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GHANA/NETHERLANDS ARTISANAL FISH PROCESSING PROJECT

RESEARCH PROJECT #9

STUDIES ON THE TRADITIONAL STORAGE OF SMOKED ANCHOVIES IN GHANA

FINAL REPORT (STAGE THREE)

COMPARATIVE EVALUATION OF THREE TRADITIONAL SMOKED ANCHOVY STORAGE STRUCTURES AT AKPLABANYA

By

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TABLE OF CONTENT

ITEM		PAGE
i.	**ACKNOWLEDGEMENT**	i
ii.	**ABSTRACT**...	vi
1.	**INTRODUCTION**...	1
2.	**MATERIALS AND METHODS**..	6
2.1.	Preparation of anchovies for storage	6
2.2.	Construction of the Traditional anchovy storage structures	6
2.3.	Monitoring environmental conditions...	19
2.4.	Sampling and sample preparation...	22
2.5.	Evaluation of physical characteristics of smoked anchovies...	23
2.6.	Sensory evaluation of fish samples	23
2.7.	Chemical Analysis of smoked anchovies.	24
2.8.	Microbiological quality evaluation	24
2.8.1.	Total viable counts (Pour plate technique)...	24
2.8.2.	Mould and Yeast counts	25
2.8.3.	Enumeration of enterobacteriaceae.	25
2.8.4.	Pathogenic organisms	26
2.8.5.	Culture identification...	26
2.9.	Hydrogen ion concentration	26
2.10.	Statistical analysis of results...	27
3.	**RESULTS AND DISCUSSION**	28
3.1.	Structural protection of smoked anchovies during traditional storage	28
3.2.	Temperature and humidity changes in structures.	28

ITEM	PAGE
3.3. Physical and sensory characteristics of smoked anchovies...	36
3.4. Changes in the proximate composition and chemical properties of smoked anchovies during storage... ..	39
3.5. Microbiological quality of smoked anchovies in traditional storage	46
3.6. Mycotoxicological quality of stored anchovies..	53
4. CONCLUSIONS	55
5. REFERENCES	56

LIST OF TABLES

		PAGE
Table 1.	Temperature and humidity changes in storage	29
Table 2.	Changes in the physical characteristics of smoked anchovies (*Anchoa guineensis*) during storage...	37
Table 3.	Quantitative descriptive analysis of traditionally stored anchovies (*Anchoa guineensis*)	40
Table 4.	Effect of traditional storage on the proximate composition and mineral content of smoked anchovies (*Anchoa guineensis*)...	41
Table 5.	Effect of traditional storage on the proximate composition and mineral content of smoked anchovies (*Anchoa guineensis*)...	42
Table 6.	Effect of traditional storage of the fat acidity, total volatile base nitrogen (TVBN) and non-protein nitrogen (NPN) content of smoked anchovies..	44
Table 7.	Effect of traditional storage on the microbiological quality of whole smoked anchovies sampled from the interior of storage structure	47
Table 8.	Effect of traditional storage on the microbiological quality of the edible portion of smoked anchovies sampled from the interior of storage structure	50
Table 9.	Effect of traditional storage on the microbiological quality of whole smoked anchovies sampled from the periphery of storage structure	51

LIST OF ILLUSTRATIONS

PAGE

Figure 1. Trays of anchovies being prepared for smoking. 7

Figure 2. Smoking of anchovies in progress.. 8

Figure 3. The traditional round mud oven 11

Figure 4. Hardcore base support platform for round oven structure 13

Figure 5. Traditional round oven structure filled to capacity 15

Figure 6. Smoked anchovies in traditional round oven storage 16

Figure 7. The sea-sand platform... 18

Figure 8. Fenced yard traditional fish storage... ... 20

Figure 9 Heaps of smoked anchovies in fenced yard storage... 21

COMPARATIVE EVALUATION OF THREE TRADITIONAL SMOKED ANCHOVY STORAGE STRUCTURES AT AKPLABANYA

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ABSTRACT

Three different techniques used for the traditional storage of smoked anchovies (*Anchoa guineensis*) by artisanal fish processors at Akplabanya (a coastal fishing village near Ada, in the Greater Accra Region of Ghana) were studied, and the major structural features, material requirements and methods of construction were determined. The storage techniques include: (a) The round oven storage structure, (b) The sea-sand platform storage structure, and (c) The fenced yard structure. A comparative assessment of their relative efficacy in the preservation of smoked fish quality during storage was undertaken over a three-month period. Freshly smoked anchovies (*Anchoa guineensis*) were stored the traditional way and samples taken at 0 and 3-month intervals to determine the physical, chemical, microbial and sensory characteristics. Changes in the environmental conditions in the storage structures were monitored with a Telog Temperature/Humidity Recorder. In general, all the structures are built with mainly locally available materials; and the choice of any of the three depends on factors such as capital input available and the volume of smoked fish to be stored. The most effective technique in terms of structural protection against environmental hazards and storage pest was the mud oven structure, followed by the sea-sand platform method. The fenced yard did not protect the stored product against insects, rodents and domesticated pests. The polyethylene cover could only protect the samples against rain damage. A fairly constant average temperature of 30 - 33°C was maintained most of the time in the round oven structure, while the sea-sand platform structure recorded a range of 28 - 38°C. A steady drop in relative humidity from about 60% to 42% was also observed in the two structures. Although the fenced yard structure also maintained average temperatures between 28 and 38°C, it however, recorded very drastic humidity increases from 42% to as high as 71%. The moisture content of samples did not change with storage time. The freshly smoked sensory quality attributes and physical characteristics of the smoked anchovies were adequately preserved by the traditional round oven and sea-sand platform storage structures. Storage yield in terms of overall physical damage was 91.5%. Proteolytic, lipolytic and microbial deterioration was minimal. The fenced yard storage method however, caused a significant decrease in the aroma and

flavour of the samples. In general, the microbial loads for the smoked fish were low, especially in the samples stored by the round oven and sea-sand platform techniques. The relatively poor structural protection offered by the fenced yard structure facilitated the invasion of insects, rodents and domesticated pests which caused significant increases in the numbers and types of contaminating microorganisms. Maximum aeration existing in the structure also enhanced the growth of more aerobic organisms. The detection of indicator organisms such as coliforms and especially faecal coli in the samples stored by the fenced yard method makes these samples unwholesome for consumption. Microorganisms isolated were *Rhizopus*, *Aspergillus* spp., Micrococci, and *Bacillus* sp.

INTRODUCTION

In Ghana and neighbouring West African countries, anchovies (*Anchoa guineensis*) are used for direct human consumption in the preparation of adult and weaning foods, and also as a main source of protein in the animal feed industry. Among the various traditional processing methods employed in Ghana to preserve fish, smoking and sun drying are the most widely used techniques for anchovies. The development of improved versions of the traditional fish smoking ovens, and the successful extension and adoption of the improved smoking techniques in many fish processing communities have further enhanced the popularity of smoking as a major fish preservation method in Ghana (Kagan, 1969; 1970; Nerquaye-Tetteh, 1989).

The advantages of the improved ovens in terms of increasing smoking capacity , fuel economy and a better quality product have been adequately demonstrated in training programmes under the Regional Training and Applied Research Project on Artisanal Fish Processing in West Africa (under the Ghana/Netherlands collaborative fish project). In fact, it was during one of such training programmes at Tema Manhean that the socio-economic significance of smoked anchovy production and the need for research into its storage problems were identified.

Large scale smoking and marketing of anchovies are undertaken in Ghanaian coastal fishing villages like Tema Manhean and Akplabanya in the Greater Accra Region of the country. The bulk of the smoked fish has to be stored for

several months for distribution during the off-season.

Apart from recent studies under the Ghana/Netherlands Artisanal Fish Processing and Applied Research Project no other studies have been undertaken on the traditional storage of smoked anchovies in particular. The situation can be explained mainly on account of the fact that large scale processing and storage of anchovies is a recent development in response to increased production and utilization for human consumption and animal feed.

Methods and general conditions of traditional fish storage in West Africa are known to be 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 anchovies in Ghana, reports have indicated post-processing losses of unprotected dried fish as high as 20 - 70 %, (Kagan, 1970; James, 1976; Osuji, 1976; Waterman, 1976; Plahar, *et al.*, 1991). Recent studies were conducted on the storage characteristics and microbial changes in smoked dry herrings in Ghana. From one of such studies, Lu *et al* (1988) reported decreases in total nitrogen, fat, thiamine and niacin content during storage but observed no changes in the amino acid and fatty acid patterns. There was, however, an increase in the acid value of the fish with storage time. Plahar *et al.* (1991) determined the relative effectiveness of several storage methods in preserving the quality of smoked dry herrings. A modification

of the traditional storage technique was found to give 97% storage yield over a 6 month period, while 30% losses were encountered in the traditional storage set-up. The salient features of the modified structure were to prevent insect infestation while providing an improved ventilation. 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 (Plahar *et al.*, 1991). Major microorganisms in stored smoked herrings were *Micrococci*, *Bacillus* spp. *Aspergillus* spp., *Penicillium*, *Rhizopus*, spp. and yeasts (Lu, *et al.* 1988; Plahar *et al.*, 1991).

The need to protect smoked anchovies from excessive microbial infection can also be considered in the light of increased awareness of the hazards of mycotoxins in stored foods. Mycotoxins can be produced by certain strains of a number of species of fungi when grown under favourable conditions on a wide variety of different substrates. The most important and toxic mycotoxins are the aflatoxin which are products of the mould *Aspergillus flavus* and *Aspergillus parasiticus*. Aflatoxin have been detected in several commodities including smoked, dried and salted fish from South East Asia. In a survey in the Philippines, 93% of 15 samples of smoked fish were found to contain aflatoxin. A similar survey also showed 83% of 24 samples of dried fish to be positive for aflatoxin (FAO, 1979). With the fast growing smoked anchovy industry in Ghana and its

socio-economic and nutritional significance, there is the urgent need to study the traditional storage techniques for possible improvements.

An approved research project under the Ghana/Netherlands Artisanal Fish Processing Project seeks to study the traditional storage of anchovies in Ghana in order to assess its effectiveness in preserving the quality of the smoked fish over a period of time. A knowledge of the status of the smoked anchovy after storage, as well as identification of the conditions that support the changes in quality is important to prevent excessive storage losses, organoleptic deterioration, nutritional losses and possible mycotoxicological health hazards.

The first stage of the project dealt with the traditional storage of smoked anchovies at Tema Manhean, a coastal fishing village near Accra. Reports were submitted on the structural characteristics of the traditional storage as well as the physical, chemical, microbiological and mycotoxicological changes during short-term and long-term traditional storage of smoked anchovies at Tema Manhean (Nerquaye-Tetteh and Plahar, 1992; Plahar, 1992; Hodari-Okae and Kpodo, 1992; Plahar, *et al.* 1992a; Plahar, *et al.* 1992b.).

A second stage of the project was also aimed at studying the traditional storage of smoked anchovies at "Akplabanya", another major fish processing village. "Akplabanya" is located near Ada, in the Greater Accra Region of Ghana. Reports

submitted on this stage of the project provided a detailed description of the structural characteristics of traditional storage techniques used by the artisanal fish processors (Nerquaye-Tetteh and Plahar, 1992b) as well as the quality changes during storage in one proto-type traditional structure studied (Plahar *et al*).

In general, three structurally different storage techniques are used for smoked anchovies at Akplabanya (Nerquaye-Tetteh and Plahar, 1992b). The purpose of the present study was to undertake a comparative evaluation of the three structures in terms of the quality preservation of the stored products.

2. MATERIALS AND METHODS

2.1. Preparation of Anchovies for storage

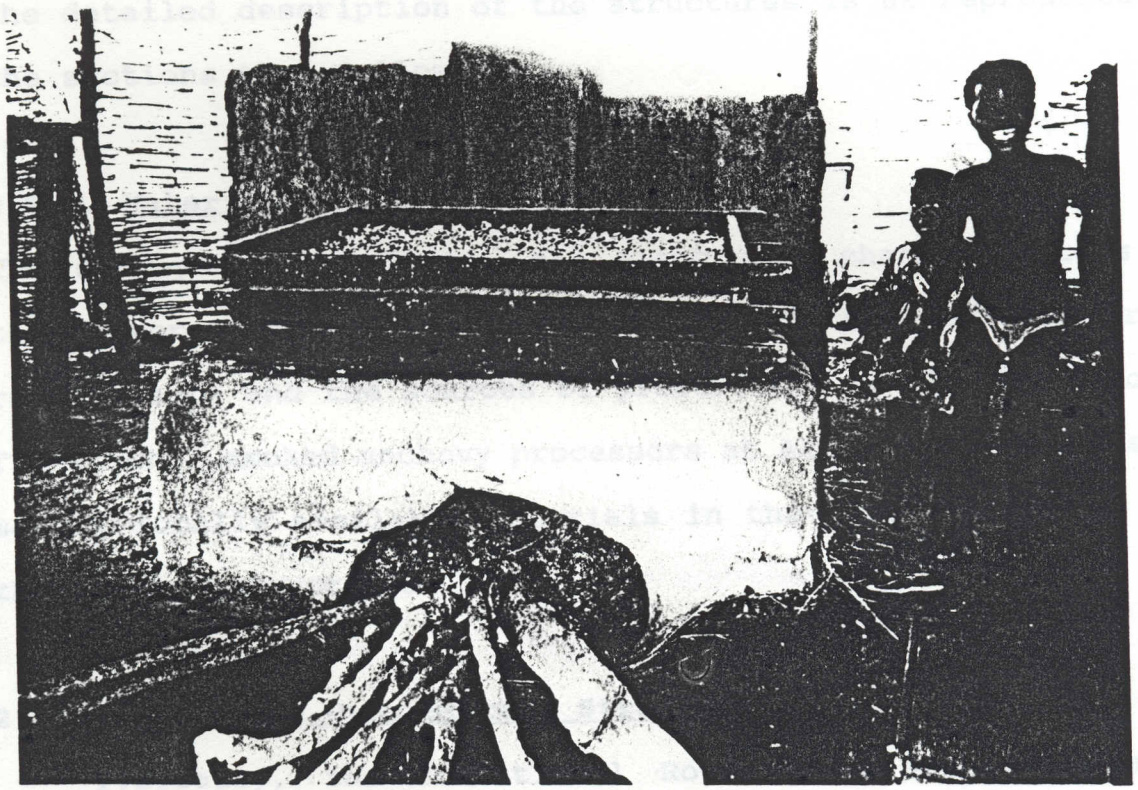
Freshly landed anchovies were purchased and prepared for smoking by washing and surface-drying. Surface-drying was carried out by spreading the fish on the smoking trays (Fig 1). The trays were left in the sun for several hours after which they were arranged on the smoking oven for the smoke-drying process (Fig 2). Earlier reports by the Fish Research team at the Food Research Institute provided detailed description and evaluation of the smoking process by the "Chorkor Smoking Oven" technique (Nerquaye-Tetteh, 1979). When ready for storage, the smoked anchovies were conveyed in large baskets to the storage site by children who received some token remuneration for their services. No matter the temptation, chewing of the product, and eating in general was prohibited while the fish was being conveyed or packed for storage. Eating while conveying or packing the smoked fish for storage is believed to cause early infestation and spoilage.

2.2. Construction of the Traditional Anchovy Storage Structures

In a previous study a survey was undertaken among the anchovy processing community at Akplabanya to study the structural features and peculiarities of the different traditional smoked anchovy storage structures used (Nerquaye-Tetteh and Plahar, 1992b). The raw material requirements, source of procurement and the method of construction of the storage

Fig. 1. Trays of anchovies being prepared for smoking

Fig. 2. Smoking of anchovies in progress



structures were determined. The structural characteristics established in the study were used to construct three proto-type structures in the village to determine their relative effectiveness in preserving the quality of smoked anchovies. Several crates of anchovies were smoked the traditional way and stored. The structures studied include:

a. the round oven type
b. the sea sand platform type
and c. the fenced yard structure

The detailed description of the structures is as reproduced in the sections that follow.

2.2.1. Material Requirement:

The survey conducted into the structural characteristics of these storage methods was able to identify the major material requirements and the sources of procurement by the processors. Traditional smoked anchovy processors at Akplabanya make use of mainly locally available materials in the construction of all the storage structures.

2.2.2. The Round Oven Storage Structure

Typically, the traditional Round Oven anchovy storage structure consists of the following identifiable parts or sections:

a. A round (cylindrical) mud oven base

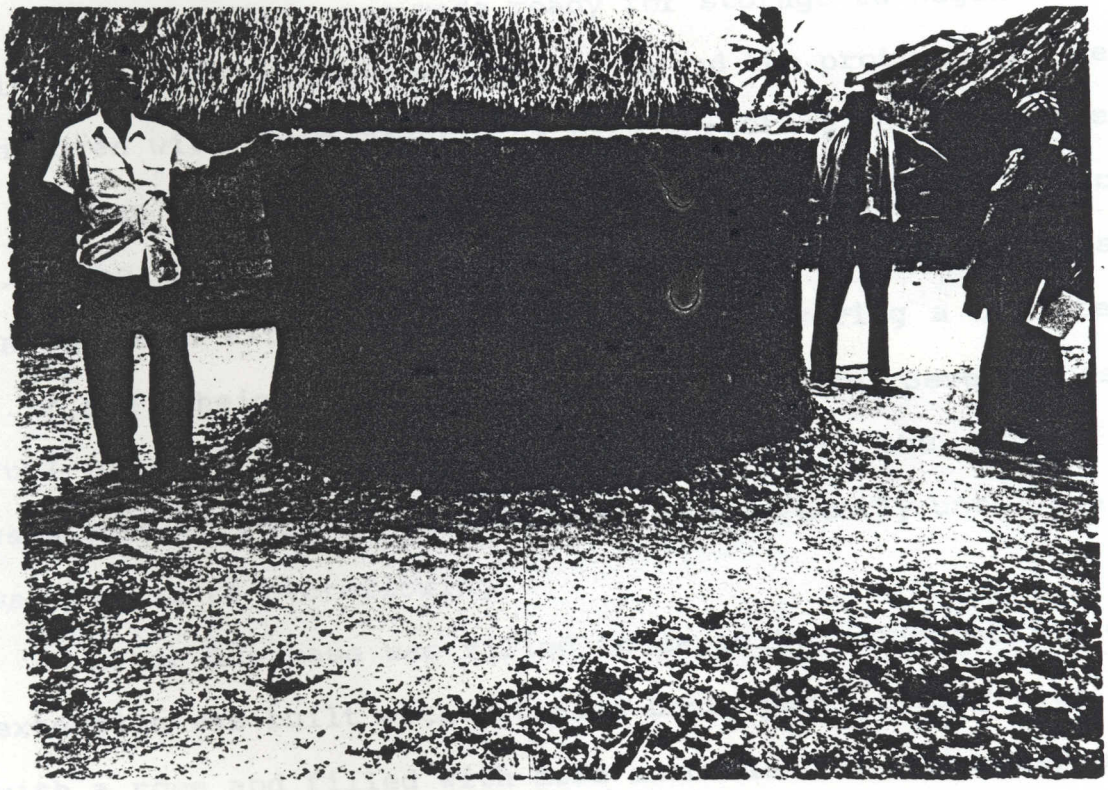
b. A dome top section

and c. A protective top covering

The round mud oven was base structure is made up of a hardcore base support constructed almost a meter above ground level inside a round mud oven. The traditional round oven formed the base housing for the whole storage structure. The oven is constructed with clay that had been thoroughly kneaded into a smooth and moldable consistency. The oven which measured 1.2m high with a top circumference of 8.3m, was constructed several weeks in advance for it to dry well before it was used for storage. The top circumference tapered down slightly to a mid-section and base circumference of 8.0m. The slight indentation of the circumference was at a distance of 0.4m from the top level of the oven. This was to facilitate the construction of the hardcore platform base at that depth in the oven for the smoked fish to be loaded on (Fig. 3).

With this arrangement, a hollow space of about 0.8m from ground level up, was created inside the oven beneath the loading level. Since the oven did not have any opening at the base, the hollow space created retained a relatively stagnant air throughout the storage period. According to the processors interviewed, air circulation enhances spoilage and is undesirable in the oven method of smoked anchovy storage.

Fig. 3. The traditional round mud oven

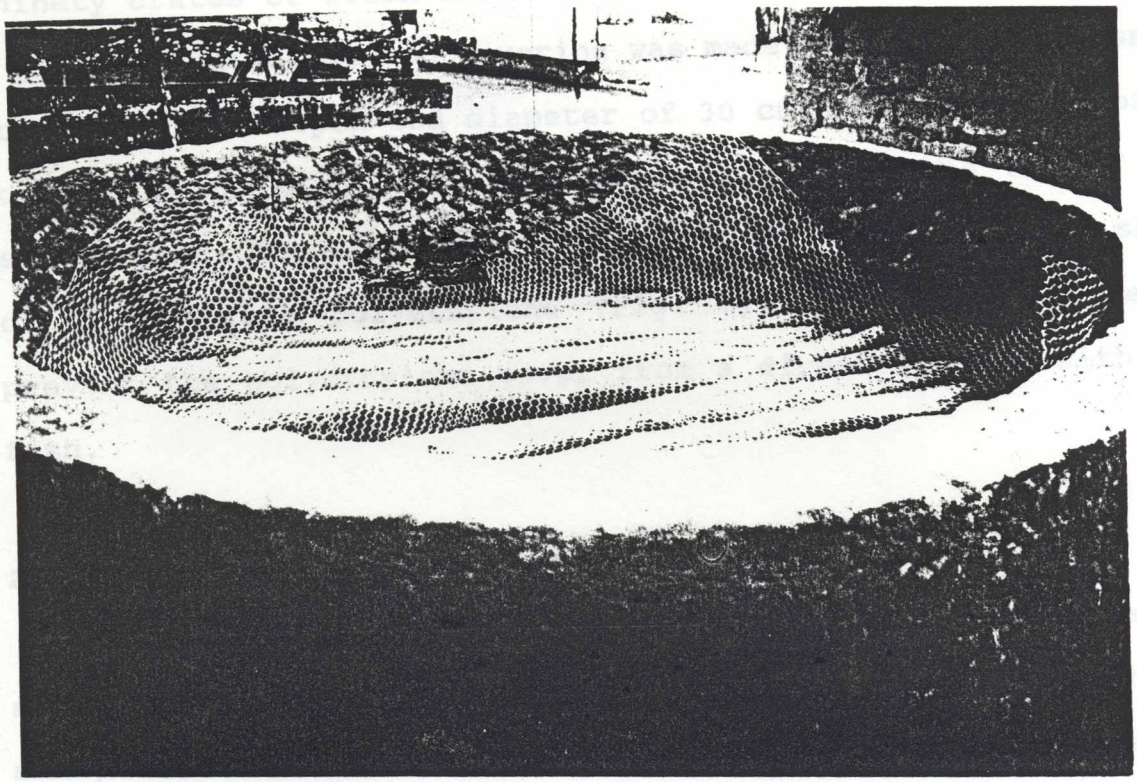


The hardcore base support platform on which the smoked fish to be stored was dumped was built with a layer of 7.0 diameter cut logs arranged horizontally to cover the entire inside base diameter of the oven (Fig 4). The wooden platform is then covered with mesh wire. In addition to providing a solid foundation for holding the weight of the stored product, this hardcore base support was constructed far above the ground in order to avoid excessive moisture diffusion from the ground into the storage. A damp environment at the base will definitely accelerate spoilage of the smoked fish.

The structure was made ready for storage to begin with the lining of the hardcore base platform and the protruding sides of the oven with brown paper. The base structure thus complete had a storage space in the form of a cone with base circumference of 8.0m, height of about 0.4m and a top diameter of 8.3m. This had an enclosed air volume of about $3.32m^3$ covering a diameter of 2.3m and a height of 0.8m beneath the platform. Several baskets full of smoked anchovies conveyed earlier to the storage site were emptied into the structure and spread neatly until the base was filled to over-flowing.

After the base was filled to capacity, construction of an extension was built with extended brown paper lining tied round with a rope and filled with more anchovies. The diameter of the mid-section widened as the relatively flexible tied paper was pushed outward under the weight of the fish load. Because of this, the greatest diameter of the whole storage structure was

Fig. 4. Hardcore base support platform



at the section above the oven level. This also formed the mid-section. At this point, the structure assumed the shape of a large dome with the strong round oven base (Fig 5). To avoid spillage, the top was arranged to form a cone shape with the top of the mid-section as its base. This cone shape section completed the capacity utilization of the smoked anchovy storage structure. The dimensions of the typical structure constructed was able to hold smoked anchovies prepared from one hundred and ninety crates of fresh anchovies.

The protective top covering was made with about five small baskets (with open end diameter of 30 cm, base diameter of 10 cm and 20 cm high) arranged upside down over the top of the stored fish. The whole structure was covered with a large sheet of thick black polyethylene (Fig. 6). The baskets were to prevent the polyethylene cover from a direct contact with the fish.

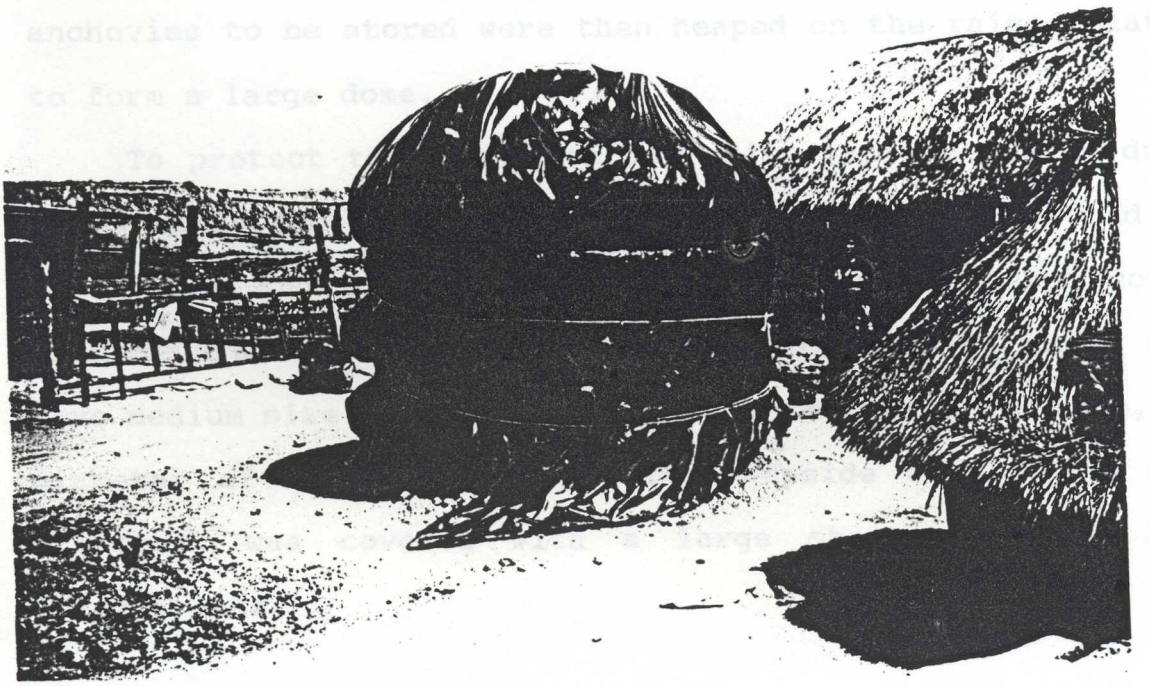
2.2.3. The Sea Sand Platform Storage Structure

The major features of the sea sand platform storage for smoked anchovies consist of a rectangular- or square-shaped sandy base covered with polyethylene sheet, brown papers and jute sacks on which the smoked fish was heaped and covered.

For the construction of the rectangular/square sand base, several pieces of 13 cm thick cement blocks were arranged to demarcate a rectangular space up to a height of bout 40 cm. The structure had a hollow space of 3.20m x 3.55m x 0.45m deep. The

Fig. 5. Traditional round oven structure filled to capacity

Fig. 6. Smoked anchovies in traditional round oven storage



space was filled with several headloads of clean white sea sand to form a raised sand platform. The platform was left in the sun to be heated for a few days by the hot tropical sun. This was necessary to destroy all insects that might be present in the sand. A large sheet of black polyethylene material was then spread on the sandy base platform to make it ready for storage (Fig 7).

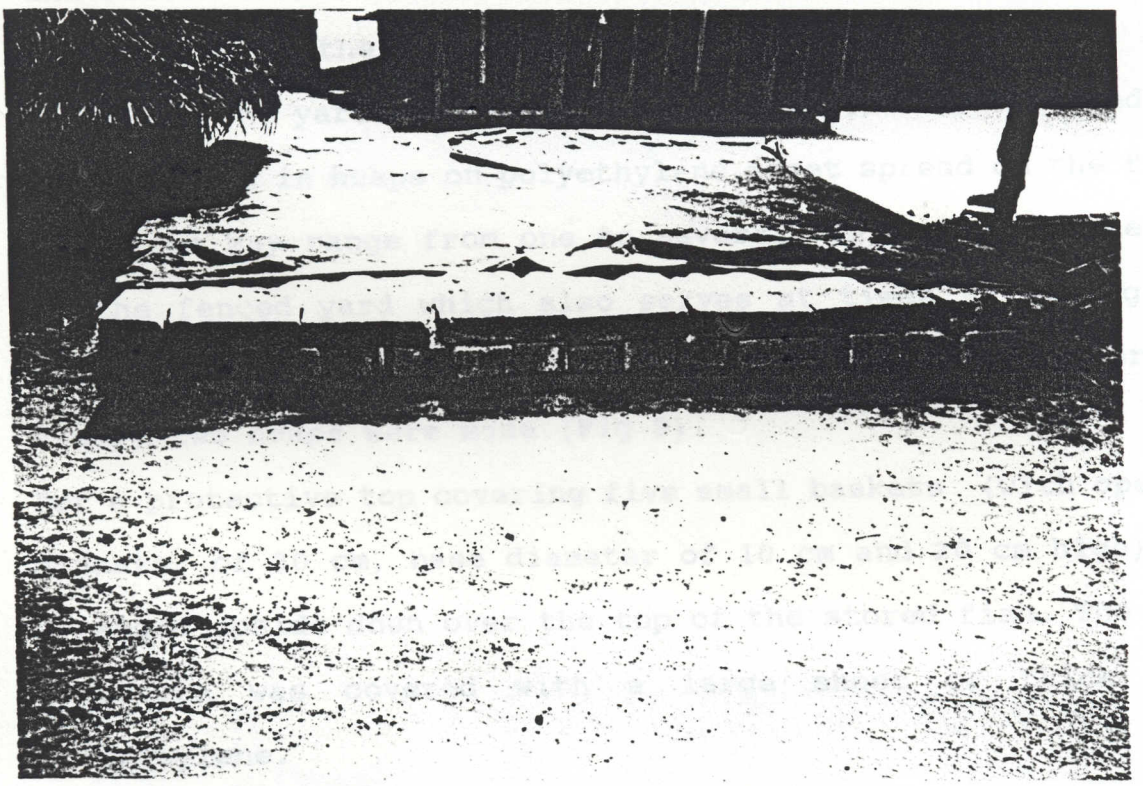
The platform was covered with a layer of jute bags on top of which was spread several sheets of brown paper. The smoked anchovies to be stored were then heaped on the raised platform to form a large dome.

To protect the fish from excessive storage losses due to the weather and insect pests, the whole heap was covered with jute sacks and polyethylene sheet. The top was first covered with several jute sacks, on top of which were arranged about five medium size baskets (with open end diameter of 30 cm, base diameter of 10 cm and 20 cm high) upside down. The whole structure was covered with a large sheet of thick black polyethylene.

2.2.4. The Fenced Yard Storage Structure

The fenced yard system of smoked anchovy storage is the simplest of the three techniques for the traditional storage of smoked anchovies at Akplabanya. The main protection effected was the prevention of domesticated animals such as goats and sheep from having easy access to the stored fish; in addition to

Fig. 7. The sea-sand platform



protection from rain with polyethylene cover. Apparently, this method of smoked anchovy storage is only a temporary one used when the product would have to be disposed of within a relatively short period of time.

The fence was constructed with long sticks interwoven to form a strong netting (Fig. 8). The interwoven stick netting fence is stronger and offered better protection than the timber board fence used by some of the villagers. For easy monitoring and surveillance, the fenced yard was constructed on a dwelling compound as is the usual practice.

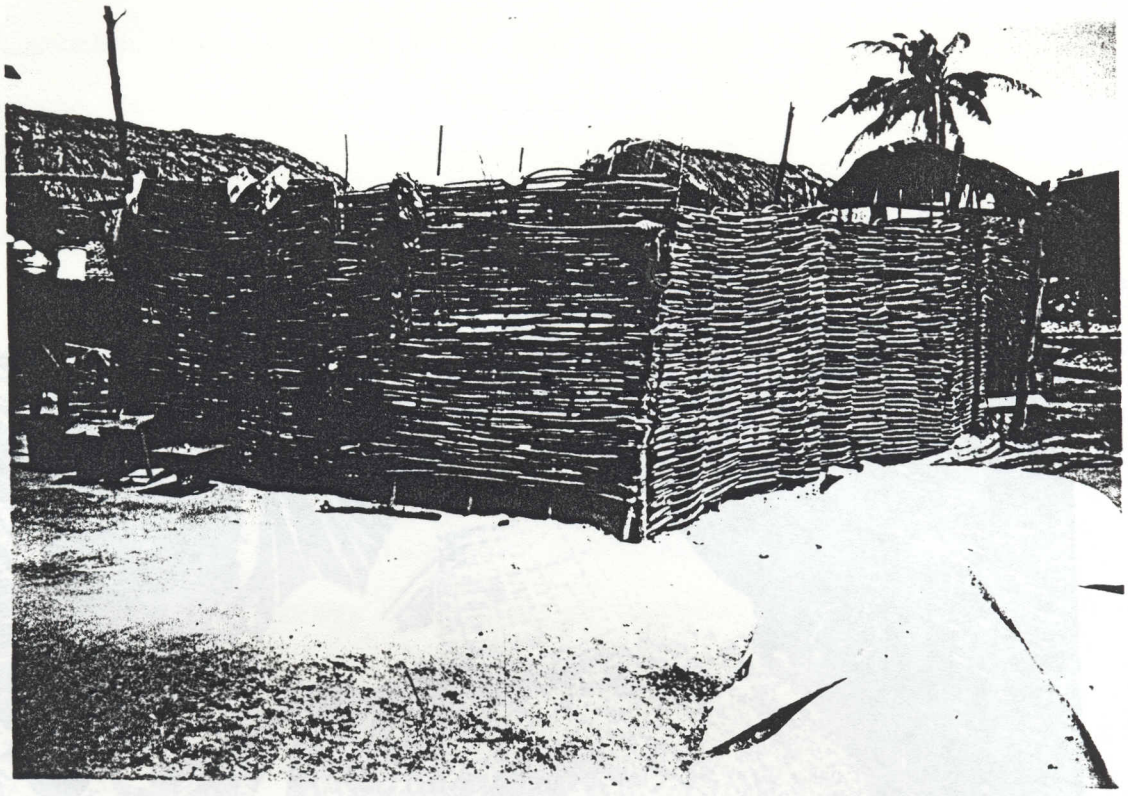
When the yard was ready, several baskets of the smoked fish were emptied in heaps on polyethylene sheet spread on the floor. The heaps may range from one to several, depending on the size of the fenced yard which also serves at times as storage for baskets used in packaging the fish for sale. in the present study, two heaps were made (Fig 9).

For a protective top covering five small baskets (with open end diameter of 30 cm, base diameter of 10 cm and 20 cm high) were arranged upside down over the top of the stored fish. The whole structure was covered with a large sheet of thick black polyethylene.

2.3. Monitoring Environmental Conditions in Storage Structure

A temperature and Humidity recorder (Model R-2126, Telog Instruments Inc., Rochester, NY) and the Telog 2100 series Support Software were used to monitor the temperature and

Fig 8. Fenced yard traditional fish storage structure



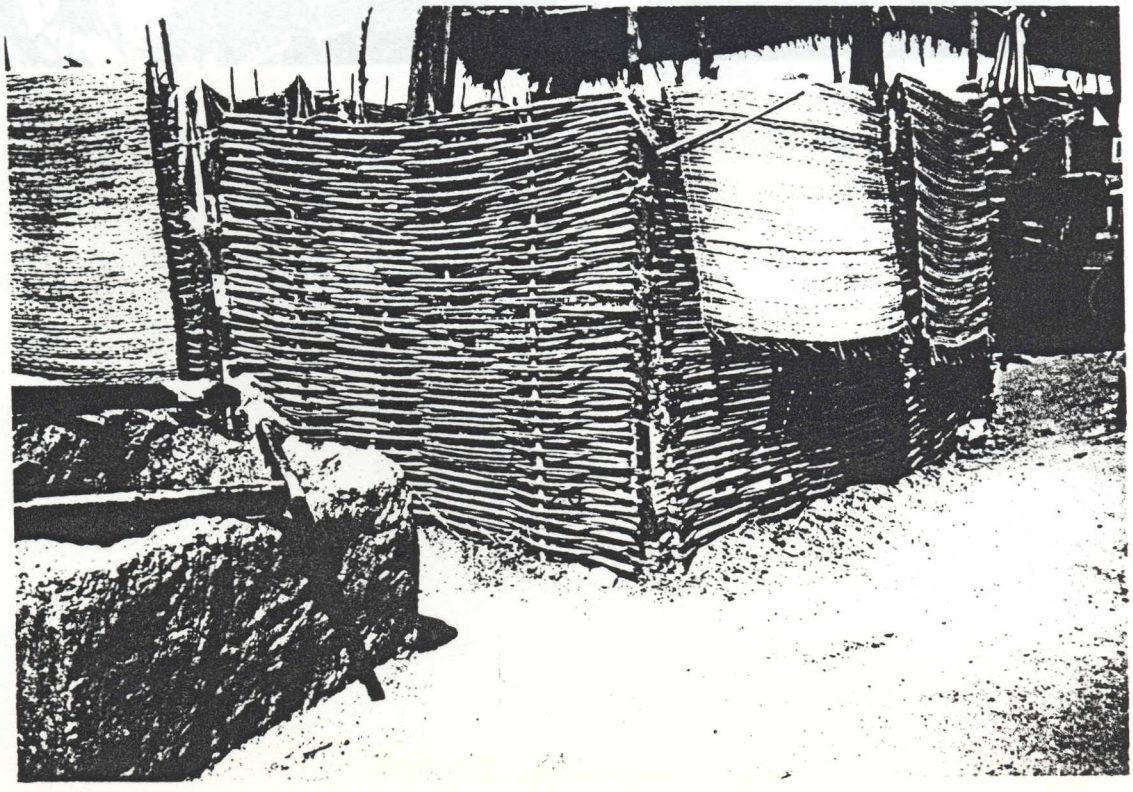


Fig 9. Heaps of smoked anchovies in fenced yard structure

humidity changes in the structures during the period of storage. The instrument was placed in a rectangular box made of framed wire mesh and mounted at the mid section of the fish pile. It was programmed to sample temperature and humidity at one minute intervals for 180 days. It was also to record the minimum, average and maximum temperatures and humidities.

2.4. Sampling and sample Preparation

Fish samples were taken at 0- and 3-month intervals and analyzed for the physical, microbiological, chemical and sensory characteristics. To determine the quality of freshly smoked anchovies before storage (zero month sampling), five samples of freshly smoked anchovies were randomly taken from each of the several large baskets filled with smoked anchovies prepared for storage. The samples were bulked together and mixed thoroughly. Sub-samples were taken from the bulk and these were evaluated for physical damage in terms of physical disintegration, visible mould damage, and insect infestation. The sub-samples were then rebulked and divided into two batches. One batch was milled whole in a laboratory hammer mill while the other batch was treated to obtain the edible portion by removing the scales, the head and the tail. This was also milled as before and the milled samples were kept in separate sterile polyethylene bags for analysis. Sampling after storage was done at both the periphery and the interior of the structure to obtain two sets of samples. For each set, five samples were taken from different locations,

bulked and treated as described earlier.

2.5. Evaluation of physical characteristics

To determine the percent overall physical damage in the smoked anchovies, samples were examined and grouped with respect to the type of physical damage experienced during processing, handling and storage. Weighed samples of the smoked fish were separated into the following four groups:

i. whole unbroken pieces,

ii. broken pieces,

iii. insect infested ,

iv. visible mouldiness.

Each group was weighed separately and expressed as a percentage of the total weight taken. The overall physically damaged portion was calculated based on the broken pieces, insect infested samples and samples showing visible mouldiness.

2.6. Sensory evaluation of fish samples

A quantitative descriptive sensory analysis was used to assess the sensory quality of the smoked anchovy samples. This involved a detailed descriptive sensory evaluation of the texture, flavour, aroma and colour of the fish, provided by expert panellists (Plahar, *et al.*, 1991). For each sample, panelists used an unstructured score card with sensory descriptions at each end of a 10 cm long line to make marks in relation to the description of the attribute (Johnson *et al.*,

1988). The distance of the tail end of the line to the mark was used as the numerical score. For each attribute, the mean score was obtained from several scores.

2.7. Chemical Analysis

Samples of milled edible portions as well as whole fish were analyzed for moisture, fat, protein and ash following standard methods (AOAC, 1984). The method of Pearson (1970) was used to determine the total volatile bases (TVBN) in the samples. 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). Fat extracts were analyzed for fat acidity (AACC, 1984, method 02-01).

2.8. Microbiological Quality Evaluation

2.8.1.Total viable counts (Pour plate technique)

A 10g portion of the fish sample was aseptically removed into a sterile sample bottle and 90 ml of quarter strength Ringers solution was added and mixed thoroughly by shaking several times. The suspension was allowed to stand for 5 min. to soak well. The mixture was again shaken vigorously and 1 ml portion was pipetted and used to prepare 10^{-1} to 10^{-6} serial dilutions. One millilitre of each serial dilution was then pipetted into sterile plates in duplicate. Each plate was overlaid with about 20 ml of Plate Count Agar cooled to 45°C.

Thorough mixing was ensured by clockwise and anti-clockwise rotation of the plates. The plates were allowed to stand to solidify after which they were incubated at 30°C for 72 hr. The edible portion of the smoked anchovy was treated in the same way to obtain the total viable counts (Harrigan and McCance, 1966).

2.8.2. Mould and Yeast Counts

For the enumeration of yeast and mould, a low acid medium was used. This medium was prepared by sterilizing 250 ml of Potato Dextrose Agar (PDA) and adding 7.5 ml of sterilized acid (i.e. 1.5 ml acid to 50 ml of PDA). Employing the Pour Plate technique, 1.0 ml of the 10^{-1} dilution of smoked fish suspension was pipetted into duplicate sterile petri dishes. This was overlaid with acidified PDA and carefully rotated in a clockwise and anti-clockwise direction for thorough mixing. The plates were then incubated at 30°C for 24 hr.

2.8.3. Enumeration of Enterobacteriaceae (Coliforms)

MacConkey broth with glass vials in test tubes were prepared and sterilized. One millilitre of 10^{-1} and 10^{-2} dilutions of fish suspension were pipetted into 10 ml duplicate broths. These were incubated for 72 hr at 37°C. Incubated samples were then identified for acid and gas production. For direct plating out, streaks were made on MacConkey agar plates using the stock fish solution prepared from each of the samples. The plates were then incubated at 37°C for 48 hr.

2.8.4. Pathogenic Organisms

Staphylococcus sp.

A 5g sample of smoked fish powder was aseptically weighed and placed in cooked meat medium with 10% salt added. It was mixed thoroughly and incubated for 12 - 18 hr at 37°C. The sample was then subcultured onto Mannitol salt agar and incubated for 72 hr at 37°C for pure culture isolation and identification.

Salmonella sp.

Twenty-five gram sample of smoked fish powder was weighed and placed in 100 ml Selenite enrichment broth and mixed well by shaking. The broth was then incubated for 12 - 18 hr at 37°C. This was subsequently subcultured onto Bismuth Sulphite agar and the plates incubated for 72 hr at 37°C.

2.8.5. Culture Identification

Smears of growth from the plates were made on clean slides with sterile loop. These were Gram stained and viewed under the microscope to identify the morphology and Gram reaction. Selective identification for *Aspergillus flavus/parasiticus* was performed using a specific medium prepared with Aspergillus Flavus Parasiticus Agar (AFPA) Base (Oxoid Limited, Hampshire, England).

2.9. Hydrogen Ion Concentration (pH)

pH of the samples were determined with a Metrohm 620 pH

meter (Swiss-made). Approximately 10g of fish powder was weighed into 200 ml beakers and 90 ml of carbon dioxide-free distilled water was added and thoroughly mixed. The mixture was left to stand for 5 min. before pH measurements were taken. The pH meter was calibrated prior to sample measurements using a standard buffer solution of pH 7.0.

2.10. Statistical analysis

Statistical significance of observed differences among means was evaluated by analysis of variance, and the least significant difference test (LSD) was used for comparison of the means (Steel and Torrie, 1980).

3. RESULTS AND DISCUSSION

3.1. Structural Protection of smoked anchovies in storage

In general, all the structures are built with mainly locally available materials; and the choice of any of the three depends on factors such as capital input available and the volume of smoked fish to be stored. The most effective technique in terms of structural protection against environmental hazards and storage pest was the mud oven structure, followed by the sea-sand platform method. The fenced yard did not protect the stored product against insects, rodents and domesticated pests. The polyethylene cover could only protect the samples against rain damage.

3.2. Temperature and Humidity Changes in Storage Structures

Similar temperatures and relative humidity conditions were observed in both the round mud oven and the sea-sand platform structures during storage (Table 1). The latter structure however, occasionally recorded slightly higher temperature conditions. A fairly constant daily average temperatures ranging between 30°C and 33°C were maintained most of the time in the mud oven structure, while the sea-sand platform structure recorded temperature range of 28 - 38°C. Relative humidity changes were not very drastic, ranging between 42% and 60%. In general however, a steady drop in the relative humidity was observed as storage progressed. The humidity dropped from an initial value of 57.5% to 45.0%. The two storage structures were

Table 1. TEMPERATURE & HUMIDITY RECORDINGS IN STORAGE STRUCTURES

Saved Recorder Status Type: 2126 Rec ID: 1088 Sample Rate: 1 min
Interval Length: 04:00:00 Total data logged: 175 days
Storage Capacity: 6492 values records: 180 days 08:00:00
Range Ch1 -40.0 - 73.7 deg°C Ch2 0.0 - 100.0 % RH
Stats Ch1 minimum average maximum Ch2 minimum average maximum

Output compressed by a factor of 6

A. TRADITIONAL ROUND OVEN TYPE

			Temperature (°C)				Rel. Humidity (%)		
Date	Time	Ch1	Min	Avg	Max	Ch2	Min	Avg	Max
03/05/93	08:29:40		30.8	32.7	34.3		55.1	57.5	60.5
03/06/93	08:29:40		31.0	32.3	33.6		55.3	57.1	59.3
03/07/93	08:29:40		31.0	32.1	33.0		55.1	56.8	58.8
03/08/93	08:29:40		31.1	32.2	33.2		54.9	56.3	57.9
03/09/93	08:29:40		31.0	32.5	33.7		54.4	56.3	58.1
03/10/93	08:29:40		31.4	32.6	33.9		54.7	56.6	58.5
03/11/93	08:29:40		31.8	32.7	33.8		54.7	56.3	58.6
03/12/93	08:29:40		31.9	33.2	34.3		54.3	55.6	56.9
03/13/93	08:29:40		31.0	33.5	38.2		53.7	55.4	57.2
03/14/93	08:29:40		29.2	33.6	60.0		27.6	54.3	56.9
03/15/93	08:29:40		31.6	33.0	38.7		51.9	53.6	54.9
03/16/93	08:29:40		31.0	33.2	35.8		51.9	53.5	55.1
03/17/93	08:29:40		31.7	33.1	35.8		50.7	52.9	54.3
03/18/93	08:29:40		31.8	33.2	38.2		51.9	54.0	57.2
03/19/93	08:29:40		32.2	33.5	35.8		52.1	53.8	55.9
03/20/93	08:29:40		31.0	33.5	35.8		52.0	53.3	54.3
03/21/93	08:29:40		32.4	33.5	38.8		51.9	53.3	54.3
03/22/93	08:29:40		31.0	33.5	38.8		52.7	53.6	54.7
03/23/93	08:29:40		32.0	33.5	38.2		51.9	53.6	54.9
03/24/93	08:29:40		31.0	33.3	38.2		51.1	53.1	54.4
03/25/93	08:29:40		32.1	33.5	38.2		51.3	53.8	56.7
03/26/93	08:29:40		32.0	33.3	40.4		51.6	53.0	54.5
03/27/93	08:29:40		31.8	33.1	38.2		51.3	52.5	53.5
03/28/93	08:29:40		31.8	32.6	33.3		51.7	52.4	53.1
03/29/93	08:29:40		31.1	32.4	35.8		51.9	53.3	54.9
03/30/93	08:29:40		31.2	32.5	35.8		51.8	53.4	54.9
03/31/93	08:29:40		31.2	32.0	32.6		49.7	50.3	50.7
04/01/93	08:29:40		31.3	32.4	35.8		51.8	53.0	54.3
04/02/93	08:29:40		31.1	32.4	35.8		50.8	53.0	55.1
04/03/93	08:29:40		30.6	31.7	32.6		50.1	51.7	53.5
04/04/93	08:29:40		30.6	31.8	32.8		49.7	51.8	53.5
04/05/93	08:29:40		31.0	32.1	33.0		50.5	52.0	53.9

04/06/93	08:29:40	31.2	32.2	33.2	50.7	52.1	53.9
04/07/93	08:29:40	31.2	32.2	33.2	50.7	52.3	54.0
04/08/93	08:29:40	29.4	31.1	32.2	48.3	50.8	53.2
04/09/93	08:29:40	29.4	31.5	32.6	48.3	51.2	53.1
04/10/93	08:29:40	31.4	32.7	35.8	51.5	52.8	55.1
04/11/93	08:29:40	30.7	32.1	35.8	51.0	52.5	54.7
04/12/93	08:29:40	30.7	31.8	32.8	50.8	52.3	54.4
04/13/93	08:29:40	30.7	32.0	35.8	51.3	53.8	56.1
04/14/93	08:29:40	30.8	31.9	33.1	52.1	54.0	56.8
04/15/93	08:29:40	30.9	31.5	32.1	51.9	52.6	53.1
04/16/93	08:29:40	31.2	31.9	32.6	52.3	52.8	53.4
04/17/93	08:29:40	31.2	31.9	32.4	52.2	52.7	53.2
04/18/93	08:29:40	29.3	31.0	32.1	49.3	51.7	53.0
04/19/93	08:29:40	28.8	29.6	30.4	49.7	50.4	51.2
04/20/93	08:29:40	28.8	29.8	30.3	49.9	50.5	51.2
04/21/93	08:29:40	29.3	30.4	31.2	49.5	50.3	51.2
04/22/93	08:29:40	29.3	30.2	30.9	49.7	50.4	51.2
04/23/93	08:29:40	29.4	30.5	31.0	49.9	50.5	51.2
04/24/93	08:29:40	30.2	31.2	31.8	49.7	50.4	51.0
04/25/93	08:29:40	30.8	31.5	32.1	49.9	50.4	50.9
04/26/93	08:29:40	30.0	31.0	32.1	48.5	49.8	51.0
04/27/93	08:29:40	30.0	31.0	31.6	49.3	50.1	50.6
04/28/93	08:29:40	30.7	31.4	32.1	49.7	50.2	50.6
04/29/93	08:29:40	30.7	31.4	32.1	50.0	50.4	50.8
04/30/93	08:29:40	31.0	31.8	32.4	50.0	50.4	50.8
05/01/93	08:29:40	31.3	32.0	32.6	49.9	50.4	50.7
05/02/93	08:29:40	31.8	32.3	32.8	49.9	50.4	50.8
05/03/93	08:29:40	31.3	32.3	33.0	48.5	50.3	50.9
05/04/93	08:29:40	31.3	32.2	32.8	49.8	50.4	50.9
05/05/93	08:29:40	31.3	32.3	33.0	49.5	50.3	51.2
05/06/93	08:29:40	30.9	32.0	32.8	48.8	50.0	50.8
05/07/93	08:29:40	30.8	31.9	32.8	48.5	49.5	50.6
05/08/93	08:29:40	30.9	31.9	32.7	48.9	49.7	50.4
05/09/93	08:29:40	31.3	32.1	32.8	48.9	49.7	50.5
05/10/93	08:29:40	30.3	32.0	32.8	47.1	49.4	50.3
05/11/93	08:29:40	30.4	31.7	32.6	48.1	49.1	49.9
05/12/93	08:29:40	28.7	29.8	31.1	46.7	47.5	48.3
05/13/93	08:29:40	28.9	30.3	31.1	46.9	47.7	48.4
05/14/93	08:29:40	30.0	31.1	31.9	47.7	48.4	49.0
05/15/93	08:29:40	30.7	31.6	32.2	47.9	48.7	49.3
05/16/93	08:29:40	29.4	32.0	35.8	46.7	49.3	51.5
05/17/93	08:29:40	29.4	30.6	31.7	47.1	47.9	48.6
05/18/93	08:29:40	29.7	30.9	31.9	47.3	48.2	48.8
05/19/93	08:29:40	30.3	31.6	32.4	47.7	48.5	49.0
05/20/93	08:29:40	30.9	31.9	32.8	47.6	48.5	49.0
05/21/93	08:29:40	31.1	32.1	33.2	47.6	48.5	49.1
05/22/93	08:29:40	31.2	32.2	35.8	47.7	48.5	49.1
05/23/93	08:29:40	30.9	32.0	32.8	47.5	48.5	49.3
05/24/93	08:29:40	30.8	31.8	32.7	47.5	48.4	49.3
05/25/93	08:29:40	30.9	32.1	33.0	47.7	48.5	49.2
05/26/93	08:29:40	31.3	32.3	35.8	47.6	48.6	49.3
05/27/93	08:29:40	31.6	32.4	33.4	48.1	48.9	49.4

05/28/93	08:29:40		31.7	32.6	35.8		48.1	48.9	49.6
05/29/93	08:29:40		31.1	32.3	35.8		47.3	48.6	49.5
05/30/93	08:29:40		31.2	32.2	33.0		47.5	48.5	49.3
05/31/93	08:29:40		31.5	32.9	33.3		47.2	48.8	49.8
06/01/93	08:29:40		31.6	32.6	35.8		47.5	48.7	49.5
06/02/93	08:29:40		30.9	32.3	35.8		46.8	48.4	49.5
06/03/93	08:29:40		31.0	32.2	35.8		47.2	48.2	49.2
06/04/93	08:29:40		29.8	32.1	34.7		45.1	48.0	49.3
06/05/93	08:29:40		28.2	29.2	29.9		44.6	45.7	46.3
06/06/93	08:29:40		28.3	30.3	31.3		44.7	46.2	46.9
06/07/93	08:29:40		27.9	31.0	32.1		42.9	46.5	47.5
06/08/93	08:29:40		27.4	28.2	28.8		43.8	44.9	45.8
06/09/93	08:29:40		27.7	29.4	30.2		44.2	45.6	46.3
06/10/93	08:29:40		28.4	29.9	31.2		44.4	45.7	46.6

B. SEA-SAND PLATFORM STRUCTURE

			Temperature (°C)				Rel. Humidity (%)		
Date	Time	Ch1	Min	Avg	Max	Ch2	Min	Avg	Max
03/05/93	06:20:51		33.1	34.1	35.9		46.7	56.3	62.6
03/06/93	06:20:51		31.9	32.7	33.9		53.5	55.5	57.5
03/07/93	06:20:51		31.2	32.4	34.0		54.5	58.1	61.1
03/08/93	06:20:51		30.7	32.3	34.2		54.8	57.9	61.4
03/09/93	06:20:51		30.7	32.4	35.0		50.0	56.5	59.5
03/10/93	06:20:51		30.8	32.6	35.8		47.8	55.9	58.5
03/11/93	06:20:51		30.9	34.5	39.6		35.5	47.9	57.7
03/12/93	06:20:51		31.9	33.3	36.1		42.2	45.9	48.5
03/13/93	06:20:51		32.2	33.4	36.3		43.4	46.5	49.1
03/14/93	06:20:51		32.3	33.6	36.6		42.9	45.9	48.1
03/15/93	06:20:51		32.5	34.0	36.5		45.2	50.0	54.4
03/16/93	06:20:51		33.2	34.6	37.6		43.6	49.0	52.0
03/17/93	06:20:51		33.2	34.5	37.1		46.9	49.3	52.2
03/18/93	06:20:51		33.4	33.9	34.7		48.1	52.3	55.6
03/19/93	06:20:51		31.2	32.3	33.4		46.9	49.6	52.0
03/20/93	06:20:51		31.0	31.9	33.0		49.3	50.2	51.2
03/21/93	06:20:51		31.2	32.3	33.8		49.3	52.8	54.5
03/22/93	06:20:51		30.3	32.2	34.7		48.8	51.9	54.6
03/23/93	06:20:51		30.1	32.1	34.8		46.4	48.7	51.2
03/24/93	06:20:51		31.8	32.4	33.6		49.0	53.8	56.1
03/25/93	06:20:51		29.6	31.9	35.3		39.9	42.7	45.6
03/26/93	06:20:51		29.7	32.1	35.7		37.0	39.8	41.5
03/27/93	06:20:51		30.2	32.4	36.1		37.5	39.9	41.7
03/28/93	06:20:51		32.2	32.8	33.4		47.1	51.4	55.2
03/29/93	06:20:51		31.2	32.0	32.7		54.3	55.4	59.0
03/30/93	06:20:51		31.6	32.2	33.3		50.5	57.0	62.4
03/31/93	06:20:51		32.4	33.0	34.1		53.0	55.5	56.6
04/01/93	06:20:51		32.5	33.3	34.6		45.7	52.3	57.6
04/02/93	06:20:51		32.6	33.1	33.9		44.0	46.8	48.6

04/03/93 06:20:51	31.0	32.4	34.7	37.2	42.7	46.2
04/04/93 06:20:51	32.5	32.9	33.8	46.4	53.0	56.0
04/05/93 06:20:51	31.6	32.3	33.1	46.2	49.0	52.0
04/06/93 06:20:51	32.2	32.9	34.1	54.0	57.8	60.7
04/07/93 06:20:51	32.7	33.0	33.2	57.2	58.7	60.4
04/08/93 06:20:51	32.8	33.1	33.4	58.9	59.5	64.4
04/09/93 06:20:51	32.2	32.9	35.3	50.0	55.8	62.2
04/10/93 06:20:51	31.9	32.5	33.5	48.9	49.8	51.2
04/11/93 06:20:51	32.4	32.8	33.6	52.1	53.6	55.2
04/12/93 06:20:51	32.1	32.6	33.5	51.4	53.4	56.1
04/13/93 06:20:51	32.4	32.7	33.2	45.7	48.2	50.8
04/14/93 06:20:51	32.1	32.7	33.7	46.4	48.0	49.4
04/15/93 06:20:51	29.2	32.1	34.5	44.9	52.9	60.2
04/16/93 06:20:51	25.7	30.2	34.2	46.2	55.4	70.7
04/17/93 06:20:51	32.7	33.3	33.9	43.8	45.8	48.0
04/18/93 06:20:51	32.8	33.2	33.6	47.5	48.9	50.0
04/19/93 06:20:51	30.7	32.2	32.7	40.4	46.2	57.7
04/20/93 06:20:51	32.3	33.0	34.0	51.9	53.4	58.1
04/21/93 06:20:51	32.2	32.9	34.3	52.5	53.4	54.7
04/22/93 06:20:51	32.0	33.0	34.9	51.1	52.8	54.6
04/23/93 06:20:51	31.2	31.7	32.3	46.1	49.9	54.0
04/24/93 06:20:51	28.7	28.9	29.3	50.8	51.9	52.7
04/25/93 06:20:51	28.6	28.8	28.9	53.7	54.3	54.9
04/26/93 06:20:51	27.7	29.6	33.7	52.6	56.3	66.2
04/27/93 06:20:51	30.3	31.8	34.5	47.3	55.7	60.0
04/28/93 06:20:51	31.2	32.5	33.8	11.3	44.4	62.1
04/29/93 06:20:51	33.3	36.5	38.9	55.9	71.5	80.2
04/30/93 06:20:51	34.3	36.3	39.7	50.3	63.3	82.3
05/01/93 06:20:51	35.2	36.5	38.4	64.4	68.0	70.8
05/02/93 06:20:51	36.2	36.8	37.6	65.6	68.5	72.3
05/03/93 06:20:51	35.4	37.0	41.1	42.6	62.2	78.3
05/04/93 06:20:51	34.4	35.6	37.3	64.9	72.3	79.2
05/05/93 06:20:51	34.6	34.9	35.1	52.2	64.3	74.4
05/06/93 06:20:51	34.6	34.8	35.0	47.6	58.5	69.0
05/07/93 06:20:51	34.8	35.8	36.9	45.2	53.1	62.6
05/08/93 06:20:51	35.1	36.2	37.4	46.5	55.0	63.8
05/09/93 06:20:51	37.2	38.3	40.0	63.3	64.7	68.1
05/10/93 06:20:51	35.3	37.2	39.1	43.5	56.2	69.0
05/11/93 06:20:51	34.7	35.0	35.2	48.4	57.4	65.0
05/12/93 06:20:51	35.0	36.2	37.5	44.7	52.3	60.7
05/13/93 06:20:51	35.1	36.1	37.1	46.6	52.8	57.9
05/14/93 06:20:51	34.8	35.0	35.5	46.7	53.1	58.1
05/15/93 06:20:51	37.6	38.6	40.1	59.1	60.8	62.2
05/16/93 06:20:51	35.8	37.7	39.1	47.0	56.7	64.9
05/17/93 06:20:51	35.7	36.5	37.6	45.5	51.3	56.7
05/18/93 06:20:51	34.9	35.1	35.4	45.5	52.3	57.9
05/19/93 06:20:51	35.2	36.5	37.9	43.3	49.8	57.4
05/20/93 06:20:51	35.3	36.8	38.3	43.3	49.8	56.7
05/21/93 06:20:51	35.2	36.6	38.0	42.2	47.5	55.2
05/22/93 06:20:51	35.1	36.3	37.8	39.7	46.1	55.3
05/23/93 06:20:51	35.1	35.5	37.6	47.0	55.2	61.0
05/24/93 06:20:51	35.6	37.0	38.9	41.4	49.4	61.8

05/25/93	06:20:51		35.2	36.5	38.0		38.8	45.8	54.1
05/26/93	06:20:51		35.2	36.5	38.0		39.5	45.6	54.6
05/27/93	06:20:51		35.4	36.7	38.4		39.0	44.8	53.4
05/28/93	06:20:51		35.2	36.2	37.4		37.9	43.5	51.1
05/29/93	06:20:51		34.9	35.2	35.5		40.3	49.4	57.8
05/30/93	06:20:51		35.1	36.2	38.7		51.1	57.4	63.5
05/31/93	06:20:51		35.1	39.0	45.8		37.4	52.9	75.5
06/01/93	06:20:51		34.5	35.9	37.1		39.2	48.5	59.1
06/02/93	06:20:51		35.7	36.8	38.0		37.5	47.4	65.2
06/03/93	06:20:51		33.1	34.1	35.9		46.7	56.3	62.6
06/04/93	06:20:51		31.0	32.5	34.7		37.2	42.7	46.2
06/05/93	06:20:51		31.9	32.7	33.9		53.5	55.5	57.5
06/06/93	06:20:51		32.2	33.4	36.3		43.4	46.5	49.1
06/07/93	06:20:51		33.2	34.5	37.1		46.9	49.3	52.2
06/08/93	06:20:51		30.3	32.2	34.7		48.8	51.9	54.6
06/09/93	06:20:51		31.2	32.3	33.4		46.9	49.6	52.0
06/10/93	06:20:51		32.2	32.8	33.4		47.1	51.4	55.2

C. FENCED YARD STRUCTURE

			Temperature (°C)				Rel. Humidity (%)		
Date	Time	Ch1	Min	Avg	Max	Ch2	Min	Avg	Max
03/05/93	06:20:51		32.3	33.7	35.8		47.1	52.9	56.9
03/06/93	06:20:51		31.2	32.3	33.9		53.1	57.3	60.8
03/07/93	06:20:51		31.2	32.4	33.9		54.5	58.1	61.1
03/08/93	06:20:51		30.9	32.4	34.0		54.4	56.8	59.2
03/09/93	06:20:51		30.7	32.3	34.2		54.8	57.9	61.4
03/10/93	06:20:51		30.8	32.2	34.3		54.5	56.9	59.1
03/11/93	06:20:51		30.7	32.3	35.0		50.0	56.5	59.5
03/12/93	06:20:51		31.2	32.9	34.9		51.6	55.5	58.4
03/13/93	06:20:51		30.8	32.6	35.8		47.8	55.9	58.5
03/14/93	06:20:51		31.8	33.5	35.7		48.4	50.0	51.6
03/15/93	06:20:51		30.8	34.5	39.6		35.5	47.9	57.7
03/16/93	06:20:51		32.2	33.9	36.1		42.4	44.4	46.4
03/17/93	06:20:51		32.0	33.3	36.1		42.2	45.9	48.5
03/18/93	06:20:51		32.4	34.1	36.0		43.9	46.0	47.6
03/19/93	06:20:51		32.6	34.4	36.2		43.3	45.3	46.6
03/20/93	06:20:51		32.3	33.6	36.6		42.9	45.9	48.1
03/21/93	06:20:51		32.9	34.7	36.5		44.8	46.5	47.4
03/22/93	06:20:51		33.7	35.1	36.5		48.8	51.8	53.4
03/23/93	06:20:51		33.2	34.6	37.6		43.6	49.0	52.0
03/24/93	06:20:51		33.5	35.3	37.4		44.6	47.2	48.0
03/25/93	06:20:51		33.8	35.2	36.9		48.7	50.2	51.8
03/26/93	06:20:51		33.4	33.9	34.7		48.1	52.3	55.6
03/27/93	06:20:51		32.6	33.8	34.5		49.7	54.3	57.0
03/28/93	06:20:51		31.0	32.0	33.3		46.5	48.6	49.6
03/29/93	06:20:51		31.0	31.9	33.0		49.3	50.2	51.2

03/30/93	06:20:51	31.3	32.1	32.8	50.3	52.6	54.4
03/31/93	06:20:51	31.2	32.3	33.8	49.3	52.8	54.5
04/01/93	06:20:51	30.4	32.1	33.7	49.6	51.5	52.6
04/02/93	06:20:51	30.2	31.8	34.2	48.5	50.3	51.5
04/03/93	06:20:51	30.1	32.1	34.8	46.4	48.7	51.2
04/04/93	06:20:51	31.9	32.9	34.7	47.0	51.0	55.1
04/05/93	06:20:51	29.8	31.2	33.4	41.6	45.8	49.6
04/06/93	06:20:51	29.6	31.8	35.2	39.9	42.7	45.6
04/07/93	06:20:51	29.8	31.4	34.1	38.9	42.4	44.3
04/08/93	06:20:51	30.2	32.1	35.3	38.5	40.3	41.2
04/09/93	06:20:51	32.3	33.4	35.9	39.1	42.5	47.9
04/10/93	06:20:51	31.5	32.4	33.2	54.0	55.0	55.9
04/11/93	06:20:51	31.2	32.0	32.7	54.3	55.4	59.0
04/12/93	06:20:51	31.8	32.1	32.6	57.7	61.7	64.1
04/13/93	06:20:51	31.6	32.2	33.3	50.5	57.0	62.4
04/14/93	06:20:51	32.4	32.7	33.0	52.4	54.3	56.2
04/15/93	06:20:51	32.4	33.0	34.2	53.0	55.5	56.6
04/16/93	06:20:51	32.9	33.2	34.0	53.7	56.5	57.8
04/17/93	06:20:51	32.6	33.3	34.6	45.7	52.3	57.6
04/18/93	06:20:51	32.5	32.9	33.9	48.3	49.7	50.8
04/19/93	06:20:51	32.5	33.1	34.0	44.0	46.8	48.6
04/20/93	06:20:51	31.3	32.3	33.7	38.7	43.6	47.3
04/21/93	06:20:51	32.5	32.9	34.5	45.8	49.7	51.9
04/22/93	06:20:51	31.7	32.2	33.4	46.9	49.7	50.8
04/23/93	06:20:51	31.6	32.3	33.1	46.2	49.0	52.0
04/24/93	06:20:51	31.9	32.2	32.5	50.3	56.5	60.7
04/25/93	06:20:51	32.5	32.8	33.4	54.0	55.0	57.5
04/26/93	06:20:51	32.7	33.0	33.2	57.2	58.7	60.4
04/27/93	06:20:51	32.8	32.9	33.1	59.4	59.8	60.1
04/28/93	06:20:51	32.8	33.1	33.4	58.9	59.5	64.4
04/29/93	06:20:51	32.2	32.9	35.3	50.0	55.8	62.2
04/30/93	06:20:51	32.0	32.6	33.9	50.4	52.9	54.6
05/01/93	06:20:51	31.9	32.5	33.5	48.9	49.8	51.2
05/02/93	06:20:51	32.4	32.6	33.0	50.0	51.9	52.7
05/03/93	06:20:51	32.3	32.7	33.5	53.5	54.5	55.2
05/04/93	06:20:51	32.1	32.6	33.5	51.4	53.4	56.1
05/06/93	06:20:51	32.5	32.6	33.0	48.1	50.6	51.9
05/07/93	06:20:51	32.4	32.7	33.2	45.7	48.2	50.8
05/08/93	06:20:51	32.1	32.5	33.0	46.5	47.5	48.7
05/09/93	06:20:51	31.7	32.2	33.3	46.5	47.4	48.0
05/10/93	06:20:51	29.2	32.1	34.5	44.9	52.9	60.2
05/11/93	06:20:51	26.5	30.1	33.9	48.0	56.4	60.5
05/12/93	06:20:51	25.7	30.2	34.2	46.2	55.4	70.7
05/13/93	06:20:51	32.8	33.2	33.9	44.8	46.7	48.4
05/14/93	06:20:51	32.9	33.1	33.8	47.6	48.9	49.8
05/15/93	06:20:51	32.8	33.2	33.6	47.5	48.9	50.0
05/16/93	06:20:51	32.3	32.8	33.6	40.5	44.4	48.0
05/17/93	06:20:51	30.7	32.2	32.7	40.4	46.2	57.7
05/18/93	06:20:51	32.3	32.4	32.5	50.8	51.7	52.4
05/19/93	06:20:51	32.3	33.0	33.9	51.9	53.4	58.1
05/20/93	06:20:51	32.2	32.7	33.6	53.3	54.2	55.2
05/21/93	06:20:51	32.2	32.9	34.3	52.5	53.4	54.7

05/22/93	06:20:51	31.9	32.6	33.8	52.5	53.7	54.4
05/23/93	06:20:51	32.0	33.0	34.9	51.1	52.8	54.6
05/24/93	06:20:51	31.4	32.5	34.5	48.8	52.5	54.9
05/25/93	06:20:51	28.7	29.6	31.8	49.7	50.5	51.6
05/26/93	06:20:51	28.7	28.9	29.3	50.8	51.9	52.7
05/27/97	06:20:51	28.9	29.1	29.2	52.5	53.4	54.0
05/28/93	06:20:51	28.6	28.8	28.9	53.7	54.3	54.9
05/29/93	06:20:51	28.1	28.6	28.8	54.5	55.1	55.5
05/30/93	06:20:51	27.7	29.6	33.7	52.6	56.3	66.2
05/31/93	06:20:51	30.3	30.8	32.0	54.7	56.9	60.1
06/01/93	06:20:51	31.3	31.9	32.8	55.3	57.2	62.7
06/02/93	06:20:51	33.3	34.5	37.3	16.5	49.6	67.4
06/03/93	06:20:51	33.3	36.5	39.0	55.9	71.5	80.2
06/04/93	06:20:51	34.8	37.3	39.4	56.6	66.3	73.1
06/05/93	06:20:51	34.3	36.3	39.7	50.3	63.3	82.3
06/06/93	06:20:51	35.4	37.5	39.4	66.2	68.1	70.2
06/07/93	06:20:51	35.2	36.5	38.4	64.4	68.0	70.8
06/08/93	06:20:51	37.1	38.1	38.7	67.1	70.7	74.2
06/09/93	06:20:51	36.2	36.7	37.6	65.6	68.5	72.3
06/10/93	06:20:51	36.7	37.2	37.6	69.9	70.8	72.1

so compact and well protected that the micro-environment created inside could not effectively equilibrate with, or be influenced by the environmental conditions outside. Earlier studies of similar structures at Akplabanya and Tema showed similar drop in the relative humidity conditions with time of storage (Plahar *et al*. 1992b; 1993).

The fenced yard structure also maintained fairly narrow average temperature range between 28°C and 38°C. On the other hand, it recorded very drastic humidity changes over the storage period. This was obviously due to a direct influence of the atmospheric humidity conditions in the area. Little protection against environmental climatic changes was offered by the fenced yard structure. The average relative humidity ranged from 42% to as high as 71%. Unlike the other two structures, no systematic decrease in the humidity was recorded in the fenced yard structure with storage time.

3.3. Physical and Sensory characteristics of smoked anchovies

Results of the physical assessment of the smoked anchovies after three-month storage in the different structures are shown in Table 2. Over 97% of the fish prepared for traditional storage were physically sound and whole. There were no visible mouldiness and no insect infestation in any of the freshly smoked samples examined. The few broken pieces observed could be the direct result of handling during packaging and storage, but not due to physical deterioration.

Table 2. Effect of traditional storage method on the physical characteristics of smoked anchovies (*Anchoa guineensis*)[1]

		Freshly smoked samples	Traditionally stored samples		
			Round oven structure	Sea-sand platform	Fenced yard structure
Total examined	(Kg)	6.00	6.74	7.51	6.88
	(%)	100	100	100	100
Whole undamaged -Storage Yield	(Kg)	5.84	6.17	6.88	5.89
	(%)	97.53	91.54	91.61	85.61
Broken pieces	(Kg)	0.16	0.32	0.24	0.21
	(%)	2.67	4.75	3.19	3.05
Visibly mouldy	(Kg)	0.00	0.20	0.32	0.34
	(%)	0.00	2.97	4.26	4.94
Insect Infested	(Kg)	0.00	0.04	0.07	0.43
	(%)	0.00	0.59	0.93	6.25
Overall physical damage	(Kg)	0.16	0.57	0.63	0.99
	(%)	2.70	8.46	8.39	14.39

[1] Values are means of triplicate determinations.

As reported in the previous studies (Plahar *et al.* 1992b) the normal practice of fish smoking for storage involves a great deal of physical handling. Apart from turning the fish over on the smoking kiln for uniform smoking during processing, the smoked fish had to be spread to cool and then packed in large baskets which may be piled on each other until ready for storage. Such packaging techniques could cause a lot of the relatively dried pieces of fish to break under the pressure of the weight. About three percent physically damaged pieces of freshly smoked anchovies observed in this and other studies is considered far below the normal anticipated breakages. Both processing and handling were therefore adequate, resulting in a high quality product for storage.

In general, traditional storage caused between 8 and 14 % physical loss, with the lowest storage yield given by the fenced yard technique. Over 14% storage losses occurred after three months of storage in the fenced yard structure. Lack of adequate protection was responsible for the relatively high insect infestation and mouldiness observed. The round oven and sea-sand storage structures produced similar storage yields. About 91.5% physically sound product was obtained with each of the two structures after three months' storage. Visible mouldiness and broken pieces were the major sources of physical loss here; but unlike the fenced yard storage samples, insect infestation was very low in the other two structures. The main insect identified was the dermestid beetle (most likely, *Dermestid maculatus*).

Table 3 shows the results of the quantitative descriptive sensory analysis of the smoked anchovies. This analysis is very useful in characterising the sensory properties of the samples quantitatively for reliable comparisons to be made. Typical of freshly smoked fish (Plahar *et al.*, 1991; 1992b; 1993), the smoked anchovies studied scored highly for flavour, aroma and colour in relation to the expected freshness values. The freshly smoked samples possessed the characteristic fresh smoky aroma with the freshly- smoked fish flavour. Other quantitative descriptive scores also characterized the samples as firm to hard, chewy as well as being neither brittle nor crumbly. These are some of the typical quality attributes that are expected to be preserved by the storage techniques employed in order to enhance product safety and consumer acceptability. During the three months of storage, there was no significant change in most of the physical characteristics of the samples. The freshly smoked quality attributes were adequately preserved by the traditional round oven and sea-sand storage techniques used. The fenced yard storage method however, caused a significant decrease in the aroma and flavour of the smoked anchovy samples.

3.4. Proximate composition and chemical properties

Freshly smoked anchovy samples prepared for the storage trials were found to be a very good source of protein and minerals (Tables 4 & 5). Both fat and moisture contents were low enough to present little deterioration problems during storage.

Table 3. Quantitative descriptive analysis of traditionally stored smoked anchovies (*Anchoa guineensis*).

Sensory attribute	Mean Sensory Scores			
		Samples stored for 3 months		
	Freshly smoked	Round oven structure	Sea sand platform	Fenced yard storage
Hardness	6.8 ± 0.2	7.0 ± 0.3	6.9 ± 0.3	7.4 ± 0.2
Brittleness	6.3 ± 0.4	6.4 ± 0.2	6.8 ± 0.5	6.6 ± 0.3
Chewiness	5.4 ± 0.3	6.5 ± 0.1	5.9 ± 0.3	6.0 ± 0.1
Flavour	9.8 ± 1.0	9.5 ± 1.0	9.4 ± 0.2	8.1 ± 0.4
Aroma	9.8 ± 1.1	9.6 ± 0.3	9.3 ± 0.4	8.6 ± 0.2
Colour	9.6 ± 1.3	9.5 ± 0.4	9.5 ± 0.2	9.3 ± 0.2

Scoring system:

Hardness : 0=very soft, 5=firm, 10=hard.
Brittleness: 0=crumbly, 10=brittle
Chewiness : 0=tender, 5=chewy, 10=tough
Flavour : 0=off flavour, 10=typical freshly smoked
Aroma : 0=mouldy or rancid, 10=fresh smoky aroma
Colour : 0=black, 10=light brown

Table 4. Effect of traditional storage on the proximate composition and mineral content of smoked anchovies (*Anchoa guineensis*)[1] sampled from interior section.

Sample Component	Freshly smoked (0 mo)	Traditionally stored for 3 months		
		Round oven structure	Sea sand platform	Fenced yard storage
Whole fish				
Moisture (%)	12.40	12.40	12.51	12.63
Protein (%)	67.58	68.38	67.95	68.00
Fat (%)	6.28	5.94	6.04	5.88
Ash (%)	19.63	19.41	19.34	20.10
Calcium(mg/100g)	2,456	2,688	2,700	2,725
Iron (mg/100g)	21.92	42.69	43.21	44.10
Phos. (mg/100g)	1,610	1,719	1,693	1,754
Edible portion				
Moisture (%)	13.20	13.50	13.43	12.89
Protein (%)	73.04	75.72	74.85	73.22
Fat (%)	4.95	4.97	4.87	4.76
Ash (%)	14.75	12.95	13.10	13.38
Calcium(mg/100g)	1,573	1,414	1,426	1,533
Iron (mg/100g)	34.69	31.91	32.11	34.70
Phos.(mg/100g)	1,218	1,114	1,180	1,346

[1]Values are means of triplicate determination expressed on dry-weight basis (except for moisture).
initial value of about 13% to less than 10% by the end of the

Table 5. Effect of traditional storage on the proximate composition and mineral content of smoked anchovies (*Anchoa guineensis*)[1] sampled from the periphery.

Sample Component	Freshly smoked (0 mo)	Traditionally stored for 3 months		
		Round oven structure	Sea sand platform	Fenced yard storage
Whole fish				
Moisture (%)	12.40	12.70	12.61	12.66
Protein (%)	67.58	70.45	69.00	67.28
Fat (%)	6.28	5.38	5.48	5.62
Ash (%)	19.63	18.44	20.41	20.31
Calcium(mg/100g)	2,456	2,914	2,993	3,004
Iron (mg/100g)	21.92	42.69	43.01	43.81
Phos. (mg/100g)	1,610	1,719	1,703	1,802
Edible portion not determined				

[1]Values are means of triplicate determination expressed on dry-weight basis (except for moisture).

High-fat smoked fish samples develop rancidity problems within a short period of storage. With moisture, earlier work by Okoso-Amaa *et al.* (1978) also indicated that the shelf-life of smoked Sardinella spp. varied according to the moisture content.

There was no significant change in the moisture content of the smoked fish samples after storage in the traditional structures. The fenced yard structure recorded a slightly higher moisture content apparently due to the higher humidity recorded. Earlier work at Tema Manhean recorded a significant reduction in the moisture content from an six-month storage period (Plahar *et al.* 1992b). No significant changes were observed in the moisture content during the first three months of storage in that study also. Longer periods of storage than three months are required for humidity decreases to cause any significant reduction in the moisture levels of stored anchovies. Other components in the stored fish samples did not change with storage.

Proteolytic and lipolytic deterioration in the fish samples at the end of the three-month storage period was quite significant for all the three storage structures used in the study. The greatest deterioration was recorded in samples at the periphery of the fenced yard structure. The fat acidity, volatile base nitrogen and non-protein nitrogen values obtained here were more than double the original values before storage (Table 6). Protein decomposition, as measured by non-protein nitrogen (NPN) and total volatile base nitrogen (TVBN) content

Table 6. Effect of traditional storage (3 mo) on the fat acidity, total volatile base nitrogen (TVBN) and non-protein nitrogen (NPN) content of freshly smoked anchovies (*Anchoa guineensis*)

Sample	Fat acidity (mg KOH/g)	TVBN (mg N/100g)	NPN (g N/100g)
Whole fish (storage interior)			
Freshly smoked	3.84	137.44	1.00
Round oven storage	5.10	204.47	1.12
Sea sand platform	5.22	210.24	1.11
Fenced yard storage	5.66	246.03	1.26
Whole fish (storage periphery)			
Freshly smoked	3.84	137.44	1.00
Round oven storage	5.70	178.81	1.01
Sea sand platform	5.63	180.48	1.14
Fenced yard storage	8.33	290.47	1.62
Edible portion (storage interior)			
Freshly smoked	3.01	127.42	1.01
Round oven storage	4.14	164.74	1.05
Sea sand platform	3.87	158.91	1.23
Fenced yard storage	5.32	181.04	1.36

was very low in both the whole fish and the edible portion of freshly smoked anchovy. The TVBN values obtained in this study ranged between 127 mg N/100g edible portion and 137 mg N/100g whole fish sample. After storage in the round oven structure, the values increased to 164 mg N/100g and 204 mg N/100g for edible and whole portions respectively, while the sea-sand platform storage produced samples with TVBN values ranging from 159 and 210 mg N/100g. Farber (1965) reported a suggested upper limit of 60 mg N/100g for marine fish. Based on about 80% moisture for fresh marine fish, this upper limit value is about 300 mg N/100g sample. The freshly smoked samples and samples stored in both the round oven and sea-sand structures were therefore far below the limit suggested for TVBN content. The periphery samples from the fenced yard structure however, gave values quite close to the upper limit for TVBN content. In a recent study, Hodari-Okae *et al.* (1991) obtained TVBN values of between 18 - 22 mg N/100 g fresh fish for some species of marine fish purchased from some fish markets in Ghana. On dry weight basis, these values are also between 90 -110 mg N/100g sample.

Non Protein Nitrogen (NPN) content of the smoked fish remained almost the same during storage. A decrease in NPN values was observed in previous studies for traditionally stored smoked herrings (Plahar *et al.* 1991) and for stored smoked anchovies (Plahar *et al.* 1992a; 1992b).

Fat acidity was also low. The initial value of about 3.8 mg KOH/g sample increased by about 50% during the three months in

storage for all the traditional methods used. Lipolytic activity and oxidative rancidity were therefore negligible due to the freshness of the samples. Hodari-Okae *et al.*(1991) observed a possible relationship between high fat acidity and marine fish freshness.

3.5. Microbiological Quality of Smoked Anchovies

Results of microbiological analysis of samples obtained prior to and after traditional storage of smoked anchovies (*Anchoa guineensis*) are as shown in Tables 7, 8 and 9. This includes examination of whole edible portions of smoked anchovies sampled from the periphery and interior portions of the storage structures at Akplabanya.

Microbial examination of any processed food product provides information which serves as the most important criterion for judging the success of the process used, the effectiveness of the production controls as well as the microbiological stability and safety of the food. In this study, bacterial and fungal loads for both the whole and edible portions of the freshly smoked anchovies were within acceptable limits.

Freshly smoked anchovies recorded a low aerobic bacterial count per gram of 67×10^1 (Table 7). After three months' storage in a round oven structure, sea-sand platform and fenced yard structure, values of aerobic organisms recorded from the interior portions were respectively, 70×10^1, 68×10^1 and

able 7. Effect of traditional storage on the microbiological quality f whole smoked anchovies (*Anchoa guineensis*) sampled from interior of torage structure.

est	Freshly smoked	Three months' storage in: Round oven structure	Sea sand platform	Fenced yard structure
iable organisms				
Aerobic bacterial count per gram	67×10^1	70×10^1	68×10^1	95×10^1
Mould and yeast count per gram	<10	2×10^1	14×10^1	25×10^1
H	5.9	5.7	5.8	5.8
ılture	Sporing *Bacillus* Gm +ve cocci	Sporing and non- sporing *Bacillus Asp.* sp.	Gm +ve cocci *Bacillus Asp.* sp	Mucor *Asp.* sp *Bacillus* Gm +ve cocci
ɔliforms in 0.1 g)	Absent	Absent	Absent	Absent
aecal coli	Absent	Absent	Absent	Absent
athogens				
Salmonella	Nil	Nil	Nil	Nil
Staphylococci	Nil	Nil	Nil	Nil

95 x 10^1 counts/g. There was no significant increase in bacterial load of samples from the round oven and sea-sand platform structures as compared to the initial value of 67 x 10^1 counts/g for the freshly smoked anchovies.

The mould and yeast counts/g for both round oven and sea-sand platform structures were significantly low indicating that the smoked anchovies had attained the required low moisture levels that do not encourage the growth and proliferation of these microorganisms. Values recorded were 2 x 10^1 counts/g and 14 x 10^1 counts/g respectively. For the fenced yard structure, 25 x 10^1 counts/g mould and yeast counts were recorded. As compared to a count of <10 organisms in the freshly smoked samples, the relatively higher numbers of these organisms after storage showed that spores on the surface of the fish might have germinated due to conducive atmospheric conditions in the immediate environment of the structures. The nature of the fenced yard structure was such that access could easily be gained by insects and rodents which could easily contaminate the fish.

Bacterial population were mainly Micrococci and sporing and non-sporing *Bacillus* spp., with *Aspergillus* sp. being the single most predominant mould that developed in all the three storage structures after the 3-month period. In the fenced yard structure however, *Mucor* was also detected.

In general however, the absence of coliforms and especially faecal coli in the samples from the interior of the structures showed that the anchovies were not contaminated with any faecal material during processing and storage. Moreso, the absence of pathogens such as

Salmonella and *Staphylococcus* as well as the low bacterial and mould loads indicated that the stored anchovies were fit for human consumption and would not pose any health hazard especially to at-risk population (eg. infants, the aged, the infirm or immunocompromised individuals).

Microbiological hazard analysis and prevention is of great importance to the food industry and hence the existing systematic Hazard Analysis Critical Control Point (HACCP) procedures used for microbiological food hazards (ICMCF, 1988; Corlett and Stier, 1991). Accordingly, the anchovies will be ranked (0) since they exhibited no microbiological hazard characteristic.

Analysis of the edible portions of the smoked anchovies sampled from the interior of the storage structures showed no significant increases in the total aerobic bacterial counts after storage in the traditional structures. The mould counts also showed insignificant differences between the freshly smoked (2×10^1 counts/g), the round oven structure (5×10^1 counts/g), the sea-sand platform structure (15×10^1 counts/g) and the fenced yard structure (89×10^1), in a reducing pH environment of 5.9 to 5.6. Microorganisms isolated from the edible portions of the anchovies were sporing and non-sporing *Bacillus* spp., Micrococci, *Rhizopus* and *Aspergillus* spp. Plahar *et al*. (1991) isolated similar organisms in freshly smoked herring (*Sardinella eba*).

Table 9 shows microbiological quality of whole smoked anchovies sampled from the periphery of the storage structures. The periphery is the section of the structure most likely to be exposed to the environmental climatic conditions. There was no significant difference

Table 8. Effect of traditional storage on the microbiological quality of edible portion of smoked anchovies (*Anchoa guineensis*) sampled from interior of storage structure.

Test	Freshly smoked	Three months' storage in: Round oven structure	Sea sand platform	Fenced yard structure
Viable organisms				
Aerobic bacterial count per gram	61×10^1	65×10^1	76×10^1	70×10^1
Mould and yeast count per gram	2×10^1	5×10^1	15×10^1	89×10^1
pH	5.9	5.6	5.8	5.6
Culture	Sporing & non- sporing Bacillus *Asp.* spp.	Sporing Bacillus *Asp.* sp.	Bacillus *Asp.* sp. Rhizopus	Bacillus Rhizopus Gm +ve cocci
Coliforms (in 0.1 g)	Absent	Absent	Absent	Absent
Faecal coli	Absent	Absent	Absent	Absent
Pathogens				
Salmonella	Nil	Nil	Nil	Nil
Staphylococci	Nil	Nil	Nil	Nil

Table 9. Effect of traditional storage on the microbiological quality of whole smoked anchovies (*Anchoa guineensis*) sampled from the periphery of storage structure.

Test	Freshly smoked	Three months' storage in: Round oven structure	Sea sand platform	Fenced yard structure
Viable organisms				
Aerobic bacterial count per gram	67×10^1	49×10^1	56×10^1	114×10^2
Mould and yeast count per gram	<10	2×10^1	15×10^1	87×10^2
pH	5.9	5.7	5.8	5.6
Culture	Gm +ve cocci Bacillus	Gm +ve cocci Bacillus *Asp* . sp.	Gm +ve cocci Bacillus *Asp*. sp.	Gm +ve cocci Bacillus *Asp*. sp. Rhizopus
Coliforms (in 0.1 g)	Absent	Absent	Absent	Present
Faecal coli	Absent	Absent	Absent	Present
Pathogens				
Salmonella	Nil	Nil	Nil	Nil
Staphylococci	Nil	Nil	Nil	Nil

in aerobic bacterial count for the freshly smoked (67 x 10^1 counts/g), round oven structure (49 x 10^1 counts/g) and the sea-sand platform structure (56 x 10^1 counts/g) samples. Samples from the fenced yard structure recorded significantly higher aerobic counts (114 x 10^2 counts/g) than the freshly smoked as well as samples from the other two structures.

Mould and yeast counts for the freshly smoked, round oven structure and the sea-sand platform were respectively <10, 2 x 10^1, and 15 x 10^1 counts/g. This indicates no significant increase in fungi loads during storage in these structures. The fenced yard structure, however, had 87 x 10^2 counts/g, showing an increase in counts with a decreasing pH value of 5.9 to 5.6. The maintenance of relatively higher humidity levels at the periphery as compared to the interior of the storage structures is expected to produce comparatively higher counts for the fenced yard structure as observed in this study. In addition, the proliferation of flying and creeping insects as well as rodents and domesticated pests which had easy access to the samples could have introduced organisms from outside into the structure. This is shown from the culture isolated that the fenced yard structure recorded many more types of microorganisms than the round oven and sea-sand storage structures.

In the freshly smoked fish only Micrococci and *Bacillus* spp. were observed. In addition to the above organisms, *Aspergillus* spp. and especially *Rhizopus* developed in samples stored in the fenced yard structure. Significantly also, was the observation of coliform and faecal coli in samples from the fenced yard structure, although these

were absent in samples from the other two structures. Faecal material might have been introduced into the structure by pests such as lizards, flies, cockroaches and also by rodents which might be visiting the structure for the purpose of feeding on the fish. Such fish may not be fit for human consumption and may pose a health hazard if consumed. Pathogenic microorganisms like *Salmonella* or *Staphylococci* were not however, isolated from any of the samples taken from the periphery of the structures.

3.6. Mycotoxicological quality of stored anchovies

Mycotoxin formation in foods is closely linked to fungal growth. Without growth of the producing fungi, generally mycotoxin production will likewise not occur. However, the presence of mycotoxic fungi in a product does not automatically indicate the presence of mycotoxins especially if growth has not occurred. On the other hand, the toxins may persist long after vegetative growth has occurred and the moulds have died.

Both freshly smoked and stored fish samples analyzed in all previous anchovy storage studies were negative for aflatoxin B_1, B_2, G_1 and G_2 (Plahar *et al.* 1992; 1993). Aflatoxin was therefore not determined in the present study. Aflatoxins are toxic mycotoxins produced by the moulds *Aspergillus flavus* and *Aspergillus parasiticus* under favourable conditions of temperature and moisture, especially during storage. They have been detected in various processed fish samples (FAO, 1979), but nothing has been reported of aflatoxin in freshly smoked fish. Aflatoxin contamination of foods is mainly a

storage problem and this usually occurs when foods are stored under conditions that are conducive to fungal growth.

Production of aflatoxin is favoured by temperatures of between 25°C to 30°C although they can be produced below 8 to 10 °C in very small amounts over much longer periods of time. Aflatoxin are produced in highest amounts at temperatures of about 25°C (Diener and Davis, 1966). During the three-month storage period, daily average temperatures inside the structures ranged from 29.2 to 34.0 °C. Although microbiological examination revealed the presence of *Aspergillus* sp., obviously the temperatures in the structure were too much on the higher side to favour the growth of the aflatoxin-producing organisms as well as the production of the toxins. The moisture content of the substrate or the relative humidity surrounding it is another important factor that affects growth and aflatoxin production (Diener and Davies, 1969). Previous work showed that optimum relative humidity for growth was 85% or greater (Austwick and Ayerst, 1963; Ayerst, 1969). Most foods with moisture contents of above 13% are known to be susceptible to growth of toxic moulds and potential mycotoxin formation (Bullerman, *et al.*,1984). The maximum average daily relative humidity in the storage structures was about 48%. This decreased progressively throughout the storage period. The moisture content of the samples did not show any significant decrease. These conditions would definitely not favour development of aflatoxin producing moulds in the traditional storage structures.

CONCLUSIONS

1. The material requirements and structural characteristics of the three most popular traditional anchovy storage structures at Akplabanya have been adequately established in the study.

2. The mud oven storage structure and the sea-sand platform techniques employed in the traditional storage of smoked anchovies were effective in preserving the product against excessive physical damage, microbial attack as well as proteolytic and lipolytic deterioration. A storage yield of over 91% was obtained within three months of storage using the two traditional methods. The fenced yard structure is not very effective.

3. A fairly constant daily average temperatures ranging between 30°C - 33°C and between 28°C - 38°C were maintained most of the time in the mud oven structure and the sea-sand platform structure respectively. Relative humidity in the two structures decreases with storage time while the fenced yard structure responds more to the environmental climatic changes in the area.

5. Microorganisms isolated from stored samples include *Aspergillus*. sp., *Micrococci*, and *Bacillus* sp.

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Fig. 1. Trays of anchovies being prepared for smoking