PN-ABG-258

Tuskegee University

Founded by Booker T. Washington

School of
Agriculture & Home Economics

February 9, 1990

Mr. Floyd O'Quinn
Research and University Relations
Bureau for Science and Technology
Agency for International Development
Washington, D.C. 20523

Dear Mr. O'Quinn:

Enclosed is a progress report and manuscript on the "Evaluation of Selected Storage Conditions on Post-Processing Losses and Quality Preservation of Smoked Dry Herrings "DAN-5053-G-SS-8021-00."

The results from this project and the previous one are proving to be significant and will impact on improving the quality of life for Ghanaians and we would like for this research to continue so that we can disseminate our findings to the Ghanaian government as well as the people of Ghana.

Sincerely,

R. D. Pace, Ph.D.
Co-Principal Investigator

J. Y. Lu, Ph.D.
Co-Principal Investigator

Enclosures: 1. Progress report
2. A copy of the manuscript sent to the J. Food Science for publication

Copy: Dr. S. Louis

ct

RECEIVED FEB 22 1990 SCITICR

Tuskegee, Alabama 36088

PROGRESS REPORT

Project Title: Evaluation of Selected Storage Conditions on Post-Processing Losses and Quality Preservation of Smoked Herrings, DNA-5053-G-SS-8021-00.

DATE: January 25, 1990

Objectives of the project:

1. To assess losses due to physical spoilage, weight loss, loss in nutritive quality as well as microbial health hazards by methods: freezer, traditional, modified and polyethylene.

2. To evaluate the efficiency of proposed modified processing and storage conditions.

Experiment I. Storage effect on yield and quality of smoked dry herring.

A. Preparation of smoked dry herrings-

The Experiments were initiated in April, 1989. Two PIs, Dr. J. Y. Lu and Dr. R. D. Pace of Tuskegee University working along with Dr. W. A. Plahar of Food research Institute (FRI), Accra, Ghana, made arrangements to purchase fish and to set up smoke dry ovens for the experiments. A large bulk (about 800 lb) of frozen herrings was purchased at Tema fishing harbor, Tema, Ghana. Tema is the largest port in Ghana about 20 miles east of Accra, the capital of Ghana.

Smoke drying was done at the FRI processing plant in Accra. Fish were thawed, washed, then smoked dried for 2-3 days until 14-15% moisture was reached. A Chorkor type smoking oven was used for smoke-drying of the fish.

B. Storage conditions-

Freshly smoked herrings were divided into 6 batches for the following storage tests.

1. Freezer storage- About 50kg of fish was packaged in plastic pouches and kept at -20°C for six months. This sample served as a control.

2. Polyethylene bag storage- Ten bag each containing three kg fish were packed in 0.004 mm polyethylene bag, size of 25 x 38 cm, stapled close at the end and stored in a room at ambient

temperatures.

3. Polyethylene bag with dessicant. The procedure was the same as above except 150g dessicant (Drierite, anhydrous $CaSO_4$) was enclosed in the bag. The dessicant was replaced twice a month during storage.

4. Traditional smoke oven storage- A thirty kg batch of smoked herrings was packed in a cylindrical traditional type smoke oven for storage. The oven was covered with a polyethylene sheet and jute sacks. A two hour smoking was conducted every month during a six month storage period. The humidity and temperature condition for the six month period was monitored (Table 1).

5. FRI/Tuskegee modified- The modified storage structure (Figure 1) was used to store 30kg of fish. The procedure was the same as traditional storage. Fish was resmoked once a month for two hours during the six month storage period.

C. Evaluation of storage

1. Storage losses- For each storage condition, fish showing signs of damage which appeared unfit for human consumption after storage were counted and expressed as percentage of the total initial number of smoked fish stored. This was done separately for rodent damage, insect/maggot damage and mold infection.

   The yield after storage was also calculated using the percent initial weight of smoked dry fish that remained sound and undamaged after the storage. To eliminate the effect of storage moisture loss, the initial weight was expressed on the basis of the final moisture content.

2. Sensory test- Two methods, descriptive and hedonic scale tests were used to evaluate acceptability by a larger number of panelists.

3. Chemical analysis- Samples of edible portions of fish were analysed for protein decomposition (total nitrogen and non protein nitrogen) and fat rancidity (total fat, peroxide value and acid value).

4. Microbial quality- Serial dilutions were made from storage samples. Plate count agar was used for bacteria while malt agar, Czapedox agar and

yeast extract agar were used for molds and yeasts. The plates were incubated at 28°C for 24 hours for bacteria, and at room temperature for 4 days for molds and yeasts. The results were expressed as number of microorganisms per gram sample. Bacteria and mold species were identified based on staining, morphological and cultural characteristics.

D. Results

1. Storage losses- polyethylene storage with or without dessicant proved unsatisfactory in preserving the smoke dry herrings effectively. Although no rodent damage was found, insect and fungal damages were quite extensive. A yield of only 4% was obtained with one month storage. Polyethylene with dessicant was better than the polyethylene alone. However, only 10% yield was obtained after three months of storage. In both cases, spoilage and rancidity of samples were obvious. Lack of ventilation compounded with high local humidity and temperatures (Table 1) enhanced microbial attack on fish resulting in a low storage yield. A very high storage yield (97%) was obtained with the FRI/Tuskegee modified structure. The modified structure protected the fish against rodent and insect attack while resulting in a relatively low mold and yeast counts. This was due to good ventilation and resmoking of fish during storage.

2. Sensory quality- The results of sensory tests are shown in Tables 3 and 4. The best quality product was the freezer stored samples. These samples had a slight increase in chewiness and were less brittle and hard; color, flavor and aroma remained unchanged. The fish samples stored in the traditional and FRI/Tuskegee modified structure had darker color, were tougher and had a slight decrease in the characteristic flavor and aroma of freshly smoked fish. However, consumer preference test (Table 4) showed that all the characteristics were highly acceptable and preference scores ranged between liked moderately to liked very much. On the other hand, fish samples stored in polyethylene bags were soft, crumbly and tender. The color changed from brown to blackish and they had a moldy and rancid odor, typical of highly deteriorated fish product.

3. Chemical changes- The effect of storage conditions on composition changes is shown in Tables 5

and 6. The moisture content of samples stored in traditional and modified structures decreased drastically. This was due to the re-smoking of these samples during storage. Better aeration of the FRI/Tuskegee modified storage structure was responsible for lower moisture content than the samples stored in the traditional storage oven structure. Total nitrogen decreased in all the samples stored under different conditions except the samples stored in the freezer. This was due to enzymatic reactions that occurred during storage. No changes were observed in the fat content regardless of storage methods. Acid value was greater for polyethylene bag stored samples indicating a high microbial infection had occurred with this storage method. The acid value of samples in the traditional structure doubled over the six month storage period while the fish samples stored in the modified structure had only a 50% increase. Oils extracted from the samples stored in polyethylene bags were darker in color and solidified at 26°C indicative of polymerization. The oils from other samples were lighter in color and remained liquid at room temperature. Peroxide values were not great for fish samples analyzed. This may not be the best index to relate the rancidity of oil in fish sample. Total volatile base nitrogen (TVBN) was used as an indicator of spoilage. The results (Table 6) showed that the TVBN value was 70.3 mg/100g for the samples stored in the modified structure which is not considered high. The small TVBN values found in both samples stored in traditional and the modified structure were probably due to evaporation of these compounds during re-smoking process. The results of chemical analysis would indicate that the fish samples stored in the modified structure had only a mild chemical change and appeared to have highly acceptable food quality.

4. Microbial quality- The highest microbial counts were observed with the samples stored in polyethylene (Table 7). Storage at -20°C did not change microbial counts significantly. Slight decreases in yeast and mold counts were observed with the samples stored in the traditional and FRI/Tuskegee modified structure stored for six months. The occasional re-smoking probably discouraged proliferation of microorganisms. The predominant bacteria identified in fish samples were *Bacillus* spp and *Micrococcus* spp. The major molds identified were *Aspergillus niger*, *A. wentii*, A. *versicolor* and *Penicillum*

spp. The results showed that bacterial count as well as mold and yeast counts were not high in fish samples stored in traditional and the modified structure indicating that the fish products preserved by these methods are acceptable from a microbiological point of view.

E. CONCLUSION

Fish and fish products provide the most important source of high quality animal protein to the majority of people in Ghana. The most important one is smoked dry herrings. The problem of this fish product is post-processing losses which occur during storage under high temperature and high humidity ambient storage condition in Ghana. The losses have been reported to reach as high as 70% depending on processing as well as storage conditions. The FRI/Tuskegee modified structure designed by the scientists of FRI and Tuskegee University demonstrated a very high yield (97%) and retained flavor and texture which are highly desirable by Ghanaian people. Only 3% difference in yield was observed between the freezer storage and the FRI/Tuskegee modified structure storage. Freezer storage is excellent, however, it is energy intensive and expensive. From an economical point of view, it appears unlikely for the majority of small scale processors in villages to be able to purchase and maintain large freezer for storage of smoke dry herrings. The FRI/Tuskegee modified structure storage technique appears feasible and adaptable to the prevailing economic conditions in Ghana as well as in other West African nations.

Experiment II. Microbial health hazard problems of smoked dry herring.

Experiments are being conducted at this time to isolate and identify the presence of pathogenic bacteria that may be present in the smoked dry herring samples. The types of bacteria under investigation are *Staphyloccus aureus*, *Salmonella spp.*, *Clostridium botulinum* and *E. coli*. A preliminary study on freshly smoke dried herrings indicated the absence of *Clostridium botulium*, *Salmonela*, *Listeria* and *Camplyobacter*, but a fair number of *Staphylococcus aureus* were isolated. The presence of pathogenic bacteria in smoke dry herring samples stored for six months is being studied at this time. The study is expected to be complete by May.

Experiment III. Nutritional quality of smoke dry herrings.

The effect of consuming smoked dry herring on health will be studied using young rats as the test animal. The animals will be fed specially prepared diet that contain smoked dry herring as the sole source of protein. After feeding 4 weeks, animals will be sacrificed for histologic and clinical analysis to detect any abnormality in organs, tissues that may occur as a result of consuming smoked and slightly rancid fish. The experiment is planned to begin in March and expected to be completed in July.

Publication:

A research paper entitled "Effect of storage method on the quality of smoked dry herrings" by W. A. Plahar, R. D. Pace and J. Y. Lu has been sent to the Journal of Food Science for publication.

Table 1: Average temperature and relative humidity conditions in storage area over the six-month period

Month	Temperature (°C)			Relative Humidity (%)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
April	24.5	30.0	28.7	70.0	96.0	78.8
May	24.5	29.5	27.8	74.0	100.0	81.6
June	24.5	28.5	26.7	75.0	100.0	85.0
July	24.0	27.5	25.8	76.0	96.0	84.3
August	23.5	27.7	25.6	75.5	100.0	83.5
September	24.0	29.0	26.5	74.0	98.0	83.0

Source: Calculated from the daily temperature and humidity recordings by the Ghana Meteorological Services Department (Accra, Ghana).

Table 2. Storage losses of smoked dry herrings (*Sardinella eba*) through insect infestation, rodent attack and microbial damage.

Storage Method and Duration (months)	Rodent Damage (%)	Insect/ Maggot Damage (%)	Mold Damage (%)	Storage Yield (%)
Frozen control 6 mo.	0.0	0.0	0.0	100.0
Polyethylene storage without dessicant 1 mo.	0. 0	92.2	80.2	3.8
with dessicant 1 mo.	0.0	3.3	10.0	86.7
3 mo.	0.0	60.0	83.0	10.0
Traditional structure 6 mo.	5.1	16.1	14.9	71.9
FRI/Tuskegee Modified structure 6 mo.	0.0	2.1	3.1	96.9

Table 3: Quantitative descriptive sensory analysis of smoked dry herrings (*Sardinella eba*) stored under different conditions

Storage method and duration	Score for sensory characteristics[1,2]					
	Hardness	Brittleness	Chewiness	Flavor	Aroma	Color
Freshly smoked 0 mo.	5.6a	6.6a	5.7a	9.8a	10.0a	9.8a
Frozen control 6 mo.	5.4a	5.2a	5.0b	9.4a	10.0a	9.6a
Polyethylene storage without dessicant 1 mo.	0.6b	0.5c	0.3c	nd	1.6b	1.4b
with dessicant 3 mo.	1.7c	2.1b	1.5d	nd	1.0c	2.5c
Traditional storage 6 mo.	7.6d	6.5a	8.0e	8.9b	9.0d	6.7d
FRI/Tuskegee structure 6 mo.	7.6d	6.4a	8.1e	8.9b	9.6d	7.5e

[1]values are means of 9 scores.

[2]interpretation of scores -

Hardness: 0 = very soft, 5 = firm, 10 = hard
Brittleness: 0 = crumbly, 10 = brittle
Chewiness: 0 = tender, 5 = chewy, 10 = tough
Flavor: 0 = off flavor, 10 = typical of freshly smoked fish
Aroma: 0 = moldy or rancid, 10 = characteristic fresh smokey aroma
Color: 0 = black, 10 = light brown

abcde = Means in a column with the same letter are not significantly different ($P > 0.05$).

nd = not determined

Table 4: Effect of Storage method on the mean sensory scores[1] of smoked herrings.

Storage method and duration	Taste	Aroma	Color	Texture	Overall Acceptability
Frozen Control 6 mo.	8.5a	8.7a	8.0a	8.6a	8.6a
Polyethylene 1 mo.	n.d	1.4e	2.8c	3.1c	1.0f
Polyethylene with dessicant 1 mo.	6.4d	6.9d	7.6b	8.0b	7.0d
3 mo.	n.d	2.1e	2.6c	2.6c	2.5e
Traditional storage 6 mo.	7.5c	7.3c	7.6b	8.1b	7.6c
FRI/Tuskegee modified structure 6 mo.	8.0b	8.4b	7.8b	8.3b	8.3b

[1] Based on a 9-point hedonic scale with 9 - like extremely and 1 = dislike extremely (Larmond, 1973).

abcdef = mean sensory scores in a column with the same letter are not significantly different ($P > 0.05$)

n.d = not determined.

Table 5: Changes in the proximate and mineral composition[1] of smoked herrings as affected by storage.

Type and duration of storage	Proximate Composition (%)			Mineral content (mg/100g)			
	Moisture	Protein	Fat	Ash	Calcium	Phosphorus	Iron
Freshly smoked 0 mo.	14.16a	76.14a	15.18a	7.56a	868a	1131b	9.6a
Frozen control 6 mo.	14.12a	76.50a	15.00a	7.49a	368a	1146b	9.3a
Polyethylene only 1 mo.	18.69b	71.68b	15.80b	8.36b	1174c	1202c	7.6c
Polyethylene with dessicant 3 mo.	14.33a	74.52c	15.69b	8.18b	1182c	1169b	9.0a
Traditional storage 6 mo.	12.86c	71.09b	15.00a	6.91c	921a	1175b	9.1a
FRI/Tuskegee modified structure 6 mo.	11.06d	72.87d	15.35a	6.97c	802b	1031a	9.5a

[1]values are means of triplicate determinations expressed on dry weight basis (except for moisture)

abcd = means in a column with the same letter are not significantly different ($P > 0.05$).

Table 6: Effect of storage method on the acid value, peroxide value, total volatile bases and non-protein nitrogen content of smoked herrings

Storage method and Duration	Acid value (mg KOH/g)[1]	Peroxide value (meq/Kg Oil)	Total volatile base nitrogen		Non-protein nitrogen	
			(mg/100g)[1]	(% of Total N)	(g/100g)[1]	(% of Total N)
Freshly smoked 0 mo.	2.90a	3.60a	139.2a	1.1a	1.38a	11.33a
Frozen control 0 mo.	2.91a	3.66a	157.1a	1.3a	1.53a	12.50a
Polyethylene storage without dessicant 1 mo.	14.91b	2.90b	656.0b	5.7b	3.27b	28.71b
with dessicant 3 mo.	10.43c	2.93b	399.8c	3.4c	1.90c	15.94c
Traditional storage 6 mo.	6.09d	2.34b	84.0d	0.7b	1.2a	11.08a
FRI/Tuskegee modified structure 6 mo.	4.59e	1.30c	70.3d	0.6d	1.18a	10.12d

[1]values are means of triplicate determinations expressed on dry weight basis.
abcde = means in a column with the same letter are not significantly different ($P > 0.05$).

Table 7: Effect of storage method on the microbial quality of smoked herrings (*Sardinella eba*)

Storage method and duration	Bacteria		Molds and Yeasts	
	Viable count/g (Aerobic)	Organisms isolated	Count/g	Organisms isolated
Freshly smoked 0 mo.	Range 2-15 x 10^2 Mean 11 x 10^2	Bacillus spp.	3-8 x 10^2 5 x 10^2	Yeast spp Penicillium Mucor Aspergillus spp
Frozen standard 6 mo.	Range 2-26 x 10^2 Mean 16 x 10^2	Bacillus spp.	2-4 x 10^2 3 x 10^2	Yeast spp Aspergillus spp Rhizopus
Polyethylene storage without dessicant 1 mo.	Range 1-35 x 10^9 Mean 19 x 10^9	Bacillus spp. Micrococci	5-34 x 10^5 22 x 10^5	Yeast spp Aspergillus spp Rhizopus
with dessicant 3 mo.	Range 2-21 x 10^7 Mean 12 x 10^7	Bacillus spp. Micrococci	9-50 x 10^5 38 x 10^5	Yeast spp Aspergillus spp order moniliales
Traditional storage 6 mo.	Range 4-11 x 10^2 Mean 7 x 10^2	Micrococci Coliform Saprophytic and Plant coryneform group	1-25 x 10 7 x 10	Yeast spp Penicillium Rhizopus Aspergillus spp
FRI/Tuskegee structure 6 mo.	Range 3-9 x 10^2 Mean 6 x 10^2	Micrococci Saprophytic and Plant coryneform	1-2 x 10 7 x 10	Yeast spp Rhizopus Aspergillus spp

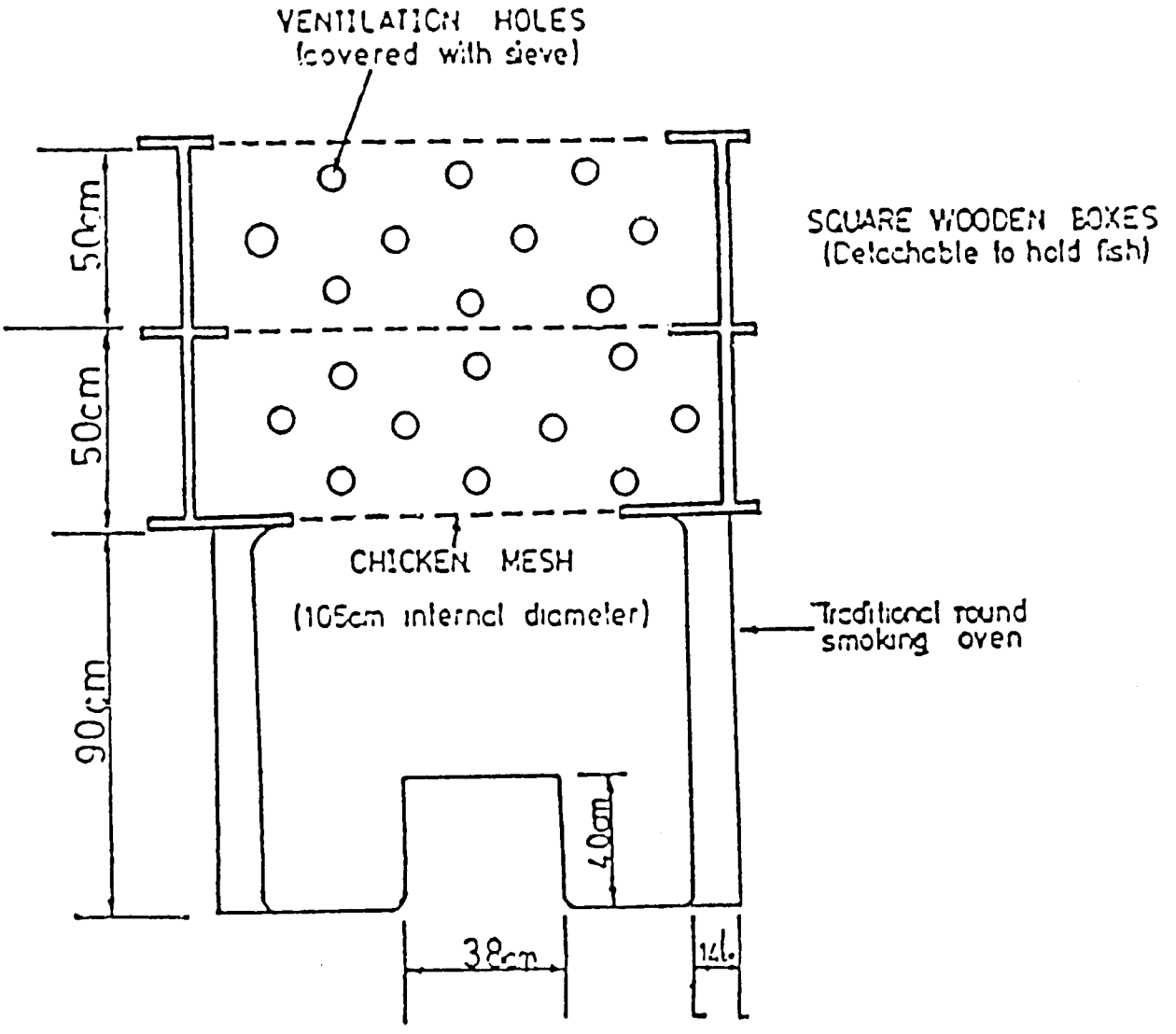

FIG. 1 F.R.I / TUSKEGEE MODIFIED STORAGE STRUCTURE FOR SMOKED FISH

XN-ABG-258-A

TITLE: Effect of storage method on the quality of smoked-dry herrings (*Sardinella eba*)

AUTHORS: Plahar, W.A., Pace, R.D., and Lu, J.Y.

AFFILIATION: Author Plahar is with the Food Research Institute, Box M20 Accra, Ghana, while authors Pace and Lu are affiliated with the Department of Home Economics at Tuskegee Universit Tuskegee, AL 36088.

RUNNING HEAD: Storage of Smoked-Dry Herrings

CONTACT AUTHOR: Dr. J. Y. Lu, Telephone (205) 727-8717

15

EFFECT OF STORAGE METHOD ON THE QUALITY OF SMOKED-DRY HERRINGS (*Sardinella eba*)

W.A. Plahar, R.D. Pace and J.Y. Lu

A B S T R A C T

Samples of freshly-smoked herrings (*Sardinella eba*) at 14% moisture content were stored for a maximum period of six months using five different storage methods: traditional oven storage, polyethylene storage, polyethylene storage with dessicant, frozen storage (-20°C) and a simple modification of the traditional storage technique. Their relative effectiveness in preserving the quality of the fish was evaluated in terms of storage losses, organoleptic changes and chemical decomposition. Next to frozen storage, the most effective method was the modified structure which gave storage yields of 97% with high sensory scores for consumer acceptability. Because of low insect and microbial infestation, proteolytic and lipolytic activities, as measured by total volatile bases, non-protein nitrogen, acid value and peroxide value, were minimal. Although the traditional structure yielded sensory and chemical properties similar to the modified storage samples, over 30% losses were recorded. Polyethylene storage methods were ineffective; and the inclusion of dessicant only extended the period for total decomposition from one month to three months. Major organisms in stored smoked herrings were *Micrococci*, *Bacillus* spp., saprophytic and plant coryneform group bacteria, *Aspergillus* spp., *Penicillium*, *Rhizopus* spp. and yeasts.

INTRODUCTION

Fish and fish products provide the most readily available source of animal protein to the majority of people in Ghana and many other West African countries. Large quantities of herrings (Sardinella spp.) are landed during the bumper season between July and October of each year, and these are preserved by one of several traditional fish processing methods to avoid excessive wastage. Smoking has been identified as the most widely used traditional processing method, covering about 70% of the total fish catch per annum (Okraku-Offei, 1970; Kagan, 1970). It dominates the artisanal fish processing and involves a high number of women all along the coast (FAO, 1987). Reusse (1968) estimated that 80% of the fish consumed in Ghana are smoked.

Because of its significant role in the preservation and consumption of fish, the traditional fish smoking technology has been studied extensively and considerable improvements made in terms of process efficiency and product quality. Improved versions of the traditional fish smoking ovens have been developed (Kagan, 1969, 1970), and successfully adopted in many fish processing communities in Ghana and neighbouring West African countries (Nerquaye-Tetteh, 1989). The advantages of the improved ovens against the traditional one include increased smoking capacity, fuel economy and a better quality product (Okraku-Offei, 1970). The successful extension and adoption of these improved smoking-ovens have further enhanced the use of smoking as a means of preserving fish for storage.

However, very little has been done to assess post-processing and general quality deterioration of smoked fish during storage.

Traditionally, dry smoked fish are stored in round smoking ovens covered with polyethylene and jute sacks. Occasional re-smoking is undertaken to maintain dryness and drive off insect pests (Okraku-Offei, 1970). Storage conditions under this traditional system are unsatisfactory due to frequent insect infestation, microbial decomposition and rodent attack (Caurie et al., 1979; Nerquaye-Tetteh, 1979). Although no statistics are available on storage losses of dry-smoked fish in Ghana, reports have indicated post-processing losses of unprotected dried fish as high as 30 - 70% in other places (James, 1976; Osuji, 1976; Kagan, 1970; Waterman, 1976). Efforts to reduce such high losses are needed if the beneficial effects of the improved processing techniques are to be derived. Any reduction in post-processing loss by simple, modification of present methods will greatly benefit fishing villages economically in Ghana and other West African countries.

The purpose of this study was to evaluate the relative effectiveness of different storage methods in preserving the quality of smoked-dry herrings (Sardinella eba) under tropical Ghanaian conditions. The methods examined include the traditional oven storage system, polyethylene storage techniques with and without dessicant, frozen storage, and the Food Research Institute (FRI)/Tuskegee structure which was designed by the authors as a simple modification of the traditional storage structure.

MATERIALS AND METHODS

Fish preparation, smoke-drying and storage

A bulk of herrings (Sardinella eba), purchased from a cold store at

the Tema fishing harbour, Tema, Ghana, was washed, surface-dried in the sun and smoke dried using the FRI-Chorkor Smokers, following the traditional procedure described by Nerquaye-Tetteh (1979). The FRI-Chorkor Smoker, an improved version of the traditional Ghanaian fish smoking oven, consists of a 65cm high rectangular combustion chamber made of burnt bricks with stoke holes leading to fire pits, and a set of framed wire mesh trays. The rectangular trays make up the smoking unit when stacked up on the oven.

In this study, ten trays, each loaded with one layer of fish, were stacked together to form the smoking unit. The unit was covered at the top with a sheet of plywood to prevent excessive smoke escape. The whole bulk of fish was smoked simultaneously at 50 - 65°C for three days. The tray positions were interchanged several times in the course of smoking to ensure a fair distribution of heat and smoke. After the third day of smoking, the smoke dried fish samples (about 14% moisture content) were left to cool in the open air and divided into six batches which were randomly allocated to the following different methods of storage.

Freshly-smoked standard: One 50kg batch of the smoked fish was used as the initial standard sample (no storage). This was immediately analysed to obtain the initial data.

Frozen-storage: A 30-kg batch was packed in a jute sack lined with polyethylene material (0.004cm gauge), tied securely at the end and stored at -20°C for six months.

Polyethylene storage: Ten three-kilogram portions of the smoked fish were packed in 0.004cm-thick polyethylene bags measuring 25 x 38cm (Polyproducts, Ghana, Ltd., Accra, Ghana). The open ends of the bags

were folded and stapled after filling. All ten bags were packed in a large cardboard box and kept in a room at about 28°C. The samples were withdrawn for analysis after one month in storage at which time physical examination indicated a high degree of deterioration.

Polyethylene storage with dessicant: This procedure was the same as described above except that 150g dessicant ("Drierite" anhydrous $CaSO_4$ obtained from W.A. Hammond Drierite Co., Xenia, Ohio) was sealed in a perforated polyethylene bag and enclosed in each bag containing 3kg fish. The dessicant was replaced twice monthly throughout the storage period.

Traditional storage: The traditional method of smoked dry fish storage in Ghana was followed (Nerquaye-Tetteh, 1979). A 30kg batch of the smoked herrings was packed in a cylindrical traditional smoking oven to form a thickness of about three layers of fish on a wire-mesh 60cm above the combustion level. It was covered with polyethylene sheets and jute sacks. A two-hour re-smoking (40-60°C) was undertaken at monthly intervals during the six months.

FRI/Tuskegee modified storage structure: Based on the problems usually encountered in the traditional storage, a modification was made by the authors aimed at reducing infestation by storage pests. The modified structure (Fig. 1) consisted of the traditional oven as the resmoking unit and one or more wooden boxes (150cm x 150cm x 50cm) as the holding unit. The bottom of each box was made of wire mesh to facilitate flow of hot smoke through the stored fish during periods of re-smoking. The boxes had open tops so that two or more loaded boxes could be re-smoked simultaneously stacked up on the oven. The top-most box was covered with plywood at all times during storage except when re-smoking. The sides of the boxes were provided with several ventilation holes (2cm diameter) and

covered with wire sieves (20 mesh) to keep out insect pests and rodents. In this study, one storage box was loaded with 30kg fish, seated on the round oven and covered with a sheet of plywood. It was left to stand under a shed with the traditional set-up for six months with the same monthly re-smoking treatment. The humidity and temperature conditions in the storage area during the six month period are shown in Table 1.

Sample preparation for analysis

At the end of the storage period the samples were evaluated for physical changes and storage losses. The bulk of several pieces in each storage group was then prepared for analysis by removing the scales, the head and the central bone. The remaining edible portion was broken into large pieces and representative samples taken for sensory analysis. The rest was milled and stored in polyethylene bags at -20°C for chemical and microbiological tests. Samples in polyethylene storage lasted for only one month without dessicant and three months with dessicant.

Determination of storage losses

For each storage condition, fish showing signs of damage which appeared unfit for consumption after the storage period were counted and expressed as a percent of the total initial number of smoked fish stored. Measurements were taken separately for rodent damage, insect/maggot damage and mold infection. The yield after storage was also calculated using the percent initial weight of smoked-dry fish that remained sound and undamaged after the storage period. To eliminate the effect of storage moisture loss, the initial weight was expressed on the basis of the final moisture content.

Sensory evaluation

The effects of storage conditions on the sensory characteristics of the smoked herrings were evaluated using a quantitative descriptive sensory analysis and consumer preference test (Stone et al., 1974; Larmond, 1977). A detailed descriptive evaluation of the texture, flavor, aroma, and color of the fish from each storage group was provided by a group of selected panelists at the FRI, Accra, Ghana. The group was screened based on ability to detect slight differences in the sensory characteristics of foods, as well as familiarity with the desired sensory properties of freshly smoked herrings. The nine panelists, 25 to 40 years of age, were given two training sessions to agree on the characteristic sensory attributes of smoked herrings and to familiarize themselves with defined characteristics to be used in the descriptive test.

For each sample presented, the panelists used an unstructured score card with sensory descriptions at each end of a 10cm long line to make marks in relationship to the description of the attribute (Johnson et al., 1988). The distances from the tail end of the line to the mark was used as the numerical score. For each attribute, the mean score was calculated from the values of the nine panelists.

A consumer preference test using a 9-point hedonic scale (Larmond, 1977) was used to determine the acceptability of the stored fish samples. Thirty workers at the FRI were also presented with the samples and their preferences in terms of color, aroma, texture, taste and overall acceptability were reported.

Chemical analyses

Samples of milled edible portions of fish from each storage group were analysed for moisture, fat, protein and ash (AOAC, 1980). Non-protein nitrogen (NPN) was determined by precipitating the protein with 5% trichloroacetic acid, centrifuging at 10,000 x G and determining the nitrogen content of aliquots of the filtrate (Lu et al., 1988). The method of Pearson (1970) was used to determine the total volatile bases (TVBN) in the samples. Acid value (AACC, 1984) and peroxide value (AOCS, 1980) were also determined in fat extracts of the smoked fish samples.

Microbial quality evaluation

Serial dilutions of 5g tissue samples, homogenized in 45ml quarter strength Ringers solution, were used in determining total microbial counts by the pour plate technique for aerobic plate count. Difco's plate count agar was used for bacteria while malt agar containing 10% sodium chloride, Czapedox agar containing 20% sucrose, and yeast extract agar were used for the fungi. Aliquots of each diluted sample were aseptically pipetted into duplicate sterile petri dishes and about 10ml of the agar medium added and mixed well before setting. The plates were incubated at 28°C for 24h for bacteria, and 4 days at room temperature for molds and yeast. The number of colonies on the plates were counted and the results expressed as number of micro-organisms per gram sample.

The identification of bacterial populations was based on their staining, morphological and cultural characteristics supplemented by biochemical tests. Molds were also identified based on their morphological and cultural characteristics (Harrigan and McCance, 1966). Yeast colonies were counted but not identified.

Statistical analysis

Statistical significance of observed differences among means was evaluated by analysis of variance followed by pairwise comparison of the means (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Storage losses

Polyethylene storage (with or without dessicant) proved highly unsatisfactory in protecting smoked dry herrings against storage pests (Table 2). Although no rodent damage was observed, insects and fungi damage were rather extensive leaving a yield of less than 4% over a period of one month. The use of dessicant extended the storage life a little beyond one month by controlling the humidity in the storage environment. However, only 10% yield could be obtained within a period of three months. Results of earlier research reported by Okoso-Amaa et al. (1978) indicated that the shelf-life of smoked Sardinella spp. varied according to the moisture content when stored in polyethylene. At 50% moisture content, smoked fish could last for only four days in sealed polyethylene while 15-20% moisture samples lasted for about forty days (which is close to the situation observed in this study). It was suggested that smoked Sardinella spp. of 10% moisture content and below could be stored in heat-sealed low density polyethylene bags for a period of nine months (Okoso-Amaa et al., 1978). Such a low moisture level could be detrimental to the sensory acceptability of the product.

A very high yield was obtained with the FRI/Tuskegee modified structure which resulted in a considerable reduction (over five-fold decrease)

in the mold and insect damages observed in the traditional storage. Compared to a 30% loss obtained with the traditional storage, only a 3% loss was measured in the modified structure. The structure adequately protected the fish against rodent and insect attack while the mold and yeast counts were relatively low under the prevailing conditions.

Effect of storage method on sensory characteristics

The sensory scores of characteristics of the stored smoked fish samples are shown in Table 3. Freezing at -20°C for 6 months slightly but significantly ($P < 0.05$) decreased the brittleness of smoked dry herrings. The samples also became more chewy. Hardness, flavor, color and aroma, however, remained the same. Both traditional storage and the FRI/Tuskegee modified storage caused a significant darkening of the samples with the traditional storage samples being darker than those of the modified structure. Samples from these two storage methods were harder, tougher and had slight decreases in the characteristic flavor and aroma of freshly smoked fish. These changes may be due to the occasional re-smoking which further dried the products with the excessive deposition of smoke causing the slight decrease in the flavor and aroma. However, as indicated by consumer preference scores (Table 4), all the characteristics were highly acceptable by consumers with preferences ranging between liking moderately to liking very much.

Polyethylene storage, on the other hand, made the samples very soft, highly crumbly and tender. The color changed from light brown to blackish and they had a moldy and rancid aroma. All the characteristics were typical of a highly deteriorated, unwholesome product.

Storage effect on proximate composition

The most significant changes in the proximate composition of smoked dry herrings stored under different conditions were in the moisture content (Table 5). There was a significant increase in the moisture content of the sample stored in polyethylene bags. Okoso-Amaa et al (1978) observed significant moisture uptake through low density polyethylene material used in the storage of smoked fish. The prevailing high humidity and temperature (Table 1), coupled with the high permeability of the material to moisture, enhanced the rate of microbial decomposition. The presence of a dessicant checked the excess moisture uptake by the fish and maintained the original moisture level of about 14%. The drastic decreases in the moisture content of samples stored in traditional and modified structures are obviously due to the re-smoking of these samples during storage. Better aeration of the FRI/Tuskegee modified structure was responsible for the lower moisture content as compared to that of the traditionally stored samples.

Total nitrogen decreased during storage in all the different storage methods used (except frozen storage). This could be due to protein decomposition by microbial enzymic action resulting in volatile components which were lost during re-smoking, or to direct physical loss of more proteinaceous parts of the fish (as in the case of insect or rodent attack). No changes were observed in the fat content of smoked fish samples stored frozen for six months or in traditional and FRI/Tuskegee modified structures (Table 5). Significant increases ($P < 0.05$) were however observed in the fat and ash content of samples stored in polyethylene bags. Calcium, phosphorous and iron contents were noticeably very high in smoked herring.

Protein decomposition and fat breakdown in stored fish samples

Results showing the effect of storage methods on the acid and peroxide values, TVBN and NPN content of smoked herrings are shown in Table 6. Smoked fish stored in polyethylene had a five-fold increase in the acid value within a period of one month. With dessicant, however, the rate of fat breakdown was slightly reduced. The high microbial infection observed in these samples during storage could be responsible for this excessive lipolytic reaction. Far lower acid values than obtained by this storage method were required to effect noticeable rancidity to the palate (Pearson, 1970). The least effects of storage on fat breakdown were recorded in the traditional and the FRI/Tuskegee modified storage structures. The acid value of samples in the traditional structure doubled over the six-month storage period while the modified structure showed just a 50% increase in the original value. A similar rate of increase in acid value of traditionally stored smoked herrings was reported by Lu et al (1988). No significant change in the acid value of smoked fish occurred during frozen storage for six months.

The acid values obtained for the samples in this study corresponded with the observed degree of deterioration that occurred under the different storage conditions. Contrary to this, the peroxide values did not give much information on the relative rates of fat oxidation by the different storage methods. Physical and sensory analyses showed an advanced stage of fat decomposition and rancidity development in fish samples stored in polyethylene bags. Oils extracted from these samples were dark brown in color and solidified on cooling to 26°C, while the other samples gave oils that remained liquid at room temperature and were lighter in color. As noted by Dugan (1976), measurement of peroxide

value is useful to the stage at which extensive decomposition of hydroperoxides begins. The low peroxide values obtained here indicated that peroxide peroxide decomposition was more rapid than their formation formed. This could be the only reason why obviously rancid samples gave peroxide values several times less than 20 meq/kg at which level rancid taste generally becomes noticeable (Pearson, 1970).

Although the content of total volatile bases (TVBN) has been found unsatisfactory as an indicator of spoilage especially in herrings (Farber, 1965), the results of this study gave a clear indication of the relative suitability of the storage methods used in terms of rate of smoked fish protein decomposition. TVBN values obtained in this study ranged between 70.3mg N/100g for the modified storage structure to as much as 656mg N/100g for highly deteriorated samples from the polyethylene storage. Farber (1965) reported a suggested upper limit of 60mg N/100g (corresponding to 200mg N/100g sample on a dry weight basis). The TVBN values for the freshly smoked samples as well as samples kept in frozen storage, traditional storage and FRI/Tuskegee modified storage were therefore within acceptable limits. This is confirmed by the high sensory scores obtained for these samples (Tables 3 and 4). The drastic reduction in the TVBN values of samples stored in traditional and modified structures was probably due to losses through evaporation as a result of the occasional hot smoke treatment given during storage. A similar decrease was observed by Lu et al (1988) for traditionally stored smoked herrings. On the other hand, the slight increase during frozen storage of samples could be the result of dimethylamine formation which is known to occur during frozen storage of fish (Howgate, 1982). A similar trend of changes as observed in the TVBN

values also occurred in the NPN content of the fish samples during storage.

Effect on microbial quality

The highest microbial counts were observed in samples stored in polyethylene (Table 7). Storage at -20°C for six months did not change the bacteria and fungi counts significantly ($P < 0.05$). Slight but significant decreases were, however, observed in the yeast and mold population of samples stored for six months in the traditional and the FRI/Tuskegee modified structures. The occasional smoking of these samples during storage was responsible for the lack of excessive microbial development and the decrease in the fungi population. The beneficial anti-microbial effects of woodsmoke are well known.

Bacillus spp. were the most predominant bacteria in the freshly smoked sample and the frozen control. Okafor and Nzeako (1985) isolated *Micrococcus*, *Lactobacillus* and *Acinetobacter* from fish caught in Nigerian fresh waters that was smoked at about 40°C, but only *Micrococcus* was isolated in samples smoked at about 70°C. During storage in polyethylene, *Micrococci* developed in addition to the *Bacillus* spp. The smoke treatment of samples in the traditional and FRI/Tuskegee modified structures resulted in the elimination of the *Bacillus* spp. over the six-month storage period. These were replaced by *Micrococci* and saprophytic and plant coryneform group bacteria. Yeasts were found in all samples and were not affected by any of the storage conditions. With the molds, *Aspergillus* spp. ersisted in all the samples under the different storage conditions throughout the period of storage. The main kinds of *Aspergillus* spp. identified were *Aspergillus niger*, *Aspergillus versicolor*, and

Aspergillus wentii. *Penicillium* initially present in the freshly smoked sample was found only in the traditionally stored samples while *mucor* was not detected in any of the stored samples. *Rhizopus* was another mold that developed in storage. In a preliminary survey of the microbial quality of dry fish in Ghana, Lu et al (1988) also found *Aspergillus* and *Penicillium* in traditionally stored smoked fish samples.

CONCLUSION

This study demonstrated the effectiveness of the FRI/Tuskegee modified fish storage structure in providing adequate protection to dry-smoked herrings against insect infestation, rodent attack and mold damage. Only about 3% storage losses were recorded over a six-month period showing a marked improvement over the 30% losses associated with traditional storage. Protein decomposition and fat breakdown were also minimal thus resulting in high sensory scores for acceptability. Polyethylene storage of smoked herrings was highly unsatisfactory, causing complete deterioration of the fish within one month in storage. The high humidity retention in the packages and the prevailing hot environment favored insect and microbial proliferation resulting in high degree of lipolytic and proteolytic reactions. Addition of dessicants could only prolong the shelflife briefly. Although a 100% yield of smoked herring was achieved with frozen storage over a six month period, this method is energy intensive and, from an economical point of view, it appears unlikely for the majority of small scale processors in villages to be able to build and maintain large freezers. Only a 3% difference in yield was observed between the freezer storage and the FRI/Tuskegee modified storage. The latter method appears feasible and adaptable to the prevailing economic conditions in Ghana and also in other West African nations.

REFERENCES

AACC. 1984. "Approved Methods" 8th ed. revised. American Association of Cereal Chemists, St. Paul MN.

AOAC. 1980. "Official Methods of Analysis", 13th ed. Association of Official Analytical Chemists. Washington, DC.

AOCS. 1980. "Official and Tentative Methods of the American Oil Chemists Society, 2nd ed. Amer. Oil Chemists Soc., Chicago.

Cauri, M. Okoso-Amaa, K. Chichester, C.O. and Lee, T.C. 1979. Artisan Fishery Technology: Ghana - A case study of West African Fishery. Univ. of Rhode Island, Kingston.

Dugan, L. Jr. 1976. Lipids. In "Principles of Food Science. Food Chemistry" Fennema, O.R. (ed.) Marcel Dekker, Inc., New York and Basel.

FAO. 1987. Measures for improving the utilization and marketing of fish in West Africa. ECA/FAO Report No. JEFAD/AMS/87/43, Food and Agricultural Organization of the U.N. Rome, Italy.

Farber, L. 1965. Freshness Tests. In "Fish as Food" Vol. IV. Borgstrom, G. (ed.) Academic Press, New York and London.

Harrigan, W. F. and McCance, M. E. 1966. Laboratory Methods in Microbiology. Academic Press, New York and London.

Howgate, P. F. 1982. Quality Assessment and Quality Control. In "Fish handling and processing" 2nd edition, Aitken, A. (ed.) Min. Agric., Fisheries and Food, Torry Research Station, Edinburgh.

James, D. G. 1976. Fish Processing and Marketing in the Tropics - Restrictions and Development. T.P.I. Conference Proceedings on Handling, Processing and Marketing of Tropical fish p. 299.

Johnson, J. M., Flick, G. J., Long, K. A. and Phillips, J. A. 1988. Menhaden (Brevoortia Tyrannus): Thermally processed for a potential food resource. J. Food Sci. 53:323.

Kagan, B. 1969. The Advantage of Using Framed Wire Nets in Fish Smoking. FAO Publications, Food and Agriculture Organization of the United Nations, Rome, Italy.

Kagan, B. 1970. Fish Processing in Ghana: Possibilities of improving traditional processing. FAO Publication AGS, SG/GHA 7. Food and Agriculture Organization of the United Nations, Rome, Italy.

Larmond, E. 1977. Methods of Sensory Testing. In "Laboratory Methods for Sensory Evaluation of Food." Canada. Dept. of Agric. Publication 1637. Ottawa, Canada.

Lu, J. Y., Pace, R. D. and Plahar, W. A. 1988. Survey of the microbial quality of dry fish, cassava and okra in Ghana. J. Food Protection. 51:660.

Lu, J. Y., Pace, R. D., King, W. M. and Plahar, W. A. 1988. Nutritive composition of smoked dry herrings in Chana. Nut. Rep. Int. 38:299.

Nerquaye-Tetteh, G. A. 1979. The traditional post-harvest fish processing technology in Ghana. F.R.I. Project Report. Food Research Institute, Accra, Ghana.

Nerquaye-Tetteh, G. A. 1989. Extension of research results to end users: Success stories and failures - the case of the FAO/FRI Chorkor smoker. F.R.I. Report. Food Research Institute, Accra, Ghana.

Okafor, N. and Nzeako, B. C. 1985. Microbial flora of fresh and smoked fish from Nigerian fresh water. In "Food Microbiology" Kirsop, B. H. (ed.). Academic Press, London.

Okoso-Amaa, K., Eyeson, K. K., Bonsu, L., and Nerquaye-Tetteh, G. A. 1978. Final report on the activities of the processing subcommittee. GH/IDRC Fishery Research and Development Project. Food Research Institute, Accra, Ghana.

Okraku-Offei, G. 1970. Processing and preservation of fish in Ghana. F.R.I. Project Report. Food Research Institute, Accra, Ghana.

Osuji, F. N. C. 1976. The influence of traditional handling methods on the quality of processed fish in Nigeria. T.P.I. Conference Proceedings on Handling, Processing and Marketing of Tropcal Fish p. 319.

Pearson, D. 1970. The Chemical Analysis of Foods. Sixth edition. J & A. Churchill, 104 Gloucester Place, London.

Reusse, E. 1968. Ghana Food Industries. Paper by UNDP Special Fund Project in Ghana. EA/SC/GHA/68. UNDP. Accra, Ghana.

Steel, R. G. D. and Torrie, J. H. 1980. Multiple Comparsion. In "Principles and Procedures of Statistics." 2nd ed. McGraw-Hill Book Co., N.Y., p. 72.

Stone, H. Sidel, J. L., Oliver, S., Woolsey, A. and Singleton, R. C. 1974. Sensory evaluation by quantitative descriptive analysis. Food Technol. 28:24.

Waterman, J. J. 1976. The production of dried fish. FAO Report. Food and Agriculture Organization of the United Nations. Rome.

ACKNOWLEDGEMENTS

This study was undertaken with funds provided by USAID, Washington (DAN-5053-G-SS-8021-00). The authors acknowledge the assistance given by Lucy Opare-Sem, Nana T. Annan and Gladys Nerquaye-Tetteh of the Food Research Institute, Ghana.

Table 1: Average temperature and relative humidity conditions in storage area over the six-month period

Month	Temperature (°C)			Relative Humidity (%)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
April	24.5	30.0	28.7	70.0	96.0	78.8
May	24.5	29.5	27.8	74.0	100.0	81.6
June	24.5	28.5	26.7	75.0	100.0	85.0
July	24.0	27.5	25.8	76.0	96.0	84.3
August	23.5	27.7	25.6	75.5	100.0	83.5
September	24.0	29.0	26.5	74.0	98.0	83.0

Source: Calculated from the daily temperature and humidity recordings by the Ghana Meteorological Services Department (Accra, Ghana).

Table 2. Storage losses of smoked dry herrings (*Sardinella eba*) through insect infestation, rodent attack and microbial damage.

Storage Method and Duration (months)	Rodent Damage (%)	Insect/ Maggot Damage (%)	Mold Damage (%)	Storage Yield (%)
Frozen control 6 mo.	0.0	0.0	0.0	100.0
Polyethylene storage without dessicant 1 mo.	0. 0	92.2	80.2	3.8
with dessicant 1 mo.	0.0	3.3	10.0	86.7
3 mo.	0.0	60.0	88.0	10.0
Traditional structure 6 mo.	5.1	16.1	14.9	71.9
FRI/Tuskegee Modified structure 6 mo.	0.0	2.1	3.1	96.9

Table 3: Quantitative descriptive sensory analysis of smoked dry herrings (*Sardinella eba*) stored under different conditions

Storage method and duration	Score for sensory characteristics[1,2]					
	Hardness	Brittleness	Chewiness	Flavor	Aroma	Color
Freshly smoked 0 mo.	5.6a	6.6a	5.7a	9.8a	10.0a	9.8a
Frozen control 6 mo.	5.4a	5.2a	5.0b	9.4a	10.0a	9.6a
Polyethylene storage without dessicant 1 mo.	0.6b	0.5c	0.3c	nd	1.6b	1.4b
with dessicant 3 mo.	1.7c	2.1b	1.5d	nd	1.0c	2.5c
Traditional storage 6 mo.	7.6d	6.5a	8.0e	8.9b	9.0d	6.7d
FRI/Tuskegee structure 6 mo.	7.6d	6.4a	8.1e	8.9b	9.6d	7.5e

[1]values are means of 9 scores.

[2]interpretation of scores -

Hardness: 0 = very soft, 5 = firm, 10 = hard
Brittleness: 0 = crumbly, 10 = brittle
Chewiness: 0 = tender, 5 = chewy, 10 = tough
Flavor: 0 = off flavor, 10 = typical of freshly smoked fish
Aroma: 0 = moldy or rancid, 10 = characteristic fresh smokey aroma
Color: 0 = black, 10 = light brown

abcde = Means in a column with the same letter are not significantly different ($P > 0.05$).

nd = not determined

Table 4: Effect of Storage method on the mean sensory scores[1] of smoked herrings.

Storage method and duration	Taste	Aroma	Color	Texture	Overall Acceptability
Frozen Control 6 mo.	8.5a	8.7a	8.0a	8.6a	8.6a
Polyethylene 1 mo.	n.d	1.4e	2.8c	3.1c	1.0f
Polyethylene with dessicant 1 mo.	6.4d	6.9d	7.6b	8.0b	7.0d
3 mo.	n.d	2.1e	2.6c	2.6c	2.5e
Traditional storage 6 mo.	7.5c	7.3c	7.6b	8.1b	7.6c
FRI/Tuskegee modified structure 6 mo.	8.0b	8.4b	7.8b	8.3b	8.3b

[1] Based on a 9-point hedonic scale with 9 - like extremely and 1 = dislike extremely (Larmond, 1973).

abcdef = mean sensory scores in a column with the same letter are not significantly different ($P > 0.05$)

n.d = not determined.

Table 5: Changes in the proximate and mineral composition[1] of smoked herrings as affected by storage.

Type and duration of storage	Proximate Composition (%)			Mineral content (mg/100g)			
	Moisture	Protein	Fat	Ash	Calcium	Phosphorus	Iron
Freshly smoked 0 mo.	14.16a	76.14a	15.18a	7.56a	868a	1131b	9.6a
Frozen control 6 mo.	14.12a	76.50a	15.00a	7.49a	868a	1146b	9.3a
Polyethylene only 1 mo.	18.69b	71.68b	15.80b	8.36b	1174c	1202c	7.6c
Polyethylene with dessicant 3 mo.	14.33a	74.52c	15.69b	8.18b	1182c	1169b	9.0a
Traditional storage 6 mo.	12.86c	71.09b	15.00a	6.91c	921a	1175b	9.1a
FRI/Tuskegee modified structure 6 mo.	11.06d	72.87d	15.35a	6.97c	802b	1031a	9.5a

[1]values are means of triplicate determinations expressed on dry weight basis (except for moisture)

abcd = means in a column with the same letter are not significantly different ($P > 0.05$).

Table 6: Effect of storage method on the acid value, peroxide value, total volatile bases and non-protein nitrogen content of smoked herrings

Storage method and Duration	Acid value (mg KOH/g)[1]	Peroxide value (meq/Kg Oil)	Total volatile base nitrogen		Non-protein nitrogen	
			(mg/100g)[1]	(% of Total N)	(g/100g)[1]	(% of Total N)
Freshly smoked 0 mo.	2.90a	3.60a	139.2a	1.1a	1.38a	11.33a
Frozen control 0 mo.	2.91a	3.66a	157.1a	1.3a	1.53a	12.50a
Polyethylene storage without dessicant 1 mo.	14.91b	2.90b	656.0b	5.7b	3.27b	28.71b
with dessicant 3 mo.	10.43c	2.93b	399.8c	3.4c	1.90c	15.94c
Traditional storage 6 mo.	6.09d	2.34b	84.0d	0.7b	1.2a	11.08a
FRI/Tuskegee modified structure 6 mo.	4.59e	1.30c	70.3d	0.6d	1.18a	10.12d

[1] values are means of triplicate determinations expressed on dry weight basis.
abcde = means in a column with the same letter are not significantly different ($P > 0.05$).

Table 7: Effect of storage method on the microbial quality of smoked herrings (*Sardinella eba*)

Storage method and duration	Bacteria		Molds and Yeasts	
	Viable count/g (Aerobic)	Organisms isolated	Count/g	Organisms isolated
Freshly smoked 0 mo.	Range 2-15 x 10^2 Mean 11 x 10^2	Bacillus spp.	3-8 x 10^2 5 x 10^2	Yeast spp Penicillium Mucor Aspergillus spp
Frozen standard 6 mo.	Range 2-26 x 10^2 Mean 16 x 10^2	Bacillus spp.	2-4 x 10^2 3 x 10^2	Yeast spp Aspergillus spp Rhizopus
Polyethylene storage without dessicant 1 mo.	Range 1-35 x 10^9 Mean 19 x 10^9	Bacillus spp. Micrococci	5-34 x 10^5 22 x 10^5	Yeast spp Aspergillus spp Rhizopus
with dessicant 3 mo.	Range 2-21 x 10^7 Mean 12 x 10^7	Bacillus spp. Micrococci	9-50 x 10^5 38 x 10^5	Yeast spp Aspergillus spp order moniliales
Traditional storage 6 mo.	Range 4-11 x 10^2 Mean 7 x 10^2	Micrococci Coliform Saprophytic and Plant coryneform group	1-25 x 10 7 x 10	Yeast spp Penicillium Rhizopus Aspergillus spp
FRI/Tuskegee structure 6 mo.	Range 3-9 x 10^2 Mean 6 x 10^2	Micrococci Saprophytic and Plant coryneform	1-2 x 10 7 x 10	Yeast spp Rhizopus Aspergillus spp

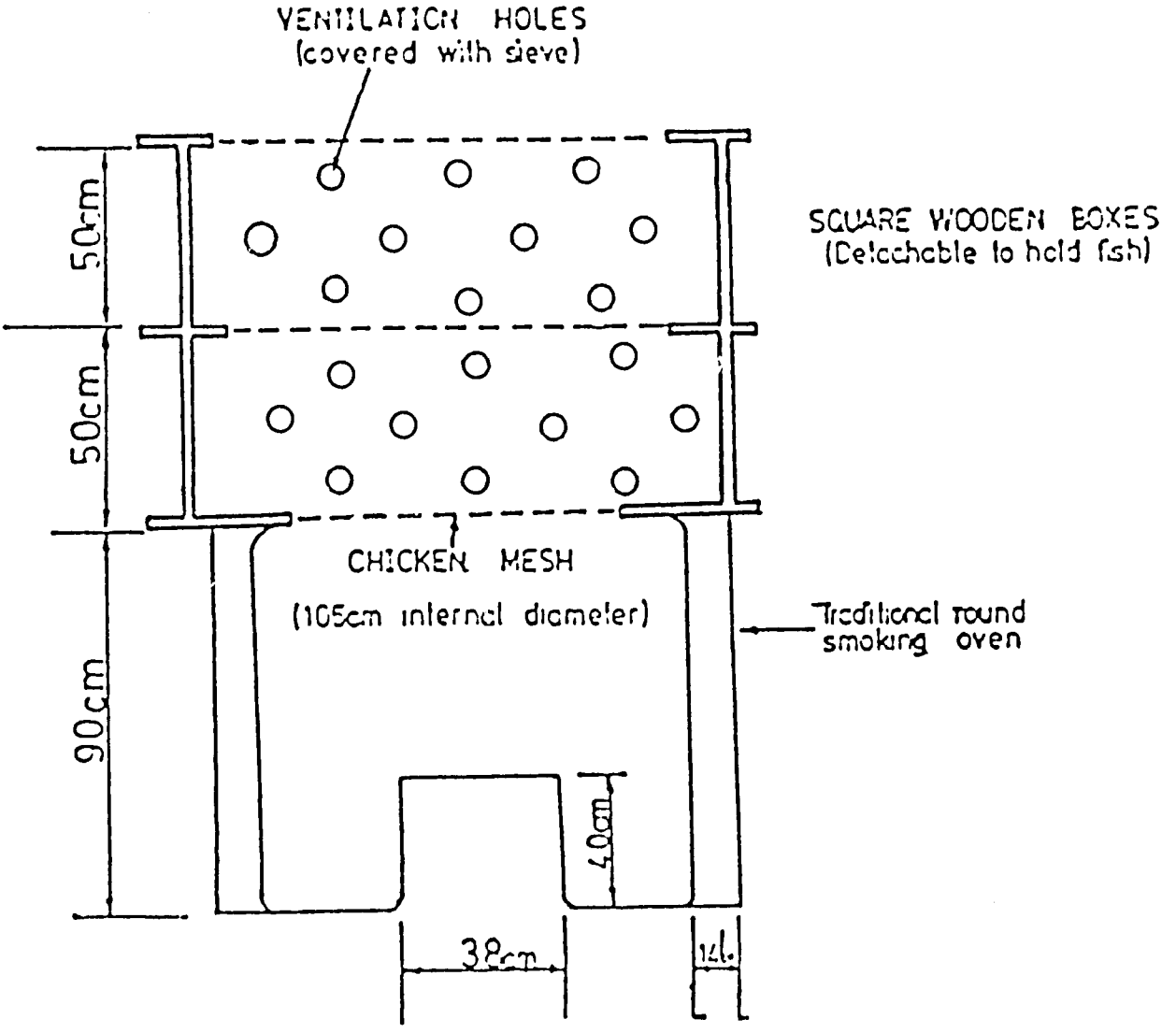

FIG. 1 F.R.I / TUSKEGEE MODIFIED STORAGE STRUCTURE FOR SMOKED FISH