cooked, the hot trays are supported on a wooden frame (Fig. 21) designed to hold each tray in position for the smoked fish to be removed and packed for sale.

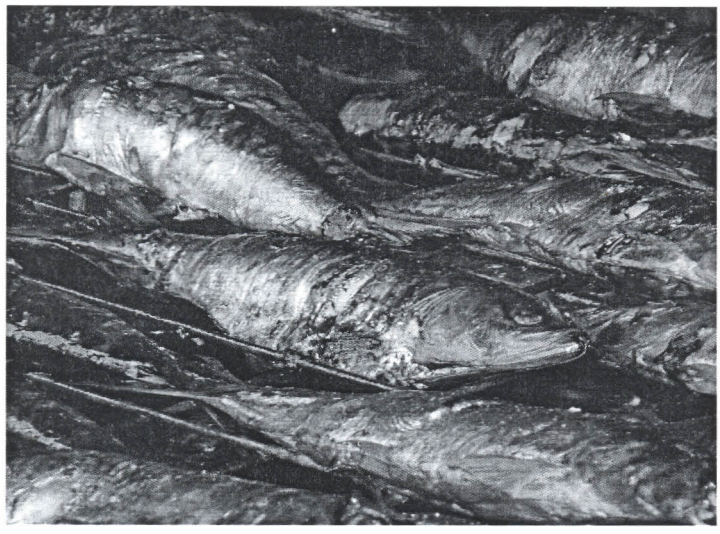


Fig. 18 Glossy and attractive fish smoked in FRIISMO

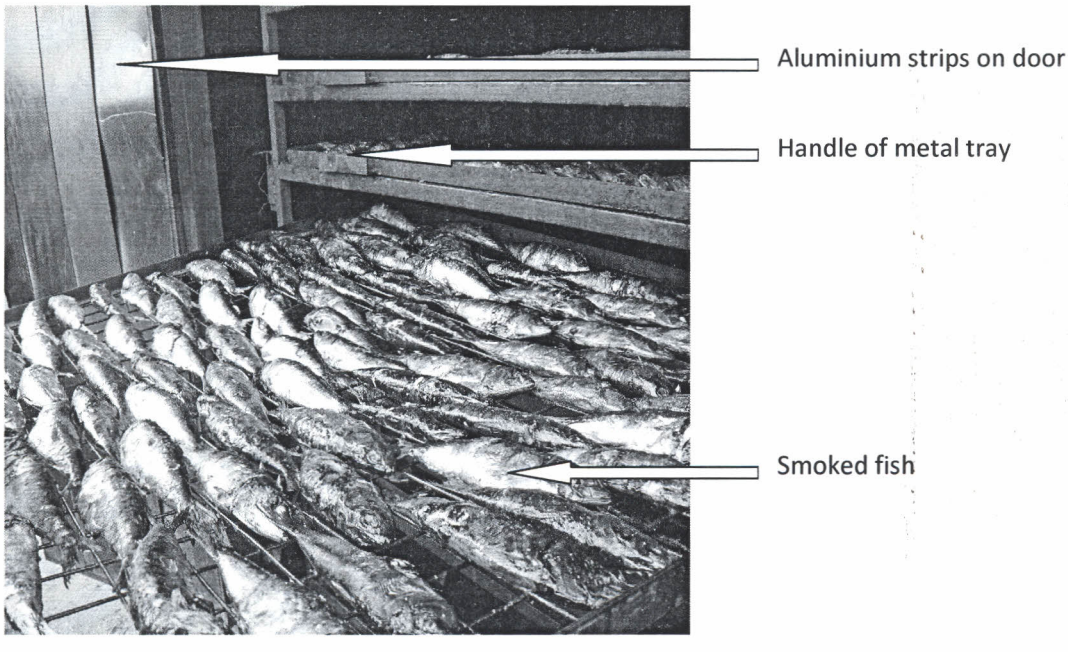


Fig. 19 Display of arrangement of trays (with handles), inner part of door and smoked fish inside FRIISMO

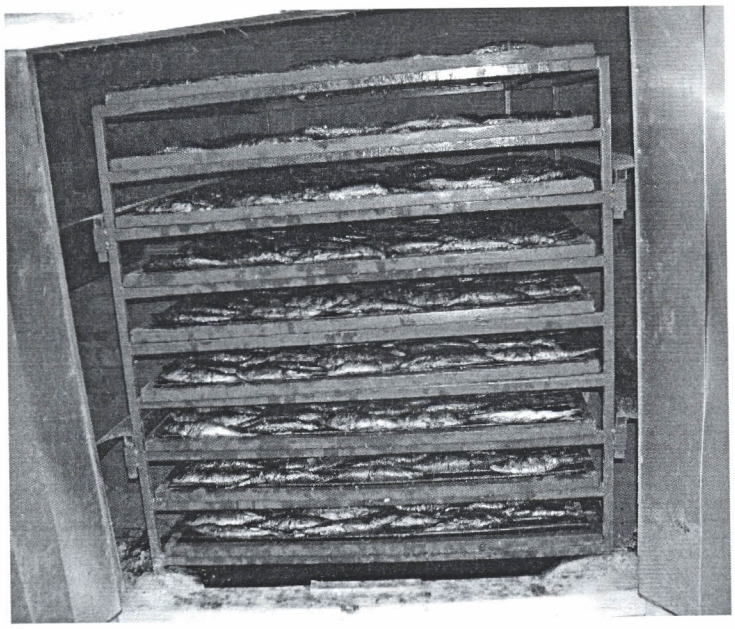


Fig. 20 Positioning of metal frame with trays and fish inside the FRIISMO

Fig. 21 Wooden support for metal trays

Pictorial presentation of the stages in the construction of FRIISMO oven

Figures 22 to 31 show the pictorial presentation of the different stages involved in the construction of the FRIISMO.

Fig. 22 Laying of foundation and positioning of metal frame

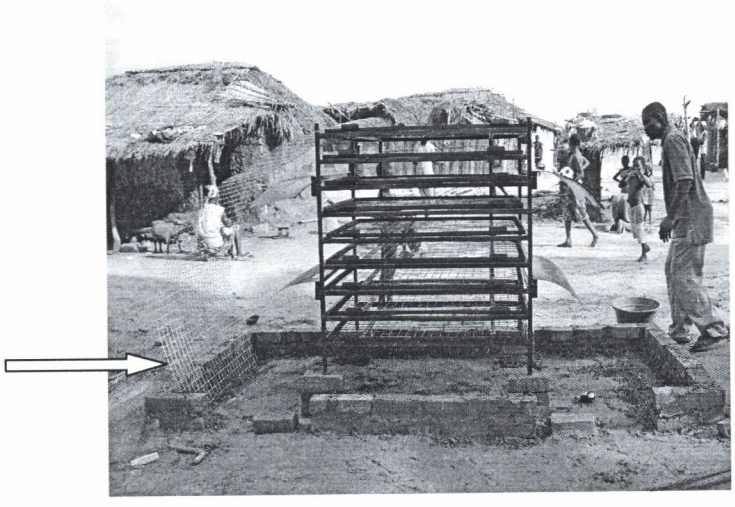


Fig. 23 Mounting and fixing of metal frame unto blocks; and positioning chicken mesh (arrowed) with mortar

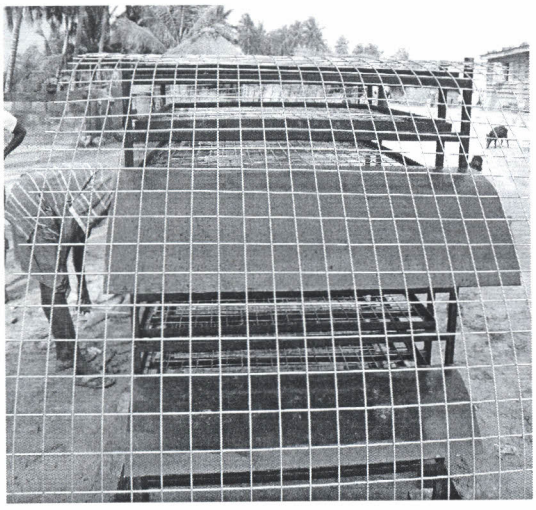


Fig. 24 Metal curvatures positioned on metal frame with chicken mesh fixed to line the inside of oven (side view)

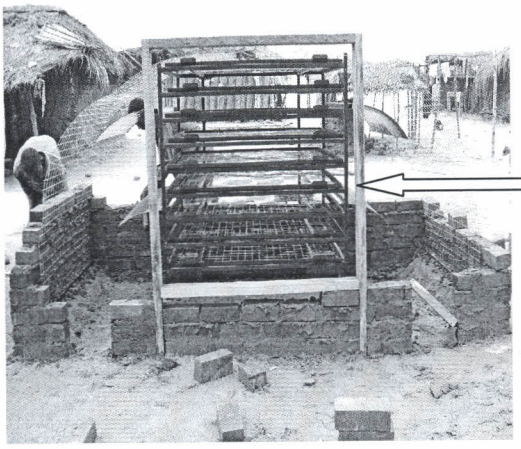


Fig. 25 Positioning of door frame to oven

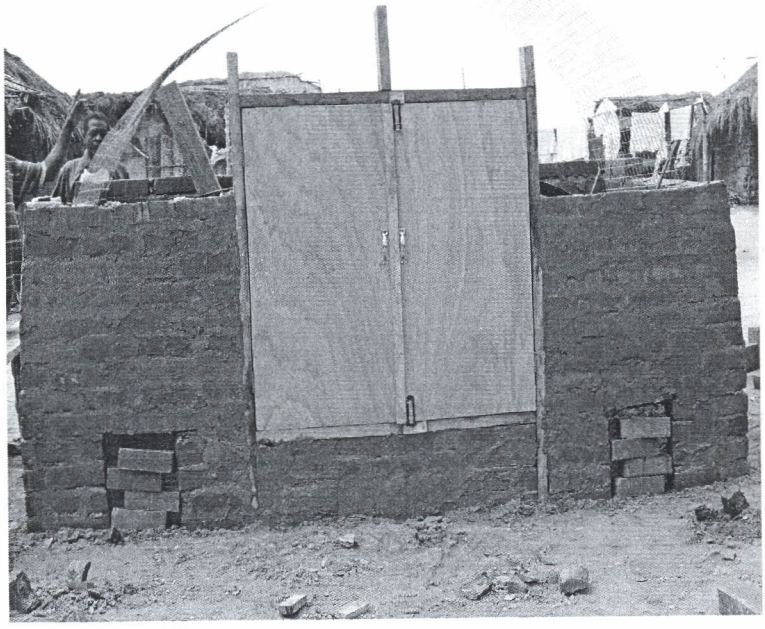


Fig. 26 Fixing of doors with handle and locks into frame. (Inner part of door is lined with aluminium sheet)

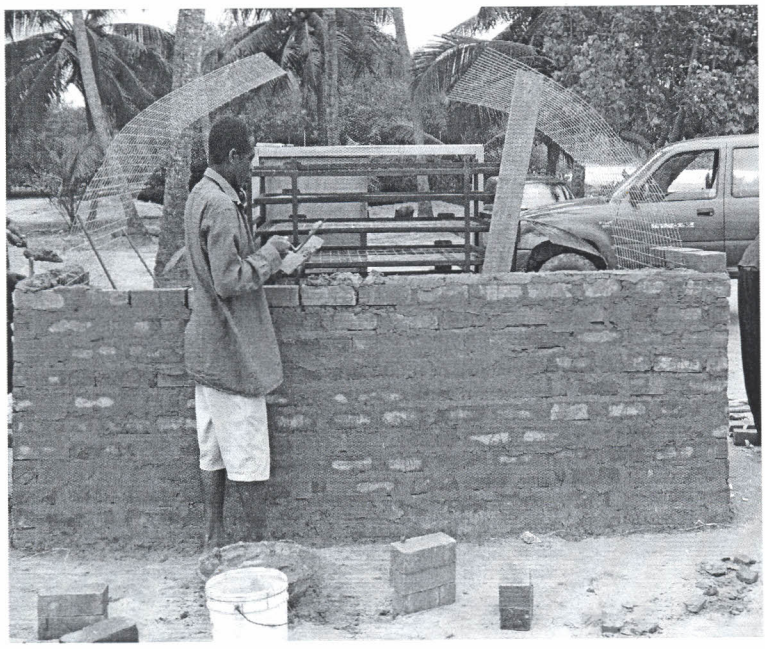


Fig. 27 Laying of bricks (back of oven)

Fig. 28 Laying bricks on top of door frame

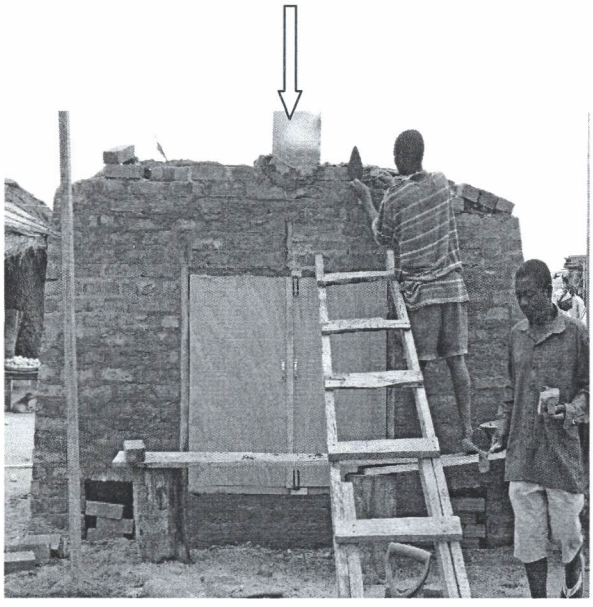


Fig. 29 Positioning of chimney (arrowed) on roof of oven

Fig. 30 Types of chimneys used

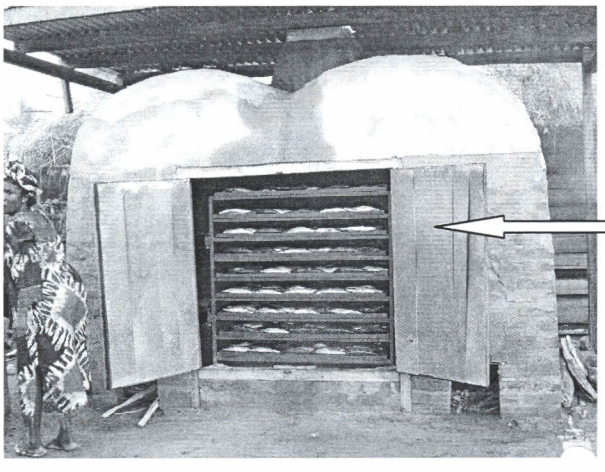


Fig. 31 FRI smoking oven (FRIISMO) with a shed

The performance of the FRIISMO in the smoking process is complimented with a wooden stand (see Fig. 21) as support for the trays in order to make the process less cumbersome in handling the fish when removing it from the oven. The short parallel vertical wooden supports are nailed to the horizontal frame according to and equal to the measured distances between the metal trays. This allows the trays to sit comfortably on the supports while the processor removes the fish from the oven. Figure 32 shows both FRIISMO (left) and Chorkor ovens (right).

Fig. 32 FRIISMO (left) and Chorkor (right) ovens

The smoking process and comparative functional characteristics of FRIISMO and Chorkor

In the FRIISMO, placement of the stoke holes at the sides of the oven, strategically designed to eliminate excess deposition of smoke/tar on the fish during smoking resulted in fish that looked more attractive, brown in colour, intact in shape and better than for that smoked in the Chorkor oven. This may be due to uniform heat and smoke distribution in FRIISMO than in the Chorkor oven. Smoking with FRIISMO oven was more environmentally friendly with the smoke directed upwards into a chimney while with the Chorkor oven, the smoke exuded from the sides of the trays and top of the plywood covering, making it uncomfortable for processors when interchanging the trays.

Trays and fish smoked with FRIISMO are not handled throughout the smoking process as compared during the process with Chorkor oven.

The FRIISMO has stoke holes that are not situated directly under the body of the fish, but rather at the sides so that the fish does not char from direct heat as in the case of the Chorkor smoker. The trays in FRIISMO are not stacked as found in the Chorkor oven, but rather slide in and out along the metal frame so that one individual can operate the oven in contrast to the Chorkor where more than one person is needed. In the case of FRIISMO, a chimney situated above the oven directs the smoke upwards. A chimney is absent from the Chorkor oven. The enclosure of the FRIISMO oven also maintains the heat, such that during smoking no heat is felt at the immediate surrounding of the oven. This affords the processors to relax unaffected by either heat or smoke while smoking. In contrast to the Chorkor where plywood is used to keep the heat and smoke within the oven, FRIISMO is enclosed such that efficient management of heat is maintained within the structure. Fish smoked in FRIISMO looked glossy and more attractive than that smoked with the Chorkor smoker.

Stakeholders' (fish operators, consumers) appreciation of products

Stakeholders, namely the women involved in the smoking of the fish, consumers, operators and retailers were asked to rate the fish and comment on smoked products from the two ovens. The results are as indicated in Table 1.

Table 1. Comparative analysis of FRIISMO and Chorkor ovens and their smoked products by stakeholders

FRIISMO	CHORKOR
a. Structure	
Expensive	Moderate cost
Safe to operate	Not too safe to operate
Simple to use	Difficult to use
b. Operation of oven	
Individual can operate oven	Need more than one person to operate
Little attendance to fish	More attendance to products
No tray interchange	Tray interchange at about one hour interval
Easy to operate, need less energy/manpower	Difficult to operate, need more energy/manpower
Safe when smoking fish	Not safe when operating
No smoke in eyes, clothes, lungs	Excessive smoke in eyes, clothes, lungs
Much time available to do house chores	No time available to do house chores
c. Products	
Products very attractive	Products less attractive
Products cooked early	Products cooked later
Liked products very much	Liked products
Uniformly smoked products	Products not all uniformly smoked
Products with higher moisture	Products have less moisture
d. Consumers comments	
Very tasty smoked fish products	Tasty smoked fish products
Glossy attractive appearance	Not glossy and as attractive
Would buy any time	Would buy when not burnt/charred

For comparability, different species of fish were smoked in the FRIISMO and Chorkor ovens at full capacity of each oven and also with equal weights of fish. FRIISMO exhibited less process time of 1.95 h than the high 3.08 h in the Chorkor smoker during the smoking of mackerel. This indicates that more quantities of mackerel can be processed in FRIISMO per specified unit time than in Chorkor during a particular time frame/period. Consequently, the high percentage yield of 65.36 % in FRIISMO as compared to the comparatively low yield of 37.97 % in Chorkor explains the greater efficiency of FRIISMO. Also the high smoking rate of FRIISMO of 45.38 kg smoked mackerel/hr as compared to 18.84 kg smoked mackerel/hr in Chorkor further indicated that FRIISMO is an oven with beneficial returns. The recorded smoking rates ratios of FRIISMO over Chorkor was 2.41, indicating that FRIISMO is 2.41 times more productive than for Chorkor oven.

During the smoking process, smoke from the Chorkor spread to the immediate surrounding of the smoking area in contrast to the FRIISMO whose smoke was directed through the chimney to a height above the immediate surroundings. This indicates that FRIISMO is environmentally friendly such that its use would not pose any health hazards to the processors as would the Chorkor smoker. In addition, no heat is generated around the FRIISMO so that the processors feel comfortable sitting around the oven when in use. The operation of the oven also affords the processors to have adequate time on their hands to do other household chores at the same time that they are smoking fish.

Parameters measured during the smoking of tuna indicated that the percentage yield in FRIISMO (59.44 %) was higher than 34.87 % registered for Chorkor. This implied that more economic returns would be realized from FRIISMO if the products are marketed immediately after smoking. The firewood consumption rate per smoked tuna was lower (0.54) in FRIISMO but higher (0.87) in Chorkor. The smoked tuna registered a higher smoking rate of 31.32 kg/h for FRIISMO as against a lower 12.13 kg/h for Chorkor. Smoking rates ratio of FRIISMO to Chorkor in the tuna smoking

process recorded 2.58 for trials, indicating that FRIISMO is 2.58 times more productive than the Chorkor during tuna processing.

For further comparative performance of the ovens when they were operated at full capacity, FRIISMO accommodated a bigger load of 172.7 kg as against 162.85 kg in the Chorkor oven. Also the process time was reduced in FRIISMO (2.15 h) than in the Chorkor oven (3.10 h). It was also observed that other trial showed higher yield of 66.6 % in FRIISMO as opposed to 46.5 % when smoking with the Chorkor oven. Furthermore, the firewood consumption rate for the smoked mackerel in the FRIISMO was lower (0.61) than for the Chorkor oven which was 0.72.

In the comparison of the efficiency of the two ovens when using the same weight of sardines of 127.5 kg, FRIISMO recorded a lower process time of 2.15 h in contrast to 3.40 h of the Chorkor oven; and a higher percentage yield of 62.9 % for FRIISMO compared to 56.5 % for the Chorkor oven. Although the firewood consumption rate of the smoked sardines were the same (0.70) for both ovens, FRIISMO showed a higher smoking rate of 37.3 kg/h for the smoked fish as compared with the Chorkor oven with 21.2 kg/h. The ratio of the smoking rates of FRIISMO over Chorkor oven was 1.76, indicating a higher level of productivity of FRIISMO over the Chorkor oven. During the smoking process, smoke from the Chorkor spread to the immediate surrounding of the smoking area in all the trials; in contrast to the FRIISMO whose smoke was directed through the chimney to a height above the immediate surroundings.

In description of the comparative functional characteristics of both ovens encompassing the structural characteristics, cost, performance and health implications to the operators, it was generally observed that the Chorkor oven is simpler, easier to construct and cheaper than FRIISMO. However, FRIISMO has structural characteristics that maintain more heat energy as well as has better advantages environmentally since the smoke is directed above the oven such that the health of the processors is guaranteed. Smoke neither enters the eyes and lungs nor engulfs the clothes of processors. Processors also have ample time on their hands to engage in other household chores since they do not spend time interchanging the trays as in the case of the Chorkor oven. With

FRIISMO, only an individual is required to operate it, whereas at least two people are required for the operation of the Chorkor oven. The appearance and general appeal of the smoked fish from FRIISMO to the consumer ranks very high as compared to products from Chorkor, as there was more charring of the fish processed with the Chorkor oven.

FRIISMO is more efficient than Chorkor oven in terms of

- Time management
- Labour exertion
- Health of processor
- Fuel wood use
- Deposition of wood smoke/tar on smoked fish
- Environmental pollution

Items and skills needed in the construction of FRIISMO and Chorkor ovens

Masonry and carpentry skills are needed in the construction of the ovens. The items for the construction of FRIISMO are nails, rope, wood, cement, sand, chicken mesh, binding wire, iron rods, metal frame, metal flaps, metal trays made to fit frame, battens, aluminium sheets, door handles, chimney and a ladder. For the construction of the Chorkor oven, items needed are nails, rope, wood, cement, sand, wire mesh, battens and mould.

In the making of the trays for the Chorkor oven the following must be taken into consideration:

- Measurement of tray must be equal to the top measurement of Chorkor smoker
- Make wooden frames: 2 long and 3 short pieces. The long ones must have ends carved as handles for easy handling
- Nail wood pieces together to form the tray frame. Divide the frame into two equal parts with a wooden partition
- Cut and first stretch mesh firmly on wood frame
- Nail metal mesh on the wooden frame
- Nail battens to hold the metal mesh unto frame
- Completed trays must stack on each other without space in between them
- Completed trays must sit firmly on the oven top without space in between
- The inner wood partition of tray must sit on the middle wall of oven

The purpose of smoking fish is to preserve it by removal of water to reduce the moisture content; apply heat to cook the fish flesh and enhance the flavour with the smoke. This will reduce the activity of spoilage microorganisms which need a certain moisture level to survive. The unavailability of adequate moisture and nutrients in the smoked fish delay spoilage

significantly. Different types/species of fish are smoked differently with respect to the length of smoking, its applicability, what kind of dishes it will be used for and what kind of storage regime will be applied. For smaller fish species like sardinella (*Anchoa guineensis*) which has storability of up to 12 months or more in Ghana, the fish is smoked dry for a longer period of time and at certain intervals before storage as compared to larger fish species like Tuna which has limited storage period and different applicability.

Table 2 shows the comparative functional characteristics of FRIISMO and Chorkor oven.

Table 2. Comparative functional characteristics of FRIISMO and Chorkor oven

	FRIISMO	CHORKOR
1. Structure of oven	Dome	rectangular
2. Construction time	6 days	2 days
3. Cost of construction of smoker with shed	High ¢10,190,000 ($1,107.61)	Low ¢3,131,000 ($340.33)
4. Relative position of trays to fire source/stoke holes	Trays in middle compartment away from direct fire source	Trays directly above fire source
5. Relative position of fish to fire source/stoke holes	Fish positioned away from source	Fish directly above fire source
6. Distribution of heat during smoking	Excellent	Good
7. Heat loss during smoking	Very low/negligible. More heat energy retained, no escape through walls, between trays and at uppermost tray. Minimum escape through chimney.	Very high. Large heat energy lost between stacked trays and top of uppermost tray.
8. Interchanging of trays during smoking	Trays fixed and not interchanged	Trays not fixed and interchanged several times before completion of smoking
8. Vent for smoke escape during smoking	Chimney positioned above smoking chamber	Absence of chimney
9. Relative smoke content on fish	Low	High
10. Burning/charring of fish during smoking	low	High
11. Temperature around oven during smoking	Low and comfortable to sit/rest around	High and uncomfortable
12. Smoke accumulation around oven during smoking	None	High
13. Fuel wood utilization	Low	Lower
14. Minimum number of persons needed to operate smoker	One person	At least two people

Table 2. Comparative functional characteristics of FRIISMO and Chorkor oven (continued)

	FRIISMO	CHORKOR
15. Level of attention of fish during smoking	Very low. Once chamber is closed, fish is left to cook with minimal attention.	Very High. The fish have to be monitored always and trays interchanged several times.
16. Time availability to person engaged in smoking	More time available to processor. Once fish is placed in oven, processor has the time to attend to other household chores as the fish require less attention.	Less time available to processor. Excessive time used in stacking trays, interchanging trays and attending to fish. Therefore less time for processor to attend to other household chores.
17. Exposure of person smoking to heat and smoke	Minimal/low exposure	Very high exposure
18. Product appeal/appearance	- evenly smoked	- less evenly smoked products
for potential market value tag	- fish not charred; fire source not directly under fish	- fish likely to be charred due to fish fat dropping directly into fire above fish to set fish ablaze
	- product attractive and glossy	- product comparatively unattractive and not glossy
	- product looks lighter and appealing.	- product looks darker and less appealing
19. Polyaromatic hydrocarbons (tar content)	Low	High
20. Moisture content of product	low	lower
21. Potential health implications to processor	-less burns from smoking fish	- could be easily burnt during tray interchange
	-no smoke inhalation	- excessive smoke inhalation leading to lung cancer
	- no smoke in the eyes	- excessive smoke in eyes leading to poor vision and eye problems
	-no smoke in clothes	- smoke in clothes gives processor bad odour

Comparison of smoked fish from Chorkor and FRIISMO

Fig. 33a Fish smoked with Chorkor

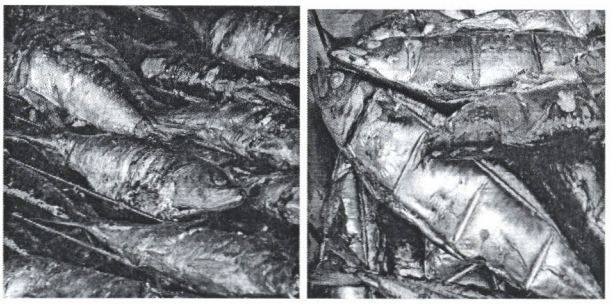


Fig. 33 b Fish smoked with FRIISMO

Smoked fish from FRIISMO (Fig. 33b) are clean, attractive, glossy, appealing and absence of charring than that from Ckorkor oven (Fig. 33a).

Dry salting and fermentation of fish

Two methods of fish salting practiced in Africa are the following:

- Dry-salting of fish
- Fermentation of fish (wet-salting)

Dry salting of fish

The fish is washed and drained of excess water. Bigger sized fish are eviscerated before salting, while smaller sized fish are salted whole. Dry rock salt in preference to granulated salt is used for dry salting of fish. The salt is rubbed on the fish and in crevices. The fish is then sun dried to further enhance its quality.

The purpose of salting fish is to effect moisture loss from the fish and thus result in depriving the fish of water molecules to a certain extent. Removal of moisture molecules from the fish retards the growth of microorganisms that cause spoilage of the fish and in the case of certain pathogens, elaborate toxins in the fish. The process of dry salting in combination with sun drying is very effective preservation method to reduce spoilage. One of such products produced in Ghana from *Tilapia* sp. is called *kobi*. A minimum concentration of 8 % wwb salt in the fish deter blowfly larvae infestation. Figure 34a and Fig. 34b show training in dry fish salting.

Fig. 34a

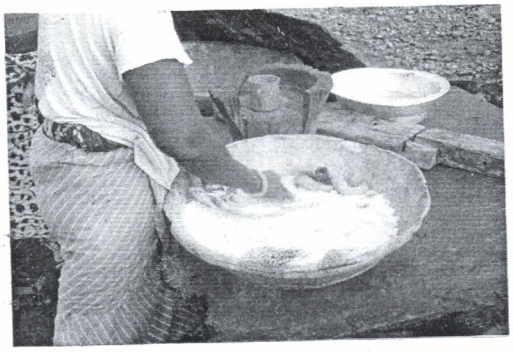


Fig. 34b

Fig. 34 Dry salting of fish

Fermentation of fish

During fish fermentation, salt is rubbed on the fish body and crevices either whole or eviscerated. The fish is then packed in alternate layers with salt in fermentation vats. The last layer of fish in the vat is covered with a layer of salt. A lid is placed on the vat and heavy weight placed on it to keep the fish submerged in its body fluids for varying periods of time for up to 12 months during which the processor may remove some fish for sale. An example of such a product produced in Ghana is called *momone* is an intermediate fermented fish product.

The rate of salt intake of fish is dependent on its size and thickness, amount of salt used, temperature of fish, temperature of brine, freshness of fish, oil content of fish (oil slows down

the rate of salt penetration because the salt ions are water-soluble but not oil-soluble). The minimum salt content is 8g salt/100g fish on wet weight basis.

Sun drying of fish

The fish is washed with potable water, drained of excess moisture and spread on either mats or raised structures to dry in the sun. In certain improved structures, fly-proof screens and nets are used to ward off flies. The process of sun drying is to utilize the sun's energy to remove moisture and further dry the fish from the heat of the sun. In sun drying of fish, the following may be observed to improve the quality of the fish:

a. Dry fish on raised racks to improve rate of drying due to good air circulation

b. Use metal mesh trays/netting/screens

c. Spread fish on clean surfaces (mat etc.)

d. Avoid overlapping of fish

e. Cover fish with waterproof sheeting during rainfall

f. Store fish to prevent moisture intake

g. Turn fish regularly during sun-drying to maintain uniform temperature throughout fish flesh

h. In low air humidity, dry fish in shade to reduce risk of case hardening

Well dried fish can store for varying periods of time, especially small sized sun dried fish which can store for 12 months and over. Figure 35 and Fig. 36 show sun drying of fish on raised racks in Senegal and Malawi respectively. Figure 36 further shows the use of polyethylene sheets used to cover the

Fig. 35 Sun drying of fish on raised racks in Senegal

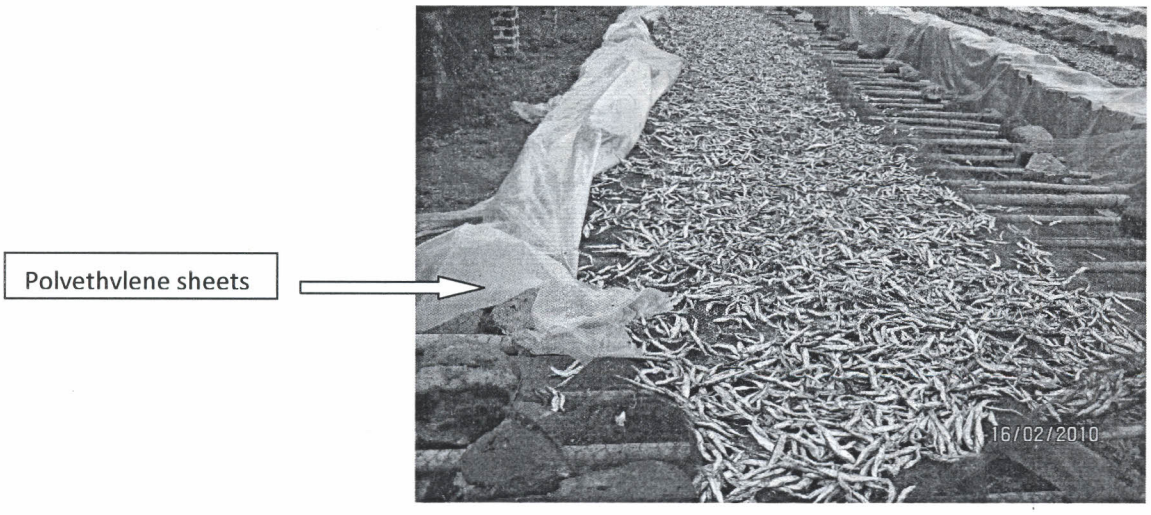


Fig. 36 Sun drying of fish on raised racks in Malawi

dried fish in the night and also during rains to avoid deposition of dew and wetting of the fish as increase in moisture content of the fish initiate microbial spoilage. During sun drying, temperatures of 45 °C and above are lethal to blowfly eggs and larvae. Drying on raised racks avoid contamination of the fish by crawling insects, lizards and domestic animals. Solar drying of fish is more effective and

cheap as solar energy is gratis, especially in the tropics where solar energy is available throughout the year. For added enhancement of product quality, good hygienic practices coupled with avoidance of accumulation of fish waste at the processing site must be practiced in order to reduce blowfly activity.

Frying of fish

Deep frying of fish is also carried out to preserve the fish for a short period (3 – 5 days). During the frying process, the fish muscle is cooked submerged in hot oil to preserve it. This product has a short shelf life of an average of up to 5 days depending on whether the fish is fried dry or not. Depending on whether the fish is fatty or bony also enhance storability. In fried products, rancidity occurs if storage of the fish is prolonged than necessary. The different species of fish are processed differently depending on the use and application desired. Smaller sized fish however keep for a longer period than bigger bulkier fish.

Grilling of fish

Grilling of fish involves washing the fish with potable water; draining it of excess water and either applying dry salt or not depending on the taste and flavour required before placing it on a grill to cook over an open fire or in an oven grill. The product from this process is normally consumed immediately or after a few hours. The process cooks the fish proteins and removes excess fat from the fish. The shelf life of the product is short and is up to 2 days.

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