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DESIGN AND CONSTRUCTION OF AFSMO – 150, AN IMPROVED FISH SMOKING OVEN

by

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Abstract

AFSMO – 150, an improved fish-smoking oven was developed at the Food Research Institute of the Council for Scientific and Industrial Research (CSIR) of Ghana under the Agro-Processing Programme of the Agricultural Services Subsector Investment Project (AgSSIP). The total cost of construction of the oven was ¢2 500 000 (approximately US$280). It exhibited various advantages over the popular chorkor smoker because of its cost effectiveness and efficiency. The design eliminated the laborious interchanging of tray positions, reduced heat loss and eliminated tar deposition on the fish. AFSMO-150 (AgSSIP/FRI Smoking Oven) is an enclosed rectangular-shaped structure composed of three basic units of two firing sections, a cooking/smoking chamber and a chimney. It could be fired by either firewood, Liquefied Petroleum Gas (LPG) or a combination of the two.

Test run of the oven with firewood fuel on mackerel showed temperature distribution with highest temperature difference of 29 °C at 90th minute and maximum temperature of 195 °C at 110th minute of operation; a smoking capacity of 150 kg of fresh fish per batch at 3 hours, fuel consumption of 39.5 kg of firewood (i.e. unit fuel consumption rate of 0.33 kg of firewood/kg of smoked fish); 80.6 percent yield with 19.4 percent moisture loss. Microbiological analyses indicated a final fish product devoid of faecal coliforms, spoilage and food poisoning micro-organisms – hence a product safe for human consumption.

Résumé

AFSMO-150, un four amélioré de fumage du poisson, a été développé à l'Institut de recherche alimentaire du «Conseil pour la recherche scientifique et industrielle au Ghana (CSIR)» dans le cadre du Programme pour l'industrie agro-alimentaire du projet d'investissement pour le sous-secteur des services agricoles (AgSSIP). Le coût total de construction du four était de 2 500 000¢ (280$EU environ). Celui-ci a montré beaucoup d'avantages par rapport au très populaire four chorkor du fait de son coût et son efficacité. Le prototype a éliminé le laborieux changement des positions des claies, a réduit la perte de chaleur, et a éliminé les dépôts de goudron sur le poisson. AFSMO-150 (four pour fumage AgSSIP/FRI) est une structure fermée à forme rectangulaire composée de trois unités de base ayant deux sections pour l'allumage, une chambre de cuisson/fumage, et une cheminée. Il peut être allumé soit par du bois combustible soit avec du Gaz Pétrole Liquéfié (LPG) ou par une combinaison des deux.

Des essais effectués avec le four à l'emploi de bois combustible pour le maquereau ont démontré une distribution de température avec une différence maximum de 29 °C à la 90ème minute et une température maximum de 195 °C à la 110ème minute d'opération ; une capacité de fumage de 150 kg de poisson frais par lot toutes les 3 heures, une consommation de 39,5 kg de bois combustible (i.e. unité de ratio de consommation de combustible de 0,33 kg de bois combustible/kg de poisson fumé); 80,6 pour cent, de rendement avec 19,4 pour cent, de perte d'humidité. Les analyses microbiologiques indiquent que le produit final de poisson est dépourvu de coliformes fécaux, de microorganismes pathogènes d'altération; le produit est donc salubre pour la consommation humaine.

1. INTRODUCTION

Smoking is the most widely used fish preservative method in Ghana among other traditional methods, such as sundrying, salting and fermenting. Thus about 70 percent of catch by artisanal fishermen are smoked using various types of ovens, such as the round/rectangular mud or metal ovens. The chorkor smoking oven was thus developed as an improvement over these aforementioned ovens (UNICEF, 1983) because it was thought to be cost effective. However, there were aspects of its operation that needed improvement. These included the laborious interchanging of tray positions during smoking to prevent the charring of the lower layers of fish closest to the fire source. In the process, a substantial amount of heat energy is expended during the operation of interchanging the trays. Also direct application of heat during smoking tended to increase the deposition of tar on the smoked product.

The objective of this project was therefore to develop an improved oven over the chorkor type that eliminated the interchanging of tray positions during smoking, reduced heat loss and made fish smoking less laborious. The improved oven also targeted the reduction/elimination of tar deposits usually associated with processed fish.

2. MATERIALS AND METHODS

2.1 Design features

The new design was created with the concept of eliminating the laborious process of interchanging tray positions during smoking with its associated heat loss and elimination of tar deposits on smoked fish products. The firing chambers were therefore located at the two sides of the smoking chamber where the trays were stacked. The curved nature of the sidewalls of the oven, coupled with the central position of the shelf structure that carried the trays in relationship to the firing chamber and the exhaust, guaranteed uniform smoking in the oven.

The height of the exhaust/chimney was such that smoke was always directed above the immediate surroundings of the smoking area, thus preventing the processors from smoke inhalation and pollution. Figure 1 shows the front, side elevation and the plan of the oven.

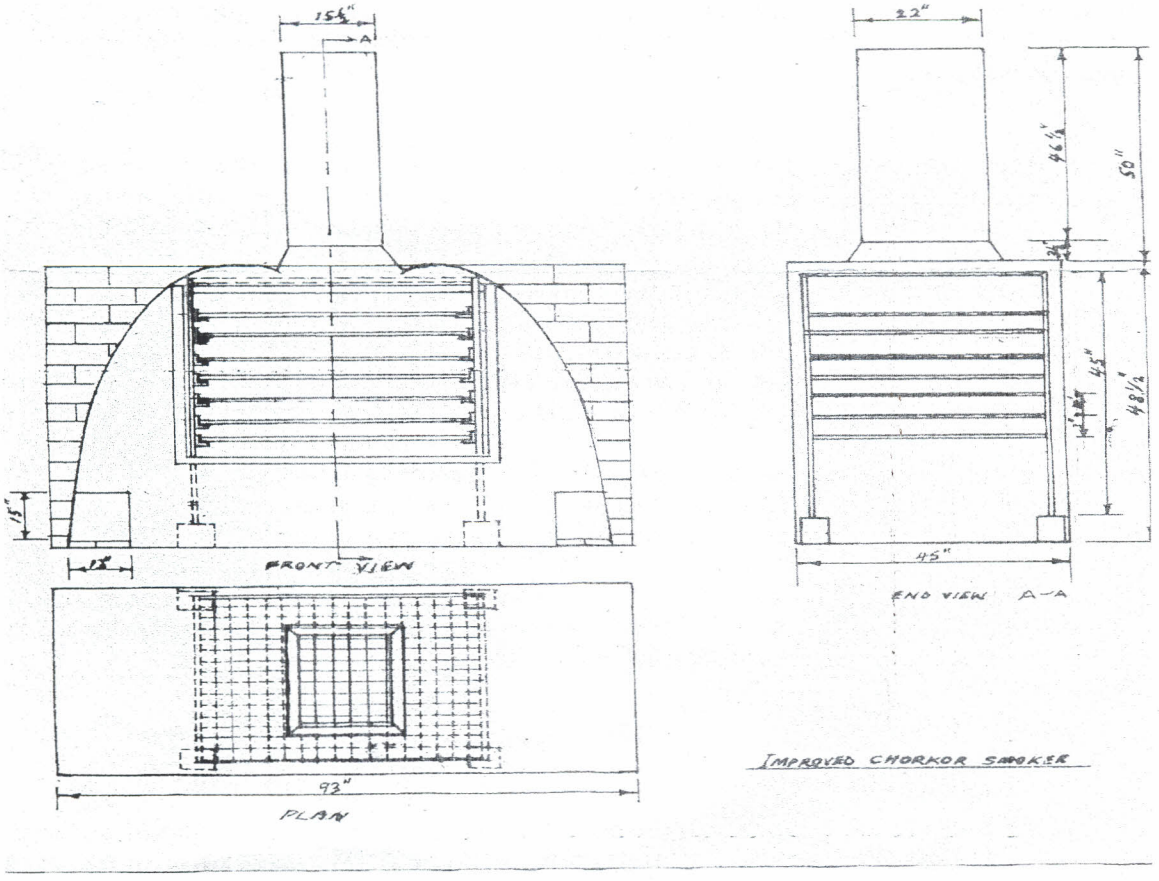

Figure 1: Front, side elevation and plan of the AFSMO-150

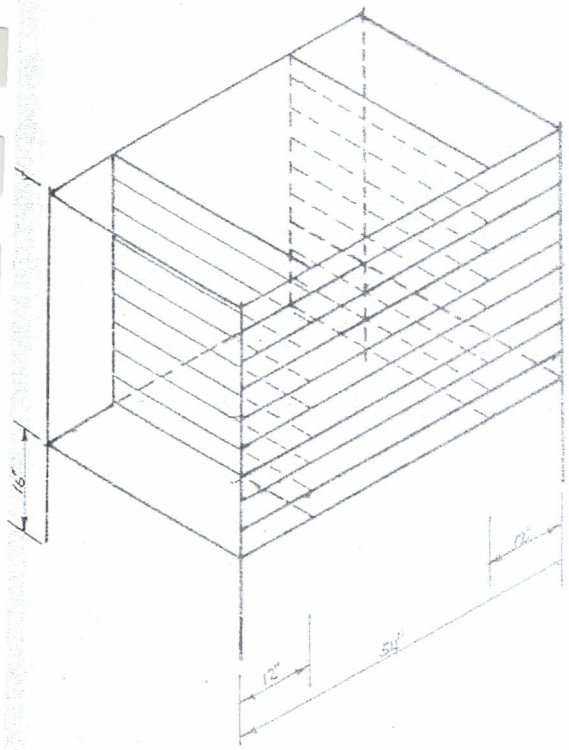

Figure 2: Shelf

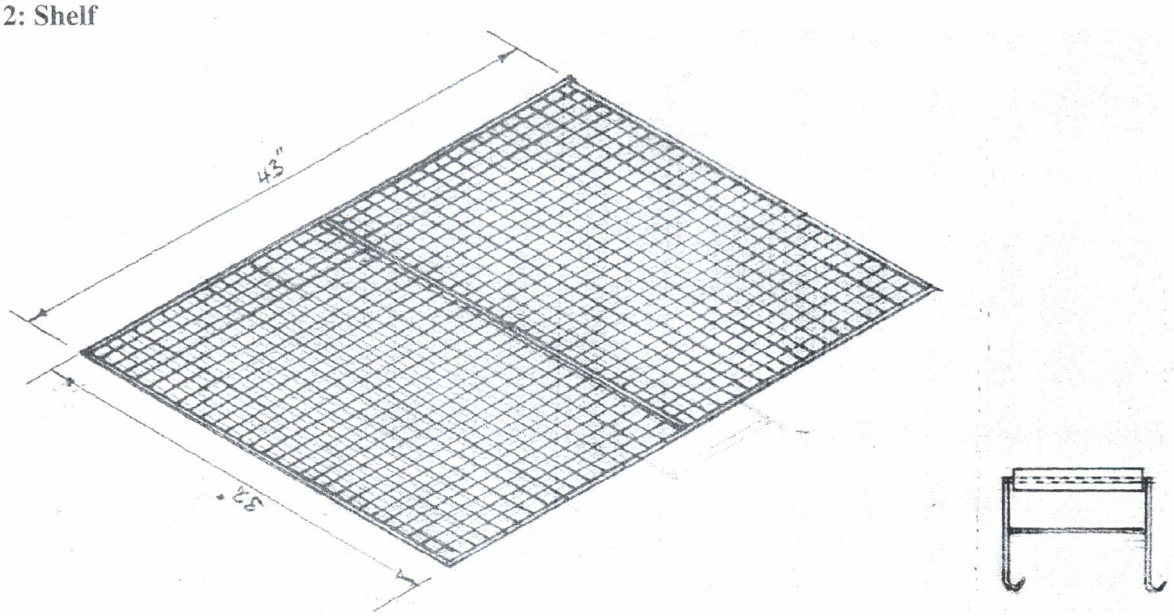

Figure 3: Tray and hook

The shelf was made from 5/8" steel rods and designed to allow easy "push-in and pull-out" of trays. The trays were made from 5/8" steel rod frames and 3 mm welded mesh. A hook with wooden handle was constructed to allow for pulling out the trays in sequence after the smoking process. Drawings of the shelf, tray and hook are as presented in Figures 2 and 3. The structural frame of the oven is as shown in Figure 4.

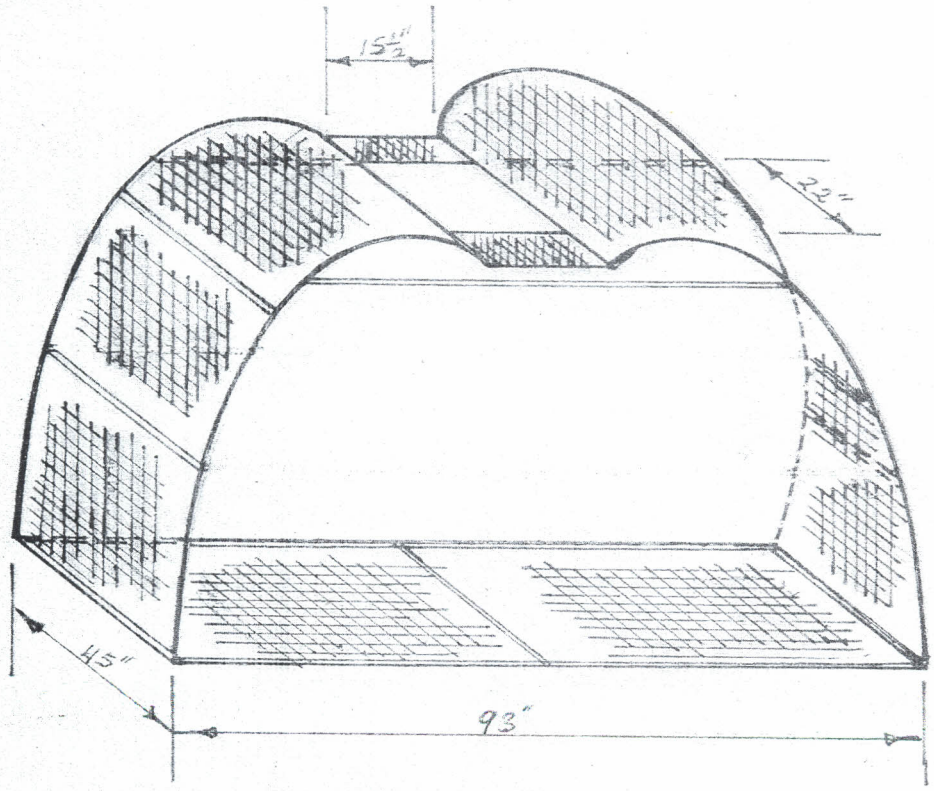

Figure 4: Structural frame of the improved oven

3. TEST RUN OF OVEN

The performance characteristics of the oven were determined by test running of the oven by smoking mackerel on firewood fuel. The mackerel was obtained in good frozen condition from a cold store facility at the Tema Fishing Harbour while the firewood was the traditional "Osha" obtained from Shiashi market near Okponglo in Accra.

3.1 Temperature distribution test

Test on temperature distribution in the oven was conducted to ascertain the uniformity of heat distribution. Three temperature probes were inserted in the oven from the back and positioned on the top, middle and bottom trays. Temperature readings were recorded every 10 minutes.

3.2 The smoking process

The fish was allowed to thaw, washed, drained of water, weighed and spread as uniformly as possible on the ten trays with each tray carrying 10 percent of the total quantity of fish to be smoked, i.e. 15 kg of the mackerel. Firewood for the smoking process was weighed, and about five or six sticks were arranged in each of the stoke holes and lit. The trays were then slid onto the shelves and the door closed. Three stages of smoking process were employed. The first stage (slow firing) covered a period of about 30 minutes during which the fire was manipulated such that temperature in the oven increased slowly and steadily but did not exceed 100 °C to prevent case hardening. The second stage (increased firing) lasted for about 2 hours during which the temperature was raised to record a maximum of about 195 °C. The third stage (cooling) was characterized by partial withdrawal of the firewood from the stoke holes to allow the fish to slowly reduce its temperature for about 30 minutes. After the third stage, the firewood was completely withdrawn and the door was opened for the fish to cool to room temperature. The trays were then pulled out of the shelves and the smoked fish weighed. The remaining firewood was also weighed and recorded.

Samples were taken from the top, middle and the bottom trays for microbiological analysis, chemical and texture analyses.

4. RESULTS AND DISCUSSIONS

Table 1 and Figure 5 show the temperature recordings at the top, middle and bottom trays during smoking. A maximum temperature difference of 29 °C representing 15 percent of the maximum working temperature of 195 °C was obtained and it fell within the smoking temperature range.

Table 1: Temperature (°C) profile in oven

Time (minutes)	Temperature Top	Temperature Middle	Temperature Bottom	Temperature difference
0	30	30	30	0
10	61	58	55	6
20	70	70	67	3
30	87	82	77	10
40	95	92	89	6
50	102	98	95	7
60	133	128	116	17
70	160	142	134	33
80	143	135	127	16
90	171	152	149	29
100	190	186	175	15
110	195	184	179	16
120	165	150	148	17
130	150	135	132	18
140	159	146	144	15
150	126	123	110	16
160	117	110	105	12
170	89	84	78	11
180	77	72	69	8

Table 2 shows data recorded before, during and after the fish smoking process. It can be deduced from the results that the oven has a smoking capacity of 150 kg per batch of 3 hours and firewood consumption of 39.5 kg.

Results of the microbiological analyses (Table 3) indicated that aerobic plate counts at 30 °C ranged between 3.0×10^1 and 2.6×10^3 cfu/g. The Ghana Standards Board Microbiological Standards (GSBMS) for food samples (1988) and the International Commission on Microbiological Specifications for Foods (ICMSF, 1982) indicated a limit of acceptability as less than 1.0×10^6 cfu/g for the total viable count in any food to be safe for consumption. Such counts recorded in the smoked fish were therefore within the limits of acceptability.

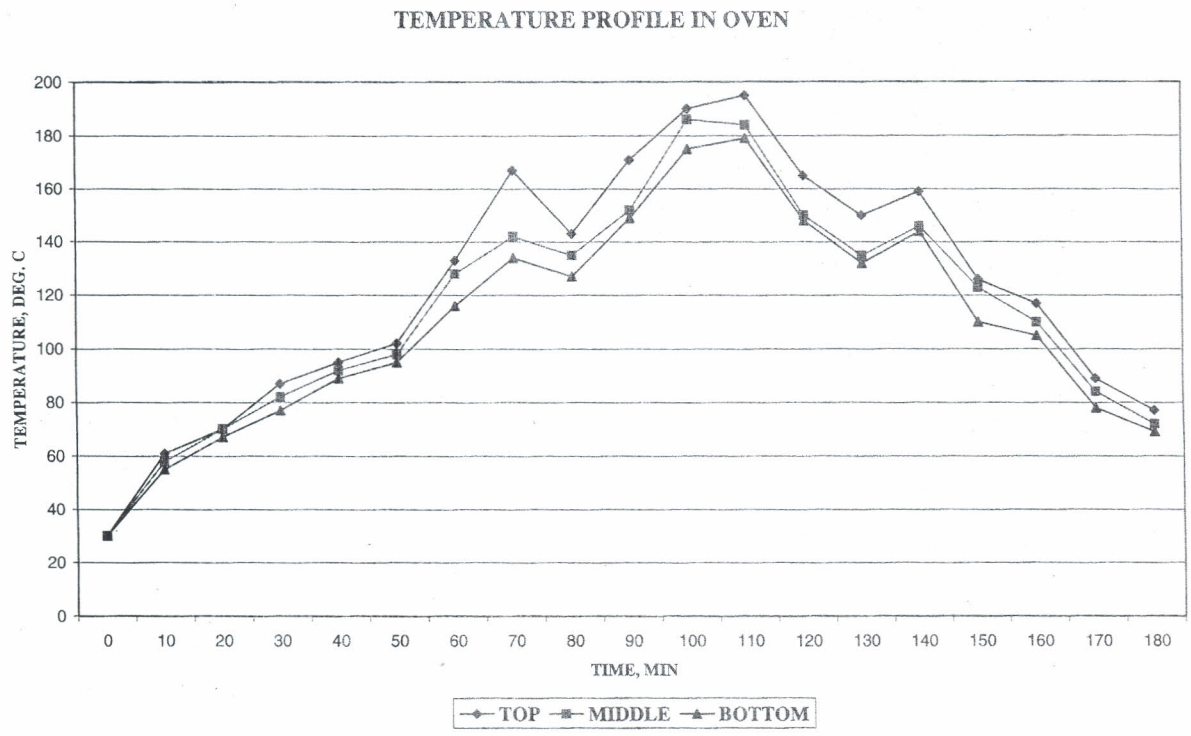

Figure 5: Temperature profile in oven during smoking of mackerel

Table 2: Fish smoking data

Type of fish	Mackerel
Type of firewood	"Osha"
Weight of firewood before smoking, kg	46.0
Weight of firewood after smoking, kg	7.5
Weight of firewood used, kg	39.5
Process time, hr	3.0
Consumption rate of firewood, kg/hr	13.2
Cost of wood per kg	¢952.38
Cost of firewood used	¢37,620
Weight of fresh fish, kg	150.0
Weight of smoked fish, kg	120.9
Weight of loss, kg	29.1
Weight loss, percent	19.4
Yield, percent	80.6
Firewood consumption rate, kg/kg smoked fish	0.33
Firewood consumption rate, kg wood/kg fresh fish	0.26
Unit energy cost of smoking, ¢/kg smoked fish	¢314.28
Unit energy cost of smoking, ¢/kg fresh fish	¢247.19

Mould and yeast counts were between 0 and 9.0×10^2 cfu/g in the smoked mackerel (Table 3). The ICMSF (1982) and GSBMS (1988) has a specification of less than 1.0×10^4 cfu/g, which indicated that the smoked fish met the specified standard requirement for safe food.

Table 3: Population of micro-organisms in smoked fish processed with improved smoker

Coliforms were absent in all the samples (Table 3), and further indications showed that *Escherichia coli* (*E. coli*) were also not detected. While ICMSF (1982) specified the levels of *E. coli* to be less than 1.0 x 10^1 cfu/g, the GSBMS (1988) indicated levels of zero cfu/g. The non-detection of these food poisoning organisms indicated that the fish was safe for consumption.

Smoked fish batch	Aerobic microorganisms at 30°C (cfu/g)	Moulds and yeasts (cfu/g)	Coliform organisms (cfu/g)	*E. coli* (cfu/g)	*Salmonella* species (/25g)	*Bacillus cereus* (cfu/g)	*Staphylococcus aureus* (cfu/g)	Dominant flora
1	1.3×10^3	8.0×10^1	0	0	Absent	0	0	*Mucor* spp., yeasts, Gram +ve rods
2	2.6×10^3	9.0×10^2	0	0	Absent	0	0	Yeasts, Gram +ve rods
3	7.7×10^2	6.0×10^1	0	0	Absent	0	0	Gram +ve rods and yeasts
4	3.0×10^1	0	0	0	Absent	0	0	Gram +ve rods

Salmonella species were not detected in 25 grams of any of the samples (Table 3). Both ICMSF (1982) and GSBMS (1988) stipulated levels of zero cfu/g of these organisms in the food to be considered safe for human consumption.

Staphylococcus aureus and *Bacillus cereus* were absent in the smoked fish samples (Table 3). For *S. aureus*, both ICMSF (1982) and GSBMS (1988) indicated safe levels of less than 1.0×10^2 cfu/g and zero cfu/g respectively; while *Bacillus cereus* levels should not exceed 1.0×10^4 cfu/g. Dominant flora observed were Gram-positive rods, yeasts and *Mucor* species.

The absence of faecal coliforms, spoilage and food poisoning micro-organisms in the smoked fish showed that it was microbiologically safe for human consumption and would not pose any health hazard when consumed.

3. CONCLUSION

A 150 kg capacity smoking oven AFSMO – 150 has been designed, constructed and tested at the Food Research Institute (FRI) of the Council for Scientific and Industrial Research (CSIR). The oven is working satisfactorily and has actually eliminated the process of interchanging trays during smoking with the chorkor smoker, thus reducing the amount of labour expended. Series of trials are being conducted to determine the tar deposits on the products, i.e. polycyclic aromatic hydrocarbons (PAH) content, texture and shelf-life properties of smoked fish with AFSMO-150.

The total cost of construction of the AFSMO-150 is ¢2 500 000 (US$280).