EFFECT OF STORAGE METHODS ON SOME QUALITY INDICES OF SMOKED HERRINGS (*Sardinella eba*)

A PROJECT REPORT

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ABSTRACT

Samples of freshly smoked herring (*Sardinella eba*) at 14% moisture were stored for a maximum period of six months using five different storage methods: in polyethylene bags at ambient temperature with and without desiccant, frozen (-20^{0}C), as well as the traditional and a modified oven storage technique. Their relative effectiveness in preserving the quality of the fish was evaluated in terms of storage losses and decomposition as indicated by fat and protein breakdown products. Next to frozen storage, the most effective method was the modified procedure which gave storage yields of 97%. Proteolytic and lipolytic deterioration was negligible in the modified oven storage. Although the traditional storage retained high sensory and chemical properties, over 30% storage losses were recorded. Storage in polyethylene bags at ambient temperature was ineffective, while inclusion of desiccant only delayed total decomposition beyond one month. Although no loss occurred in frozen storage of smoked herring for 6 months, this method is energy intensive and, from an economical viewpoint, it appears unlikely that many small-scale village processors would be able to afford the cost involved.

INTRODUCTION

Large quantities of herring (*Sardinella spp*) landed during the bumper season between July and October of each year, are preserved by one of several traditional fish processing methods to prevent spoilage. Smoking has been identified as the most widely used traditional processing method, representing about 70% of the annual fish catch (Kagan 1970; Okraku-Offei). It dominates artisanal fish processing and involves a large number of women all along the coast (FAO 1987). Reusse (1968) estimated that 80% of fish consumed in Ghana are smoked.

Traditional fish smoking technology has been studied extensively and considerable improvements have been 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 over the traditional ones include increased 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, smoke-dried fish are stored in round smoking ovens covered with polyethylene and jute sacks. Occasional re-smoking is undertaken to maintain dryness and to 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 (Cauri *et al* 1979; Nerquaye-Tetteh 1979). Although no statistics are available on storage losses of smoke-dried fish in Ghana, reports have indicated post-processing losses of unprotected dried fish as high as 30-70% (Kagan 1970; James 1976; Osuji 1976; Waterman 1976). Efforts to reduce 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 herring (*Sardinella eba*) under tropical Ghanaian conditions. The methods examined include the traditional and modified oven storage, polyethylene bag storage with and without desiccant, and frozen storage.

MATERIALS AND METHODS

Fish preparation, smoke-drying and storage

Fish preparation and smoke-drying

A bulk of herring (*Sardinella eba*), purchased from a cold store at the Tema fishing harbour, Tema, was washed, surface dried in the sun and smoked using 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 65-cm-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^{0}C for 3 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, with a moisture content of about 14%, were randomly allocated to the different methods of storage.

Frozen storage

A 30-kg batch of the smoked fish was packed in a jute sack lined with polyethylene film (40 µm gauge), tied securely at the end and stored at – 20^{0}C for 6 months.

Polyethylene bag storage

Ten 3-kg portions of the smoked fish were packed in 40µm-thick polyethylene bags measuring 25 x 38 cm (Polyproducts Ghana Ltd., Accra). The open ends of the bags were folded and securely stapled after filling. All ten bags were packed in a large cardboard box and kept in a room at about 28^{0}C.

Polyethylene bag storage with desiccant

This procedure was the same as described above except that 150g desiccant ('Drierite' anhydrous $CaSO_4$ obtained from W A Hammond Drierite Co, Xenia, OH, USA) was sealed in a perforated polyethylene bag and enclosed in each bag containing 3 kg fish. The desiccant was replaced twice a month throughout the storage period.

Traditional storage

A 30-kg batch of the smoked herring was packed in a cylindrical traditional smoking oven to form a thickness of about three layers of fish on a wire mesh 60 cm above the combustion level. It was covered with polyethylene sheets and jute sacks. A 2-h re-smoking at 40-60^{0}C was undertaken at monthly intervals during the 6 months in storage.

Modified storage

A modification was made by the authors aimed at reducing infestation by storage pests. The modified structure consisted of the traditional oven as the re-smoking unit and one or more wooden boxes measuring 150 x 150 x 50 cm as the holding unit (Fig.1). The bottom end of each box was made of wire mesh to facilitate the flow of hot smoke through the stored fish during periods of re-smoking. The boxes had open tops so that two or more boxes could be re-smoked simultaneously stacked up on the oven. The topmost 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 (2 cm diameter) and covered with 0.51-mm wire mesh to keep out insect pests and rodents. One storage box was loaded with 30 kg fish, seated on the round oven, covered with a sheet of plywood and re-smoked monthly during the 6 months' storage.

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 backbone. The remaining edible portion was broken into large pieces and representative samples were taken for sensory analysis. The rest was milled and stored in polyethylene bags at -20^{0}C for chemical analysis.

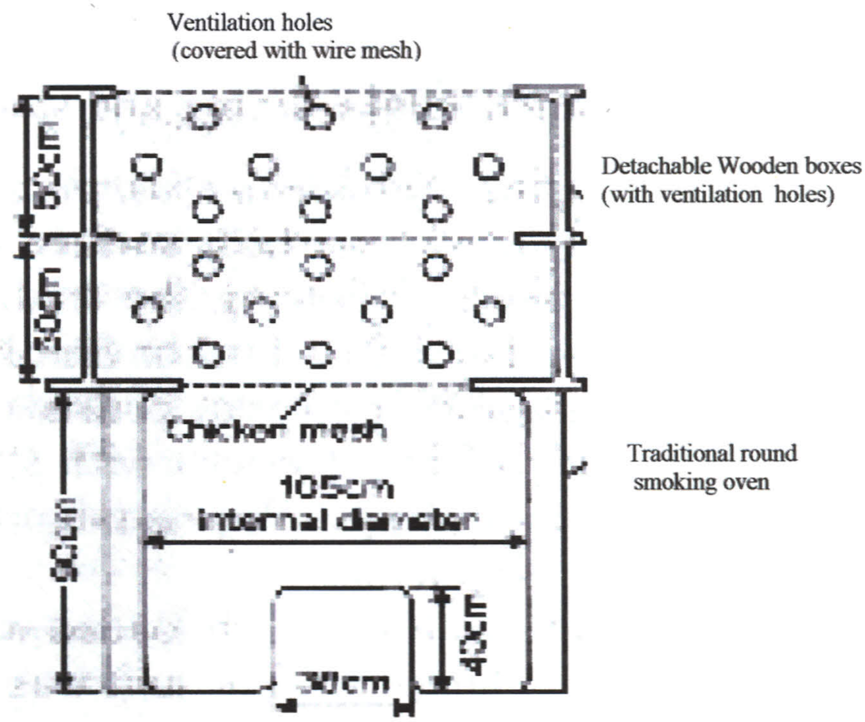

Fig. 1. Modified structure for smoked herring storage

Determination of storage losses

For each storage condition, storage losses were estimated in terms of the proportion of total initial smoked fish that showed signs of damage which appeared unfit for consumption after the storage period. Measurements were taken separately for rodent damage, insect/maggot damage and mould infection. The overall storage yield was also calculated based on the proportion of the initial weight of smoke-dried fish that remained sound and undamaged after the storage period. The influence of moisture differences was eliminated by using the formula:

$$\text{Yield} = [W_2(100 - M_1) \times 100]/[W_1(100 - M_2)]\%$$

Where W_1 and W_2 are the weights of initial and final undamaged fish respectively, and M_1 and M_2 represent the initial and final moisture content respectively.

Chemical analysis

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 50g litre^{-1} trichloroacetic acid, centrifuging at 10,000 x g and determining the nitrogen content of aliquots of the filtrate (Lu *et al* 1988b). The method of Pearson (1970) was used to determine the total volatile bases (TVB) in the samples. Free fatty acids, FFA (AACC 1984, method 02-01), and peroxide value (AOCS 1980), were determined in fat extracts of the smoked fish samples.

Statistical analysis

Statistical significance of observed differences among treatment 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). The treatment means were obtained from three repeated measurements on samples from each storage condition.

RESULTS AND DISCUSSION

Storage losses

Storage in polyethylene bags (with or without desiccant) proved highly unsatisfactory in protecting smoke-dried herring from pests (Table 1). Although no rodent damage was observed, insect and fungal damage was rather extensive, leaving a yield of less than 4% at the end of 1 month's storage. The use of desiccant increased the yield to 87% at 1 month but only 10% yield was obtained after 3 months' storage. 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 sealed polyethylene bags. With 50% moisture, smoked fish could last for only 4 days whereas fish with 15-20% moisture lasted for about 40 days in sealed polyethylene. It was suggested that smoked Sardinella spp of 10% moisture and below could be stored in heat-sealed low density polyethylene bags for a period of 9 months (Okoso-Amaa *et al.*, 1978). However, a 10% moisture level could be detrimental to the sensory quality of the product.

A very high yield (96.9%) was obtained with modified storage compared with traditional storage (71.9%). This difference was due to the reduction of rodent damage from 5.1 to 0%, insect damage from 16.1 to 2.1% and mould infestation from 14.9 to 3.1%.

Effect of storage on proximate composition

The most significant changes in the proximate composition of smoke-dried herring stored under different conditions were in the moisture content (Table 2). There was a significant increase in the moisture content of samples stored in polyethylene bags. Okoso-Amaa *et al.* (1978) also observed significant moisture uptake through low density polyethylene film used in the storage of smoked fish. The prevailing high humidity and temperature coupled with the high permeability of the film to moisture enhanced the rate of microbial decomposition. The presence of desiccant in some of the polyethylene bags checked the excess moisture uptake by the fish and maintained the original moisture level at about 14%. The drastic decrease in moisture in samples in traditional and modified storage is obviously due to the re-smoking during storage. Better aeration as a result of the modified structure was responsible for the lower moisture compared with that of the traditionally stored samples.

Table 1. Storage losses (%) in smoked herring (*Sardinella eba*) through insect infestation, rodent attack and mouldiness

Storage method and duration	Rodent damage	Insect/maggot damage	Mould damage	Yield
Frozen control 6 months	0.0	0.0	0.0	100.0
Polyethylene bags without desiccant				
1 month	0.0	92.2	80.2	3.8
Polyethylene bags with desiccant				
1 month	0.0	3.3	10.0	86.7
3 months	0.0	60.0	88.0	10.0
Traditional storage 6 months	5.1	16.1	14.9	71.9
Modified storage 6 months	0.0	2.1	3.1	96.9

Table 2. Changes in the proximate and mineral composition of smoked herring as affected by storage[a]

Storage method and duration	Content (g kg^{-1})						
	Moisture	Protein	Fat	Ash	Ca	P	Fe
Freshly smoked 0 month	142	761	152	76	8.7	11.3	0.10
Frozen control 6 months	141	765	150	75	8.7	11.5	0.09
Polyethylene bags							
without desiccant 1 month	187	717	158	84	11.7	12.2	0.07
with desiccant 3 months	143	745	157	82	11.8	11.7	0.09
Traditional storage 6 months	128	711	150	69	9.2	11.8	0.09
Modified storage 6 months	111	729	154	70	8.0	10.3	0.10
Least significant difference	6.0	10.5	4.0	7.0	0.8	0.8	0.03

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

Total nitrogen decreased during storage under all storage conditions (except freezing). This could be due to protein decomposition by microbial enzymic action resulting in volatile components 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 6 months or in traditional and modified structures (Table 2). Significant increases ($P<0.05$) were, however, observed in the fat and ash contents of samples stored in polyethylene bags. Calcium, phosphorus and iron contents were noticeably very high in smoked herring.

Protein decomposition and fat breakdown

Results showing the effect of storage methods on the free fatty acids, peroxide value, TVB and NPN content of smoked herring are given in Table 3. Smoked fish stored in polyethylene had a five-fold increase in free fatty acids within a period of 1 month. With desiccant, however, the rate of fat breakdown was significantly reduced (10.43 mg/g sample), although the product was rancid. The high microbial spoilage observed in these samples during storage could be responsible for this lipolysis. Far lower FFA values than obtained by this storage method were required to produce noticeable rancidity to the palate (Pearson 1970). No significant change was observed in the FFA of the frozen samples whereas the modified and traditional storage methods caused up to twofold increases.

Peroxide values recorded did not reflect the degree of decomposition in the samples. Physical and sensory analyses showed an advanced stage of fat decomposition and rancidity development in the samples stored in polyethylene bags. Oils extracted from these samples were dark brown in colour and solidified on cooling to 25^0C. Samples from the other storage methods, on the other hand, gave oils that remained liquid at room temperature and were lighter in colour. As noted by Dugan (1976), measurement of peroxide value is useful to the stage at which extensive decomposition of hydro peroxides begins. The low values obtained here indicated that peroxide decomposition was more rapid than its formation. This could explain why obviously rancid samples gave peroxide values several times less than the 20 meq/kg at which rancid taste generally becomes noticeable (Pearson 1970).

Table 3. Effect of storage method on the free fatty acids, peroxide value, total volatile base nitrogen (TVBN) and non-protein nitrogen (NPN) content of smoked herring

Storage method and duration	FFA (mg g^{-1})	Peroxide (meq/kg)	TVB Content (g/kg)	NPN Content (g/kg)
Freshly smoked 0 month	2.90^{e}	3.60^{a}	1.39^{c}	13.8^{c}
Frozen control 6 months	2.91^{e}	3.66^{a}	1.57^{c}	15.3^{c}
Polyethylene bags without desiccant 1 month	14.91^{a}	2.90^{b}	6.56^{a}	32.7^{a}
Polyethylene bags with desiccant 3 months	10.43^{b}	2.93^{b}	4.00^{b}	19.0^{b}
Traditional storage 6 months	6.09^{c}	2.34^{b}	0.84^{d}	12.0^{c}
Modified storage 6 months	4.59^{d}	1.30^{c}	0.70^{d}	11.8^{c}
Least significant difference	1.05	0.61	0.38	3.6

[1] Values are means of triplicate determinations expressed on dry weight basis.
[a-e] Means in a column with different letters are significantly different ($P<0.05$)

Although total volatile base nitrogen (TVBN) has been found unsatisfactory by other workers as an indicator of herring spoilage (Farber 1965), the TVBN values obtained in this study clearly demonstrated the relative suitability of each storage method used in preserving smoked herring against protein decomposition. TVBN values obtained ranged between 0.70 g/kg for the modified storage and as much as 6.56g/kg for the highly deteriorated samples stored in polyethylene bags. Farber (1965) reported a suggested upper limit of 0.60 g/kg (corresponding to about 2.0 g/kg 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 modified storage were therefore within acceptable limits. 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 re-smoking treatment. A similar increase was observed by Lu *et al.* (1988b) for traditionally stored smoked herring. On the other hand, the slight increase in TVBN during frozen storage could be the result of diethyl amine formation which is known to occur during frozen storage of fish (Howgate 1982). The decomposition of protein in the stored samples, as indicated by the changes in the TVBN values, was further confirmed by a similar trend of changes in the non-protein nitrogen (NPN) values (Table 3). NPN almost tripled after one month's storage in polyethylene but did not change significantly under the traditional and modified storage conditions.

CONCLUSION

This study demonstrated the effectiveness of the modified storage structure in providing adequate protection to smoke-dried herring against insect infestation, rodent attack and mould damage. Only about 3% storage losses were recorded over a 6-month period, showing a marked improvement over the 28% losses associated with traditional storage. Protein decomposition and fat breakdown as measured by TVBN, NPN, FFA and peroxide value were also very low, thus resulting in high sensory scores for acceptability. Storage in polyethylene is highly unsatisfactory, causing complete deterioration of the fish within one month. Addition of desiccant can only prolong the shelf life briefly. Although no loss occurred in frozen storage of smoked herring for 6 months, this method is energy intensive and, from an economical viewpoint, it appears unlikely that many small-scale village processors would be able to build large freezers. Only a 3% difference in yield was observed between freezer storage and modified storage. The latter method appears feasible and adaptable to the prevailing economic conditions in many West African nations.

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