“IMPROVED TRADITIONAL FISH PROCESSING METHODS BY SMOKING AND SOLAR DRYING IN TANA RIVER AND SOUTH COAST AREAS OF KENYA”

A REPORT

By

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CHAPTER 1

1. Introduction

In Kenya, the most popular traditional fish preservation methods are by smoke-drying, hot smoking, sun drying and dry salting. This is also reflected in the bulk of the fish sold in most markets.
In most landing areas in Coast Province between the months of April and October, the local inhabitants admit that they do not have fish.

In the other periods between November and March, when there is glut they cannot process the excess harvest hence they sell cheaply to middlemen with the rest going to waste.
The reason for this is that most beaches at the Kenyan coast e.g. Vanga, Tana River, Lamu are distant and access is difficult because of lack of regular transport, refrigeration etc. The long lapse in time from the point of catch to the landing beaches combined with other factors such as absence of ready market, high ambient temperature, deficient access roads to fishing villages and consumers demand for stable processed fish, necessitates the need for efficient preservation and storage practices to enhance its distribution. It is thus important that methods are devised for fish caught in these areas for sale to keep for long periods and retain high quality.

Fish smoking is a practice in the Tana River area of coast province where catfish is the predominantly smoked fish. Fish smoking is relevant in the artisanal fisheries in that it prolongs the shelf life of the fish, enhances flavour and increases utilization of the fish, reduces waste when catches are good, and increases protein availability to people (Jallow, 1995). Traditionally, the method uses much labour, with women complaining of smoke in their eyes. Lots of firewood is used which raise environmental concerns. Poor quality, burnt and breakable fish products with low market value are produced in the end. The use of sun dried fish is also common in several other areas of the coast. During glut, the processors in some of these areas however lay the fish on the ground or on sand occasionally covered with fishing nets or on rocks to dry (Per. Com. Fisheries Dept.). The disadvantage of this method is that the slow drying process makes it unhygienic and also contributes to partial destruction of proteins and lipid oxidation. If drying is near homes, the fish has to be brought inside every time it rains and each evening to avoid dew and its consequences such as moulds. Dust contamination, insect infestation, and exposure to harmful human and animal handling are the other disadvantages of natural outdoor drying. All these result in very low quality fish with limited market circulation hence low income.

Biochemical changes that affect quality of the traditionally processed fish occur at all times during storage. Lipid oxidation is one of the most important factors responsible for quality deterioration of fish during any form of (Serdaraghu & Felekoghi 2005) storage. Lipids are important because they carry odours and flavours and contribute to the palatability of the meats. There are also potential health benefits especially of the highly polyunsaturated fatty acids in sea fish (Cox and Karahadian, 1998). Lipid peroxidation has also received much attention because of its possible contributions to cancer and ageing. Extensive auto oxidation of fishery products is usually adequate to prevent their being marketed. Lipid oxidation in muscle can be initiated by non enzymatic and enzymatic reactions (Akhtar et al, 1998). Reactions between the by products that are derived from lipid oxidation and proteins cause undesirable changes of food properties including protein denaturation, loss of protein solubility, alteration of texture and functional properties of protein and destruction of nutrient components.

Hydroxides are the major initial reaction products of fatty acids with oxygen as shown by the following reactions of initiation, propogation and termination.

Initiation $RH + 0_2 = R\cdot + \cdot OH$

Propagation $R\cdot + 0_2 = ROO\cdot$

$ROO\cdot + RH = ROOH + R\cdot$

Termination $R\cdot + R\cdot = RR$

$R\cdot + ROO\cdot = ROOR$

RH refers to any unsaturated fatty acid in which the hydrogen is labile by being on a carbon atom adjacent to a double bond; R· refers to a free radical formed by removal of labile hydrogen (Gray 1978). Peroxides and hydro peroxides also formed in the presence of oxygen readily decompose to secondary products such as aldehydes, ketones, alcohols, hydrocarbons and polymers among others (White, 1991, Boyd et al, 1992).

Peroxide value is the most commonly used assay of oxidation in fats and oils.

The PV is an indicator of the products of primary oxidation. It measures rancidity or degree of oxidation but not stability of the fat.

Aerobic oxidative products of animal tissues give a colour reaction with Thiobarbituric acid (TBA). The intensity of the colour is a measure of degree of oxidation.

The types of TBA reactive substances produced depend on the substrate and oxidation conditions.

In this study therefore, a solar tunnel dryer has been designed for use in drying fish in south coast to try and see the advantages of drying in a closed environment heated by the sun to obtain a better quality product. Attempts have also be made to try and introduce better or improved smoking methods or ovens in consultation with and participation of the local communities and to monitor biochemical changes of products during storage of smoked and solar dried fish with emphasis on lipid oxidation..

The aim of this study was to introduce improved traditional processing techniques that could hopefully give more competitive products in the market.

1.1 Objectives

1. Production of improved traditional quality fish made by solar dryer and modified smoking oven
2. Study biochemical /physical /organoleptic changes in smoked and solar dried fish products during storage.

Hypothesis 1

Fish produced using solar drying will be of better overall quality than fish produced by traditional methods.

Hypothesis 2

Fish produced using improved smoking methods will be of better overall quality than fish produced by traditional methods.

Hypothesis 3

The shelf life of fish processed by improved smoking methods will be longer than fish produced by conventional traditional methods.

Hypothesis 4

The shelf life of fish processed by solar drying will be longer than fish produced by traditional drying methods

CHAPTER 2

2. Materials and methods

2.1 Socio-economic view towards improved fish processing

Questionnaires were designed and administered to identify individuals, communities or organized groups that are actually interested in improved traditional fish processing in some regions of the Coast Province. This was to help know groups that would own the projects in future once introduced.
The places identified where interest was shown were Mpeketoni in Lamu, Moa and Lango la Simba in Garsen Witu area of Tana River, South coast areas of Vanga and Gazi also showed an interest in solar dried methods of processing fish as well as smoking.

2.1.1 The Lango La Simba area

This lies along the Garsen – Lamu road and in between Garsen and Witu. There are individual fish smokers. They fish in the ox – Bow Lake also called Lango la Simba. Tilapia, Catfish (Clarias) and Lungfish (Protopterus) are the common fish landed. The fish are mainly smoked. The processors are mainly female. They are comprised of tribes like the Luo and Luhyia as well as the local Pokomos. Their current method of smoking involves use of gurney bags pegged on 4 wooden pillars acting as support and creating a smoking chamber. At the top, a wire mesh is laid with the corners lying on the wooden pillars and providing support. The fish are laid on the wire mesh and the fire source is firewood from a normal three stone corner traditional cooking stove. Old women are involved in fish smoking while men go fishing. The younger generation is not involved. They cite a lot of work involved in the processing as the main undoing. They market their fish as far as Malindi and Mombasa. The Catfish fish range from 0.5Kg to 1kg, some of the tilapia can reach 0.5 kg and the lungfish range from 0.5 kg to even 3kg. The individuals are interested in improved fish smoking and a chorkor like oven might be constructed for them in future to be shared.

2.1. 2 Mpeketoni

This is in Lamu area. There is an organized women's group of fish smokers by the name "Lake side Women group" comprising four tribes – the Luo, Kikuyu, Kamba and Luhyia and a sub- set group within them called Ounde women group comprising only the Luo. They are in Lake Kenyatta. They also use gurney bags just like are used by those in Lango la Simba. They mainly smoke Tilapia which

are all stunted in size ranging from 10 -15 cm. They sell them for Kshs. 2 per piece after smoking in areas like Kaloleni and Kokotoni mainly to the Giriamas. They store the fish in sacks and any unsold pieces are re-smoked using low heat then sold. They complain of fire, too much smoke, lots of firewood being used, inconsistency of smoke volume and non-uniformity of smoke distribution during the smoking process. The older women smoke the fish; the men go fishing while the youth site same issues like the work being tedious. The groups are quite interested in introduction of improved smoking methods.

2.1.3 Tana River – Moa

Moa is in Tana River district. It is a major fishing village that lies 4 km off the Garsen- Witu road.

2.1.4 Background of the fishing area –

The fishing area is one of the ox bow lakes along Tana River. The Lake is known as lake Moa. The source of Lake Moa is the Tana River that empties its waters during flooding into this lake.

2.1.5 Abundant Catch Period

During drought the water level reduces and the river is cut off from the lake, this is when most fish are concentrated in one place in the lake and abundant catches occur.

2.1.6 Dominant species

Catfish (*Clarias)*, Tilapia and lungfish (*Protopterus*) are the main fish landed and preferred in the area. Some species of marine fish like the marine Catfish *Galeichthys* and a close relative of "crocodile fish" – *Palleliofeliceps* find their way in these waters and are landed.

2.1.7 Processing

Fish smoking and sun drying are predominant methods of preservation

Catfish is most popular among the landed fish.

The survey in Moa however yielded slightly different observations from Mpeketoni and Lango la Simba.. The fisher-folk process the fish themselves. Men are involved in both fishing and smoking. Men have built smoking ovens made of clay next to their huts. The fish is landed in fairly fresh

condition as it takes a shorter time from end of fishing to landing. Very few fish are sold fresh. Most fish are just smoked by the owners. They have transformed themselves such that it is not possible for a third party to buy any of the landed fresh fish.

2.1.8 The processors

The composition of people here is mainly Luo, Luhyas and lately the Ormas have been influenced and joined in the fish trade. They live all in mud huts with grass thatched roofs. They are mainly Christians and Muslims. They have constructed traditional smoking ovens next to their huts. Each household has at least one smoking oven. The smoking ovens are manned and owned by individuals. The villages extend over several kilometers along the lake and mainly along the river. The trend of housing and smoking ovens is repeated all through. Both married and unmarried men are involved in the trade with the age bracket of 31-45 years forming the majority. The fishing is a full time occupation. They send their wives who are stationed in market outlets elsewhere the fish to sell.

2.1.9 Income from fishing

Most people abandoned farming for economic reasons and have been in the fish trade for more than 5 years.

The monthly incomes are between 4000 to 8,000/=. This is still below the monthly income of the lowest paid government worker. They are therefore not rich as this translates to about 1.7-3.5 $ a day gross.

For the Luos and Luhyias any other form of farming like rearing of cattle is done on their behalf up country.

2.1.10. Fishing facilities

All fishermen use dug out canoes. The investments are mainly in the nets that cost Ksh. 800/= ($10). The Ormas however use line fishing and spearing as well as traps. There are no cold storage facilities in the area. There is no investment in any type of cooling facilities be it ice, ice boxes etc Most people have chosen smoking and sun drying because of shelf life and preferences.

2.1.11 Trade

They do whole sale and retailing. The men fish and smoke the fish which in turn they give to their wives to sell in other markets far from the landing places. This is a closely-knit business society. The cost of operations they meet are during transportation of the fish and municipal fees in the markets. Packaging is in newspapers at time of retail.

Incase outsiders penetrate the purchasing ring at the landing beaches they purchase the fish and hire the smoking kilns belonging to the fishermen.

Otherwise fishermen preserve the fish themselves and only sell the excess they cannot cope with to outsiders because of low capacity of their smoking kilns.

The market area for the smoked fish is wide and reaches as far as Mombasa, Nairobi and even Kisumu. Quantities of fish fluctuate though.

There is room for improvement especially on quality and quantity to get a wider market. The fish once smoked are sold at about Ksh. 50 per Kg (0.7 $)

2.1.12 Trade projection

Most fishermen cum smokers are interested in expanding their trade and would prefer better market prices and better quality fish and are open to advise.

2.1.13 Introduction of improved fish processing methods

After a series of interactions, meetings between the fishing community in Moa, the local administration and the lead scientist from KMFRI, it was agreed that the improved method of smoking be tried out to evaluate differences in fish quality and fuel consumption among others. This improved smoking oven was to be set beside the traditional smoking oven in use next to the hut of a selected individual after agreements among the fishers.

2.1.14 Marine Fish smoking in Gazi and Majoreni

In Majoreni, Sineno Ngoma group which has 46 members of both men and women with an interest in fish smoking were also identified through questionnaires. They are located at Majoreni in Vanga area – a major fishing region in the coast. This group has some members with rudimentary interests and

structures in improved fish smoking methods. The Sineno Ngoma group was chosen as one pilot site for improved fish smoking of marine fish. Fishing in Majoreni also goes on through out the year unless it is raining because the shelf is sheltered.

In Gazi, the women groups identified were Mpaji ni Mungu and Shikamoo women groups. The technology of fish smoking had never been practiced by the two women groups in Gazi. They were involved in each step of the process in the initial days of training and were able to smoke the fish themselves subsequently.

2.2 Construction of smoking oven in Gazi and Moa

This included construction of some chorkor-like ovens with all the necessary parts- a combustion chamber, smoking unit and a set of trays. The combustion chamber was rectangular, twice as long as it was wide and was divided by a wall down the middle and with two stokeholes in front. The length of the chamber was 92 inches with a breadth of 46 inches and a height of 24 inches. The thickness of the wall was 6 inches. The width and height of the stokehole was 15 inches and the depth of the fire pit 5 inches. The combustion chamber was constructed using blocks in Gazi while in Moa clay was used to imitate the existing smoking ovens. The trays were 88 inches long and 40 inches wide with holding handles. An oil drum was also moulded in Gazi and Majoreni as an example of traditional process and its operation during the smoking process was demonstrated. Its holding capacity was however found to be small and less interest was shown in it further.

2.3 Some Preliminary preparations for fish smoking in the study areas

All items for processing like buckets, basins etc were purchased for the groups in Moa, Majoreni and Gazi. This has helped to generate interest in the village as we encourage the locals to participate in the smoking exercise.

Complete repair of a borehole in Majoreni to ease water problem during processing was also undertaken successfully.

2.4 Women Group Training in Gazi

Since the two women groups in Gazi had never practiced this technology of fish smoking, they were involved in each step of the process in the initial days of training and were starting to learn to do it

themselves subsequently. They started to smoke the fish themselves and organoleptic and storage score for the fish smoked by them is reported

2.5 Fish procurement

Fish was purchased or donated in the Gazi beach landing site from the Gazi fishermen cooperative society a day to processing by the local field officer and on instructions about which species to try and select. They were taken and kept in a deep freezer in the Gazi village about 1km away from the smoking point. In Majoreni fish was also either donated or money given to representatives of Sineno Ngoma women group to purchase fish a day or night before processing. In Moa fish was purchased and some contributed by fishermen for trials on the improved smoking oven.

2.6 Fish handling and initial processing

Organoleptic quality of the fish was assessed to establish freshness. In Gazi, the fish were then transferred to the cleaning slabs in the fish Banda whereas in Majoreni they were taken to the concrete slab next to the borehole. In Moa, fish were washed and placed in containers without salt. In all the three places the fish were identified, gutted, gilled, washed, sorted according to size and placed in plastic containers waiting for salting. Fresh samples were taken from each representative species and kept in ice in cool boxes to be transferred to the lab in KMFRI to provide baseline data. Most marine fish were noted to be grade II at the start of the smoking experiments owing to delayed icing or cooling as the fishing boats carry no ice and the pre-processing period is long. The fish from Moa were very fresh as landing delays were avoided. Most representative species landed according to quantity were used. Though with time, this became a problem because getting similar samples repeatedly was not easy to sustain the study.

The fish were salted while in the buckets diversely. The smaller fish weighing up to 500g were salted just enough to human taste, (220g against 5 Kg of fish) muscle of the bigger fish were slit using knives and salt rubbed in. All the treatments were left to stand for 30 minutes. The fish were then transferred to the plastic baskets with sieves to drain. The fish were transferred to the smoking trays, which were held at an angle for about 1 hr for complete drainage and for development of gloss after which smoking commenced.

2.7 Smoking process

The wire mesh of the improved chorkor-like oven was cleaned with vegetable oil to condition it so that fish muscle does not get stuck during the process of turning the fish and reduce quality.
The fresh fish were laid on the layers of chorkor- like trays. The bigger fish were laid at the centre of the trays nearer the heat while the smaller ones according to sizes towards the outer sides with the smallest at the furthest end of the tray edges. As smoking commenced, the top most tray was covered with a fitting sheet of plywood to control smoke loss and to concentrate the smoke.

2.8. Quantities of wood

The amount of wood used to smoke the fish was weighed at the start of the smoking process to compare wood fuel consumption between the traditional and improved smoking oven in Moa where both types practically existed. Each time the wood was depleted during smoking any fresh wood to keep the fire on was weighed before being added. The total weight of wood at the completion of smoking was recorded as the final weight used.

2.9. Number of smoked fish

This was tested in Moa. The fish to be smoked were laid on the smoking trays on the improved oven and on the smoking rack of the traditional oven. The traditional oven could only accommodate fish in one layer. For a similar area occupied, the fish were placed in 3 trays in the improved oven one on top of the other.

2.10. Drying rate

Moisture loss was compared over specified times during the drying process for information purposes only. This will be studied in more detail in future.

2.11 Completion of smoking

Towards the end of the smoking process, brown sugar purchased from the local supermarkets in Mombasa was added to the fire in case of Gazi fish and rice bran grown locally in Vanga in case of Majoreni fish to impart colour.

The fish were then removed at the end of the smoking period, placed in open plastic trays to cool and later transferred to smaller plastic trays with smaller mesh sizes to prevent rodents and larger insects. They were then transported to the laboratory in KMFRI. They were kept in open lab benches. Small insects (ants) were a problem initially. A particular plant oil was applied in areas around the trays keeping a distance of 5 cm all round. This prevented further insect infestation though further investigations on insect infestation during storage are encouraged. Fresh samples were kept at -20 ^{O} C in the freezer at KMFRI till analysis.

2.12 Sampling

Sampling at regular intervals to assess the chemical and organoleptic quality parameters during shelf storage was carried out. Initially however sampling was done during the actual smoking process and at specific intervals to determine some biochemical changes especially lipid oxidation with emphasis on TBARS and PV occurring during the actual process of smoking and during storage of the fish. In Moa, an instant reaction to the smoked fish using traditional and improved methods of smoking was carried out to evaluate the effectiveness of the improved smoking method.

There was lack of consistency in landed marine fish at times especially in Gazi and Majoreni to allow for collection of adequate similar species. So situations arose whereby fish landed variously were of different species each time. This made consistency for studying a particular species difficult. In which case we could end up with less fish of a particular species not enough to give samples for analysis of all the parameters.. This has forced us to give results only for parameters analysed as per available quantity of the fish. Such results are also reported

2.15 Biochemical analysis

Moisture content, TBARS and Peroxide Value (PV) were determined according to standard methods.

2.16 Organoleptic Assessment

A taste panel was established in KMFRI among staff members.(though quite a number of unofficial tasters existed in the village areas as well as among those who chanced to come across the smoked fish).This panel at KMFRI was not a trained one. The attributes were taste, texture, odour, shape, appearance and aroma. The hedonic scale used was from 1- 9 where a score of 9 was like extremely and a score of 1 was dislike extremely. A score of 5 and above was considered acceptable.

2.17 Determination of Peroxide Value

2.17.1 Lipid extraction

This was done according to Bligh and Dyer (1959) with some modifications. 10g of fish mince was homogenized with a mixture of 20ml chloroform and 40 ml methanol every 30 seconds for 2 minutes in an omni mixer. A further 20ml of chloroform was added and the mixture homogenized for 30 seconds (15 seconds each time). 20mls of distilled water was added. Homogenization took place for 30 seconds split into 15 seconds each. The mixture was then filtered under vacuum using a buchner funnel and whatman filter paper No.1. The filtrate was stored and the remaining defatted cake underwent the same process as above.The final filtrate was pooled together and the defatted muscle discarded.The filtrate was then centrifuged at 3,000g for 10 minutes The resulting chloroform lipid mixture was then filtered off after mixing with anhydrous sodium sulphate. The resultant solution was filtered off and the remaining chloroform evaporated. The oil was then weighed, stored under in vials at – 20 deg C. till required.

2.17.2 Peroxide value

A standard curve was prepared in triplicate as follows:
10ml screw cap vials were washed with acetone. In each vial 5ml of ethanol, 100 µlitres of 30% ammonium thiocyanate (NH_4SCN), 200µlitres hexane and 3.5% HCl was added to give the concentrations 0-10 µlitres as shown below in the table below. Ferric chloride solution (10 µgrams/100µlitres 3.5% HCl) was finally added and the solution mixed for exactly 3 minutes before absorbance was read at 500nm.

Ethanol was used to autozero the spectrophotometer.

Vial	$FeCl_3$ (µlitres)	3.5% HCl (µlitres)
A	0	100
B	25	75
C	50	50
D	75	25
E	100	0
F	200	0

A standard curve was then plotted with the following values:

$FeCl_3$ Conc. µlitres/ml	Absorbance
0	.014
2.5	.05
5.0	.082
7.5	.130
10.0	.178
20.0	.330

Blank absorbance =.085

Intercept =.0092

Slope =.01632

The concentration of peroxide value in the oil was read against the standard curve.

2.17.3 Oil sample treatment

Weighed amounts of oil from the various species were placed in screw cap vials. 100 µlitres of hexane was added to dissolve the oil. 5 ml absolute ethanol and 100 µlitres NH_4SCN solution was added and the mixture vortexed. 100 µlitres of ferrous chloride solution (40mg $FeCl_2.4H_2O$ in 10 ml 3.5% HCl) was added. The whole mixture was vortexed for exactly 3 minutes and absorbance read at 500 nm.

The blank was prepared by mixing 200 microlitres of hexane, 5ml ethanol, 100 µlitres 30% NH_4SCN, 100µlitres $FeCl_2$ in a screw cap vial, vortexed for 3 min and absorbance read at 500nm

The peroxide value was calculated as follows:

$$PV = \frac{Abs\ (s) - Abs\ (b) - c/m}{55.84 * \text{Sample mass}}$$

Where

Abs (s) = Absorbance of Sample

Abs (b) = Absorbance of Blank

c = Intercept of Standard curve

m = Slope of standard curve

$$\text{Sample mass} = \frac{\text{Weight of oil}}{\text{Solvent Volume}}$$

Units : MilliEquivalents of Peroxyoxygen/Kg of sample

2.18 Determination of TBARS

This was according to Pearson (1991). 10g of fish muscle was macerated with 50 ml distilled water for 2 minutes and then washed into a distillation flask with 47.5 ml water. 2.5 ml of 4 M hydrochloric acid was added to bring the pH to 1.5. This was then followed by anti foaming reagents. An electric mantle was used to heat the flask. 50 ml of distillate was collected in 10 minutes. 5 mls of the distillate was pipetted into a glass-stoppered tube, 5 ml TBA reagent was then added, stoppered and shaken. It was the boiled in a water bath for 35 minutes. A blank was prepared. The tubes were cooled and absorbance was read at 538 nm using 1 cm cells from the spectrophotometer.

The TBA no. (as mg malondialdehyde per kg sample was calculated as) = 7.8D where D was the absorbance from the spectrophotometer.

2.19 Moisture Content

Dry aluminium pans were dried in an air oven in duplicate at 100 ^{0}C for 15 to 30 min. The pans were cooled in the desiccators, weighed and their weights recorded. 1-2 g fish muscle samples were added and the weight of the pan and sample recorded. The dry pans and sample were placed in the oven at 100 ^{0}C overnight. They were then removed, cooled in desiccators weighed and weights recorded. The calculations as dry matter were computed as follows;

% Dry Matter = (Dry weight/Wet weight) * 100

% moisture = 1- Dry Matter

Data Analysis

SPSS was used.

Units of Expression: PV as Milliequivalents per Kg of Oil and TBARS as Milligrams of Malondialdehyde per Kg of fish.

CHAPTER 3

3.0 Results and Discussion (smoked fish)

The oxidation of unsaturated fatty acids or triglycerides in seafood involves the formation of free radicals and hydro peroxides. Such intermediary compounds are unstable and cause oxidation of pigments, flavours and vitamins.

The oxidation depends on the composition of the fat lipids in the fish (Al Khayat &Schwall, 1983) and the rate and extent of oxidative deterioration depends on factors such as storage period and temperature, saturation degree of fatty acids, presence of antioxidants or prooxidants, and availability of oxygen (Serdaroglu and Felekogly 2005). The highly unsaturated fatty acids commonly found in seafood are particularly sensitive to oxidative changes during storage. This is because during storage and heat treatment, fat is subjected to hydrolysis, oxidation and polymerization that result in quality deterioration with respect to sensory quality and nutritive value (Marzena & Mirislawa, 2005). Although the mechanisms of such processes are essentially the same in different fats, the rates at which different fats undergo deterioration reactions vary (Che Man et al, 1999).

3.1 Lipid oxidation in some smoked marine fish caught in July

The fish studied were *Gerres oyena*, *Lutjenus argentimaculatus* (Red Snapper) and *Vanamugil seheli* (Mullet). The fish were landed in Majoreni.

The oil content in smoked Gerres oyena after day 1 was 7.53 %. This rose to 11.30 after 8 days and finally to 10.19 after 28 days in storage. The PV increased from 10.80 in day 1 to 18.17 in day 8. It then peaked at 21.48 in day 11. There was a slight reduction in PV on day 14 to 20.71 and then a drop to 8.50 mEq/Kg after 28 days (Table1).

Table 1 %Oil and PV for Gerres oyena caught in Majoreni in July

Day	Oil	PV(mEq/Kg of oil
1	7.53 ±3.36	10.80 ±1.07
8	11.30±3.33	18.17 ± 0.39
11	7.27±4.8	21.48 ±0.44
14	5.38	20.71 ±0.34
28	10.19	8.50 ±2.34

The oil content *for Pomadysis hasta* increased during storage from 9.7 to 14.8 in day 6 and finally to 17.96 after 11 days storage period. The PV was 15.95 on the first day of storage after smoking. This rose to 25.68 in day 6 and dropped to 15.26 after 11 days (Table 2).

Table 2 % Oil and PV in *Pomadysis hasta* caught in Majoreni in July

Day	%Oil	PV mEq/Kg
1	9.70	15.95±0.75
6	14.81	25.68±0.75
11	17.96	15.26±2.17

The red snapper had an oil content of 2.33 at the beginning that increased to 4.88 on the 11th day of storage.

The PV was 61.65 on the 4th day of storage. This increased to 112.86 after 6 days then dropped to 15.17 by the 11th day (Table 3).

Table 3 % Oil and PV in Red snapper caught in Majoreni in July

Day	% Oil	PV mEq/Kg
4	2.33	61.65 ±0.09
6	2.41	112.86 ±0.19
8	3.05	31.06 ±0.32
11	4.88	15.17 ± 0.54

The PV for mullet was 57.79 in day 1. This increased to 76.55 in day 8 then dropped to undetectable levels in day 28 (Table 4).

Table 4 % Oil and PV Mullet in Majoreni in July

Day	%Oil	PV mEq/Kg
1	4.49	57.79 ±0.114
4	5.78	70.06 ± 0.49
8	-	76.55 ±1.67
11	14.51	16.91± 1.22
28	6.52	0.000

The fluctuation in oil was probably due to decreased moisture in the sample leading to greater amounts of sample being used hence increase in oil. Also, after smoking, the % fat increased due to loss of moisture and an increase in dry matter content per unit weight following sample dehydration. The fluctuation in the oil content may be was also due to variation in individual fish selected at sampling periods because of heterogeneity in fish body composition.

Table 5 % Moisture in Mullet caught in Majoreni in July

Day	% Moisture
1	30.17±
10	20.75±0.77
14	33.11±
19	20.66±0.56
22	20.28±

Table 6 % Moisture in Red snapper caught in Majoreni in July

Day	% moisture
1	46.23 ±3.69
10	29.85±0.83
11	23.21± 0.44
14	12.66±
19	16.70±0.10
22	20.42±0.14

Table 7% moisture for Geres oyena caught & smoked in Majoreni in July

Day	% Moisture
1	45.01 ± 0.12
11	42.59±
14	24.91±4.56
19	17.00 ±1.75
22	17.66 ± 0.19
28	13.53 ± 0.79

The moisture pattern for Mullet, Red snapper and *Gerres oyena* decreased after smoking and continued to decrease during storage (Tables 5, 6, 7). This may have been due to reduced water holding capacity and evaporation due to storage conditions to some extent. The fish were kept on open lab benches.
The level of TBARS in *Gerres oyena* was 0.39 mg/Kg (Table 8). This increased to 0.59 on day 8 and dropped to 0.07 on the 19th day of storage.

Table 8 TBARS for Gerres oyena caught in Majoreni in July

Day	TBARS (mg Malondialdehye/Kg
0	0.39 ±0.09
8	0.59 ±0.09
14	0.42 ±0.04
19	0.07 ±0.004

For Mullet, the TBARS for fresh fish was 0.83 (Table 9). This increased to and peaked between 3.96 and 3.74 on days 4 and 8 respectively. Then the levels declined to 0.12 in day 19.

Table 9 % TBARS in Mullet caught in Majoreni in July

Day	TBARS mg malondialdehde/ Kg
0	0.83 ±0.10
4	3.96 ± 0.119
8	3.74 ± 0.03
11	0.41 ± 0.03
14	0.38 ± 0.01
19	0.12 ±0.04

For the Red snapper, the level of TBARS in the fresh fish was 0.93 (Table 10). During the storage period on day 1, the level was 0.16. Then as storage proceeded, the level increased to 0.16 and as storage progressed, it increased to peak at 1.87 after 8 days of storage. It later dropped to 0.06 after 23 days of storage.

Table 10 % TBARS in Red snapper caught in Majoreni in July

Day	TBARS mg Malondialdehyde/Kg
0	0.93 ± 0.36
1	0.16 ±0.01
4	0.22 ± 0.09
8	1.87 ± 0.03
14	0.34 ± 0.026
19	0.11 ± 0.03
23	0.06

The peak value in PV for Gerres oyena was on day 11 to 14 with values of 21.48 and 20.71 respectively. The peak values of PV for mullet were in days 4 to 8 with values of 70.06 and 76.54 respectively. These two latter values were rather high but equally high were values of TBARS during the same period (3.95 and 3.7). The PV for Red snapper was highest in day 6 with a value of 112.8.

The pattern of increase then decrease in PV is seen in all the cases. Such observations where there is a rise in PV levels and then a drop over time had been made by Al Bulushi et al, (2005); Nair et al, (1976) and Ke et al, (1977)

From these results, there was some pattern on PV and TBARS during storage. Not much is available on lipid oxidation during storage of traditionally smoked fish. Marzena and Miroslawa (2005) observed increase in PV and TBARS then a drop when they used a model oil frying system. A decrease in PV after an initial increase has been observed by Che Man et al (1999). A significant decrease of PV after reaching maximum values confirm that peroxides are unstable components and are highly susceptible to further changes that result in formation of secondary products (Marzena and Miroslawa, 2005). According to Nair, (1986), malonaldehyde, a TBA reactive compound is capable of crosslinking amino acids through amide linkages and may also crosslink with nuclei bases or may transfer the MDA moiety from one to another. This could help explain the decrease in levels of TBARS with time. The decrease in levels of TBARS after an increase is because the carbonyls are unstable and react easily with other compounds (Aubourg, 1997). It is also known that oxygen accessibility, degree of tissue disruption, storage temperatures can affect shelf life and are important in rancidity (Undeland et al, 1999). During the process of oxidation of oil, there is rapid build up of hydroperoxides (Undeland et al, 1999). When storage is further extended, it could be postulated that

the rate of hydroperoxide cleavage and hydroperoxide reactions exceed the hydroperoxide formation rate (Undeland et al, 1999) However this would imply that other oxidation products would form more rapidly and detected as TBARS. But TBARS also react and breakdown so may not necessarily accumulate. This explains therefore the decrease of TBARS in time. Also, the process of lipid oxidation takes place via chemical pathways of initiation, propagation and termination. At the onset of smoking at increased temperature and in the presence of oxygen, initiation, propagation and termination would proceed at rapid rates in one phase at the end of smoking. By the time the smoked fish storage starts, very little products of oxidation are remaining most having been produced and consumed by the smoking process. Oil is however still present in the fish being stored capable of going through the cycle of oxidation again. After smoking and at the beginning of storage of smoked fish, TBARS and PV are however quite low and lipid oxidation in this phase could enter an "induction phase". With time however, due to exposure of the fish to further ambient temperatures and in the presence of oxygen, lipid oxidation again moves to initiation, propagation and termination stages may be at much lower levels. During initiation and propagation stages, the levels of PV increase and during termination they decline hence the drop. The heterogenous nature of fish fats and the smoke itself are also responsible for lack of clear patterns in lipid oxidation in smoked fish with reference to PV and TBARS.

3.2 Lipid Oxidation in Freshwater fish from Tana Tiver

This included Galiechythis feliceps (Marine Catfish), Clarias gariepinus (catfish) and Pappiliofeliceps spp- (fish resembling "crocodile fish") and to a limited extent Protopterus.

The TBARS for Clarias was 0.29 when fresh. After 2 days storage, (Table 11) it was 0.12 then it decreased further to 0.05 after 5 days then to undetectable levels after 10 days in storage.

Table 11 TBARS in Clarias

Days	TBARS mg Malondialdehde/Kg
0	0.29
2	0.12
5	0.005
10	0.000000

For marine catfish which is found in the Lake Moa, the TBARS were 0.38 for the fresh fish (Table 12). At the onset of storage on day 1, the TBARS were 0.33. This decreased to 0.09 in day 5 and to undetectable levels from day 18 to 23.

Table 12. TBARS in smoked marine Catfish during storage

Day	TBARS mg malondialdeyde/kg
0	0.38
1	0.33
5	0.04
18	undetectable
23	undetectable

For the *Pappiliofeliceps like fish resembling* - "crocodile fish" the TBARS were 0.70 after 1 day of storage (Table 13). This decreased to 0.56 on day 2 then to 0.54 in day 10 and decreased further to 0.20 on day 23.

Table 13 TBARS in smoked "Pappiliofeliceps "

Day	TBARS mg malondialdehyde/kg
1	0.70
2	0.56
10	0.54
23	0.20

The oil content of the fresh fish is as summarized in table 14.

Table 14 % Oil content of fish from Tana River area

Species	% Oil content for fresh fish
Clarius (Fresh water catfish)	0.64
Galeichthys feliceps(Marine catfish)	0.30
"Pappiliofeliceps"	0.34

The lower levels of TBARS could be due to unstable nature of the products after smoking in fresh water fish coupled with low levels of fat recorded.

3.3 Organoleptic results for selected marine fish caught in July

Freshness test results from organoleptic tests indicate that *Gerres oyena* was still acceptable at day 15 with a score of 5.38. (Fig 2). For Red snapper, the score was 7.5 after 15 days storage (Fig 3).

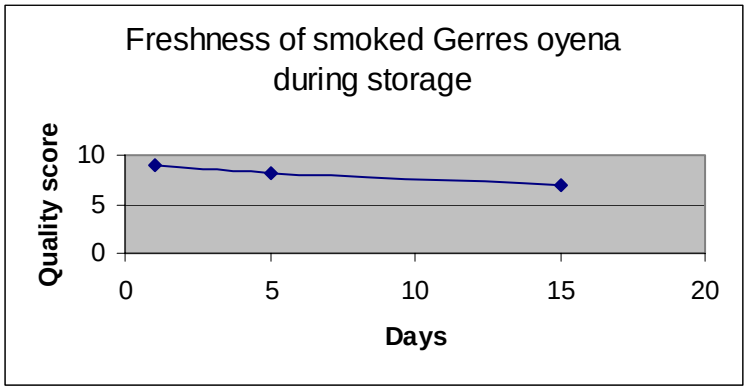

Fig 2 Freshness of smoked G. oyena during storage

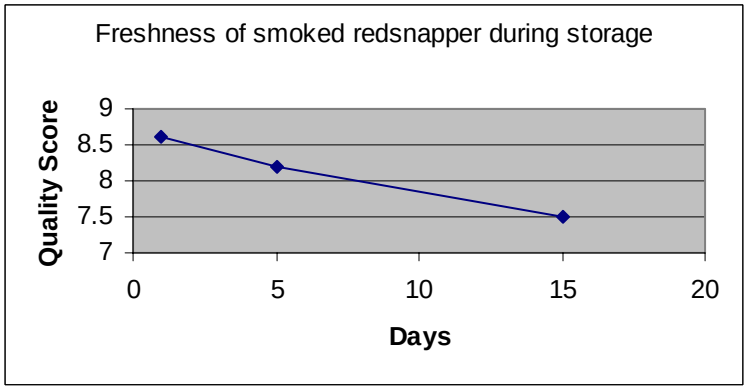

Fig 3. Freshness for smoked Red snapper during storage

This was quite acceptable while for mullet in this batch, 15 days was still fresh with a score of 7.2 (Fig 4)

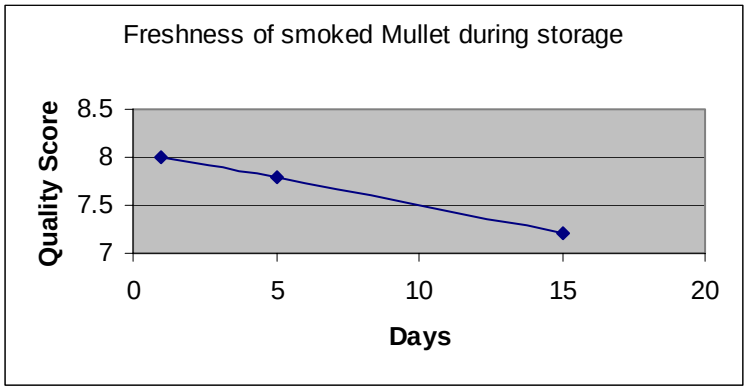

Fig 4. Freshness for smoked mullet during storage

It is important to note that the freshness scores were however decreasing with time and that Gerres oyena had the lowest score meaning that it showed faster level of deterioration with low acceptability figures though with a score above 5 it was still fine

3.4 Response to organoleptic attributes for the fish smoked in July

Results from response to the 6 attributes for Red snapper, Mullet and Gerres oyena caught in July gave an overall mean score 6.22 which was category for "liked" score. The most preferred attribute was taste with a mean score for all the fish of 6.50 (Table 15). Appearance was next with a score of 6.43. This information helps to guide in future decisions on which attributes to consider during production.

Table 15 Mean response by panelists to all attributes for G. oyena, Red Snapper & Mullet

Attribute		Atribute score
Taste	Mean	6.50
	N	30
	Std. Deviation	2.047
Texture	Mean	6.27
	N	30
	Std. Deviation	2.258
Odour	Mean	6.07
	N	30
	Std. Deviation	2.164
Appearance	Mean	6.43
	N	30
	Std. Deviation	1.924
Aroma	Mean	5.93
	N	30
	Std. Deviation	2.067
Flavour	Mean	6.13
	N	30
	Std. Deviation	2.315
Total	Mean	6.22
	N	180
	Std. Deviation	2.113

In terms of preference per individual species after considering all the attributes, the Red snapper was preferred by the panelists with a score of 7.43. It was followed by Gerres oyena with a score of 6.00 and Mullet with a score of 5.23 (Table 16)

Table 16. Preference for G. oyena, Red snapper and Mullet landed in July

Species		Attribute score
Mullet	Mean	5.23
	N	60
	Std. Deviation	1.807
Redsnapper	Mean	7.43
	N	60
	Std. Deviation	1.711
Gerres oyena	Mean	6.00
	N	60
	Std. Deviation	2.194
Total	Mean	6.22
	N	180
	Std. Deviation	2.113

A comparison between the species however showed that the overall response to the tested attributes did not differ significantly between the test species. No further tests of significance were therefore carried out between the species owing to this though p<.06 was quite close to significant differences being in existence (Table 17).

Table 17. Statistical response to attribute and species

	Species	Attribute
Chi-Square	14.912	6.594
df	8	8
Asymp. Sig.	.061	.581

a Kruskal Wallis Test
b Grouping Variable: Attribute score

3.5 Organoleptic responses to fish caught in Tana River

The most preferred attribute was appearance. This is important because the fish turn up in remarkable contrasting shapes and appearances. This was followed by taste with a score of 5.53 (table 18). Therefore in production attention must be paid to final appearance of the fish during and after smoking. This is achieved better with the improved smoking oven.

Table 18 Response to attributes for fish smoked in Tana River

Attribute		Attribute score
Taste	Mean	5.53
	N	40
	Std. Deviation	1.908
Texture	Mean	5.00
	N	40
	Std. Deviation	2.038
Appearance	Mean	5.97
	N	40
	Std. Deviation	1.941
Aroma	Mean	5.33
	N	40
	Std. Deviation	2.105
Flavour	Mean	5.40
	N	40
	Std. Deviation	2.307
Total	Mean	5.55
	N	240
	Std. Deviation	2.059

In terms of overall preference, Clarias (catfish) had a score of 6.25 follwed by Galiechythis (which is closely related) with a score of 6.00. “Pappiliofeliceps” had an overall score of 5.28 while Protopterus (Lungfish) had a score of 4.65 (Table 19)

Table 19 Overall organoleptic responses to preference for selected fish from Tana River

Species		Attribute score
Galiechythis	Mean	6.00
	N	60
	Std. Deviation	1.913
Clarias	Mean	6.25
	N	60
	Std. Deviation	2.014
“Pappiliofeliceps”	Mean	5.28
	N	60
	Std. Deviation	1.896
Protopterus	Mean	4.65
	N	60
	Std. Deviation	2.065
Total	Mean	5.55
	N	240
	Std. Deviation	2.059

After performing a Kruskal-Wallis Test, it was noted that there was a significant difference in response between the species (Table 20).

Table 20. Statistcal response to species

Kruskal-Wallis Test

Test Statistics (a,b)

	Attribute	Species
Chi-Square	6.000	24.555
df	8	8
Asymp. Sig.	.647	.002
a Kruskal Wallis Test		
b Grouping Variable: Attribute score		

Comparison between species shows that the overall response to the tested attributes differed significantly between the test species (Chi square=24.55, p= 0.002). Further statistical evaluation was carried out. It was noted that there was no significant difference in response (p=0.402) between Clarias (Catfish) and Galiechythys (Table 21). There was however a significant difference in response (p<0.05) between Clarias and "crocodile fish". There was a preference for Clarias. There was a highly significant difference (p< 0.05) between Clarias and Protopterus. There was a strong preference for Clarias. There was a significant difference (p<0.05) in preference between Galiethychys and "Pappiliofeliceps". There was preference for Galiechythys. There was no statistical difference between "Pappiliofeliceps" and Protopterus though there was better response for "Pappiliofeliceps"

Table21. Responses to various smoked fish species from Tana River by taste panel

Species	Mean Rank	Sig. Difference	Comment
Clarias griepinus	63.12	0.402	No Sign. Difference. Better response for Clarias
Galiechthys feliceps	57.88		
Clarias gariepinus	67.03	0.037	Sign. Difference. Better response to Clarias
"Pappiliofeliceps"	53.98		
Clarias gariepinus	71.47	0.00	Sign. Difference. Better response to C.gariepinus
Propterus	49.53		
Galiechythys feliceps	69.14	0.006	Sign. Difference. Better response to Galiechthys
"*Pappiliofeliceps"*	51.86		

3.6 Organoleptic response to smoked marine fish landed between February and April

The batch of fish landed between February and April 2005 consisted of Mullet (Vanamugil seheli), Carangidae, Pomadysis hasta, Pomadysis maltimaliculatum and Crenidence. In this batch, taste had the highest mean response as an attribute with a score of 6.03. Scores for texture, odour, appearance, shape ranged between 5.53 to 5.94 (Table 22).

Table 22 Mean response by panelists to all attributes

Attribute	Mean	N	s.e.m
Taste	6.03	200	.209
Aroma	5.94	200	.208

Texture	5.85	200	.201
Shape	5.53	200	.201
Appearance	5.53	200	.207
Odour	5.48	200	.207

Response to taste was always higher in score than the other attributes like texture, odour, aroma, appearance shape etc . There was a statistically significant difference in response between *V. seheli* and *C. carangoides*. The response was better for *V. seheli* as compared to *C. armatus* (Table 23*)*. There was a significant difference ($p<0.05$) between *P. hasta* and *V. seheli*. Preference was better for *P.hasta*. There was a significant difference in response between *V. saheli* and *P. maltimaliculatum* ($p<0.05$) with better preference being shown towards *V. seheli*. There was a significant difference in response between *C. armatus* and *P. multimaliculatum*. There was better preference for *C. armatus*. There was a significant difference in response between *P. hasta* and *P. multimaliculatum*. There was better preference for *P. hasta*. There was a significant difference in response between *C. armatus* and *P. hasta*. *P. hasta* was preferred. There was a significant difference in response between *V. seheli* and *C. crenidence*. *V. seheli* was preferred. *P. hasta* was significantly preferred to *C. crenidence* ($p<0.05$) and *C. crenidence* was preferred to *P. multimaliculatum* ($P< 0.05$).

Table 23. Responses to various fish species by Taste Panel

Species	Mean Rank	Sig. Difference	Comment
Valamugil seheli	254.6	0.023	Sign. Difference. Better response for V. seheli
Carangoides armatus	226.40		
V. seheli	226.42	0.023	Sign. Difference. Better response to P. hasta
Pomadysis hasta	254.58		
C.armatus	213.58	0.00	Sign. Difference. Better response to P. hasta
P. hasta	267.72		
C. armatus	269.25	0.00	Sign. Difference. Better response to C. armatus
Pomadysis multimaliculatum	211.75		
P. hasta	286.42	0.00	Sign. Difference. Better response to P. hasta
P. multimaliculatum	194.58		
P. hasta	260.27	0.001	Sig. Difference. Better response to P. hasta
Crenidence crenidence	220.73		
P. multimaliculatum	221.35	0.002	Sig. Difference. Better response to C. crenidence.
C. crenidence	259.65		

Preference in this batch of fish was for *Pomadysis hasta* with a score of 6.56 followed by Mullet 6.43, *Carangidae* 6.10, *Crenidence* 5.16 and *Pomadysis maltimaliculatum* 4.38 (Table 24).

Table 24. Overall preference of fish according to scores by taste panelists

Species	Mean	N	s.e.m
P. hasta	6.56	240	0.137
V. saheli	6.43	240	0.137
C. armatus	6.10	240	0.132
C. crenidence	5.16	240	0.235
P. multimaliculatum	4.38	240	0.218

During storage, freshness was maintained above the score of 5 till day 14. This means that organoleptically the fish is acceptable till that time (Table 25).

Table 25. Quality score over time

	Day 1	Day 5	Day 9	Day 14
V. saheli	6.52	6.95	6.67	5.58
C. armatus	5.62	6.72	6.40	5.70
P. hasta	6.72	6.75	7.32	5.45
P. multimaliculatum	6.47	5.53	-	5.52
C. crenidence	7.05	6.63	-	6.67

3.7 Lipid oxidation in selected smoked marine fish caught between February and April

Valamugil seheli (Mullet)

The fish was landed between March and April. The TBARS were monitored over a 14 day period. There was a fluctuation in the TBARS as shown in table 26

Table 26. TBARS and PV levels during shelf storage of hot smoked mullet fish

Day	TBARS mg Malonaldehyde/Kg	PV mEquivalents/Kg
0	13.0962 ±0.11	0.26 ±
1	1.3078 ±0.016	0.1 ±
5	0.5356 ±0.016	0.05 ±
6	0.8294 ±0.009	0.3 ±
9	2.3346 ±0.03	0.16 ±
14	0.27 ±0.011	0.24 ±

The levels of TBARS were 13.09 when fresh. This was due to the holding conditions before smoking. The fish were not iced through out from landing till they were smoked. The temperatures were adequate for lipid oxidation to occur via the processes of initiation, propagation and termination. There was a drop after smoking in Day1. This could be due to the high temperatures during smoking that caused disintegration of the oxidation products. The rather low levels of TBARS continued to day 9 when there was a rise. This was due to a threshold over time being reached for oxidation to occur in the classical lipid oxidation mechanism as the samples were stored in the open and had access to oxygen and right temperatures. TBARS are also known to non specifically react with compounds such as sugars, ascorbic acid and non enzymatic browning products often present in foods (Decker et al 1998). The type of TBARS produced also depends on substrate and oxidation conditions, composition of the fat or lipid in the fish (Al Khayat & Schwall, 1983). Sen and Bhandary (1978) showed that cooking of sardine fish causes a significant decrease in oxidation rate of fatty acid components. This was seen from the trends of lipid oxidation patterns as observed by TBA determination. It was shown from their study that to obtain a significant effect during storage, 1 hr of heating was necessary. In our case, the fish is also cooked as it is being smoked. Protection against oxidative rancidity observed in cooked fish may be ascribed to destruction of lipoxidase, formation of water soluble antioxidants and destruction of heme compounds among others (Khayat and Schwall, 1983) and therefore subsequent low levels of TBARS could be due to the facts mentioned since smoke has little antioxidant effect.

According to Melton (1983), lipid oxidation products like aldehydes decrease along with increased lipid oxidation. In determining TBARS we are measuring some aldehydes. Marzena and Mirislawa (2005) observed an increase in TBARS then a drop when they used a model oil frying or heating system. In this study, there was an increase in TBARS from day 5 to 9 then a drop. TBARS showed a maximum then a decline in the presence of heat. Once the fish were smoked, they were stored in open

plastic trays on lab benches at ambient temperatures that could also fluctuate. According to Nair (1986), malondialdehyde (MDA) a TBA reactive compound is capable of crosslinking amino acids through vinly-amidine linkages and also may cross-link with nuclei bases or transfer the MDA moiety from one to another. This could explain the decline in TBARS between day 9 and 14. Carbonyls are also unstable and react easily with other compounds (Aubourg, 1997). During the period when TBARS were quite low during storage, lipid oxidation could have again entered the induction phase, then the initiation, propagation and termination at day 14 hence the decline.

3.8 Peroxide Value

The peroxide value was 0.26 mEq/Kg at day 0 when the fish was still fresh (Table 26). It dropped to 0.1 mEq/Kg after smoking. This drop loosely corresponded to the drop in TBARS. During early stages of oxidation, the amounts of TBA reactive substances in oxidized unsaturated fatty acids are closely correlated with PV, oxygen uptake and diene conjugation (Dahl et al, 1962). This was probably what happened upto day 5 of storage. Between day 5 and 6 there was an increase in PV from 0.05 to 0.3 then a drop to 0.16 in day 9 and finally it increased to 0.24 on day 14. There were fluctuations not showing any patterns with TBARS. Al Bulushi et al (2005) heated oil samples up to 105 ^{0}C for PV analysis. They could detect PV only after the second week of storage. Its value increased from 4th to 8th week then dropped slightly after 12 weeks storage. In our case, we are dealing with highly labile HUFAs whose formation and deterioration rates are faster but the pattern is the same as in the study by Al-Bulushi et al (2005). Though it is not known what standards are allowed for PV values in smoked fish oils, fresh oil usually has a PV well below 10 mEq/Kg of fat and a rancid taste may be noticed when PV is between 20 and 40 mEq/Kg (Al bulushi et al, 2005). In this study, the values are still low hence based on PV alone, the products still have good eating quality. The storage of smoked mullet can still be said to be safe in terms of lipid oxidation for a period of 14 days. This is significant because currently fried mullet which is popular takes only 2-3 days to spoil (Pers. Observation). Since the objective of this study is reduce frequency of going fishing, it is advisable that smoked mullet be considered in the diets and that goes for all fish that stay longer than fried fish during storage.

Sphyraena barracuda (Barracuda)

Barracuda was caught in February 2005. The parameters determined were Oil content,
PV and TBARS as shown in table 27

Table 27 PV, TBARS, Oil, Moisture during storage of Barracuda

Day	% Oil	PV mEq/Kilogram	TBARS mg malonaldehyde/Kg	%Moisture
0	1.25	222.12±0.15	0.16±0.011	65.77±0.88
4	2.6	92.75±0.33	0.06±0.009	44.65±
5	1,48	75.79±0.15	0.03±0.007	28.72
6	1.52	120.21±0.03	0.065±0.01	29.15±1.83
7	3	85.08±0.55	0.12±0.007	28.70±0.04

The oil content of fresh barracuda was 1.25%. The oil content showed a final value of 3 %. This was due to loss of moisture and an increase in the dry matter content per unit weight following sample dehydration. The PV levels in fresh barracuda were 222mEq/Kg. This high PV value reduced during storage. The high PV value is an indicator of primary oxidation taking place. As measured by PV, studies using tuna muscle at elevated temperatures of 40 ^{0}C have shown that tuna muscle oxidized readily without an induction period (Medina et al, 1999). During the month of February, temperatures at the coast were over 30 ^{0} C. The fish were actually held at these high temperatures before smoking. The period between landing and smoking of the fish could be more than 10 hrs with the fish being in sunlight for up to 8 hours. This period of high temperature and in the presence of oxygen and enzymes for fresh fish is ideal for lipid oxidation. So, just like tuna, the oxidation in fresh fish proceeded rapidly. Medina et al (1999) found maximum peroxide values during the first 24 hours and then decreased significantly as a result of decomposition. It is reasonable to postulate that at the onset of smoking at such high smoking temperatures and also in the presence of oxygen, there will be lipid oxidation with initiation, propagation and termination phase taking place at rapid rates and can all be lumped together as “one phase”. By the time storage of fish starts after smoking, very little products of oxidation remain, most having been produced and consumed during the smoking process. During the process of storage, the PV levels though low, it is important to note that oil is still present in the muscle. The lipid oxidation in this phase could have entered the induction phase then as storage progressed, initiation and propagation took place: oxygen and temperature are available and finally the drop was due to termination phase. Again it is not known how PV levels are to be rated for smoked fish. In the initial 4 days, the level of TBARS dropped just as PV and continued to drop till day 5. The “higher levels” of TBARS (0.16 m malondialdehyde) compared to other days is because fish once landed is held for a while at ambient temperature before smoking. The delayed period affects lipid

oxidation conditions as explained above for PV. The norm would be that secondary oxidation products are formed after primary oxidation products. Once the oxidation process approaches and is in the propagation phase, there is rapid build up of hydroperoxides (Underland et al, 1999). When the storage period is further extended, it could be postulated that the rate of hydroperoxide cleavage and hydroperoxide reactions exceed the hydroperoxide formation rate. However, this would imply that other oxidation products would form more rapidly and detected as TBARS. But TBARS also react and breakdown so may not necessarily accumulate.

Out of this study where efforts were made to see whether lipid oxidation products can be used or monitored as indicators of smoked fish spoilage during storage, the answer is varied as it depends on species, the fat composition, spawning period etc. The seven day period the bararacuda was stored it was still fresh and organoleptic tests showed palatability so in this case PV though high could not be necessarily of concern until levels or standards are established.

3.9 Lipid oxidation in relation to changes in TBARs for some smoked marine fish not caught in large quantities

Siganus canalicatus (Tafi)

These were caught during different places and periods. One group was landed in March 26th in Majoreni and kept for 21 days. The other was stored for 14 days and having been landed in June 2005.

Table 28 TBARS for *Siganids* landed in June 2005

Day	TBARS mg malondialdehyde/ Kg
1	0.15 ±0.035
5	0.28 ±0.02
14	0.23 ±0.18

Table 29.PV and Oil content for *Siganids* landed in March 2005

Day	% Oil	Peroxide value in mEq/ Kg
0	4.2	17.9±0.89
5	5.2	22.3±1.46
14	6.3	20.7±2.94
21	4.4	27.2±0.33

This is an example of lipid (Table 28 and 29) oxidation proceeding with time. In table 29, day 0 was characterized by fairly high levels of PV. This was the time when the fish was still fresh. The level of oxidation at this stage was due to oxidation depending on ambient temperatures, availability of oxygen and microorganisms in the lipooxygenase system. Lipid oxidation in the muscle can be initiated by non-enzymatic and enymatic reactions (Akhtar et al, 1998). The rate and extent of oxidative deterioration depends on factors such as storage period, temperature, saturation degree of fatty acids, presence of antioxidants and prooxidants and availability of oxygen (Serdaroglu and Felakogly, 2005). Lipid oxidation limits the possibilities of storage due to contact between highly unsaturated lipids and strong catalytic systems. However, a certain control of lipid catalysis interactions is provided for by the presence of natural antioxidants in the tissue. Immediately after catch, the antioxidant level is generally high and most oxidative attacks are inhibited. However, with time, an array of changes takes place in the tissue that disturbs the delicate balance that initially exists between catalysts and antioxidants. Among these changes are a decrease in reducing capacity, an increase in free iron, activation of heme proteins and membrane disintegration (Undeland et al 1999). Just holding fish alone in ice before freezing allows lipid oxidation to progress. Primary, secondary and tertiary lipid oxidation products (Bandara et al, 1997; Petillo & Hultin, 1995; Watanabe et al, 1999, Botta and Shaw, 1976; Aubourg 1997, Aubourg, 1995) are formed. Thus, lipid oxidation or at least the conditions for lipid oxidation to take place appear to be greatly favoured by preprocessing storage either on ice or as in our case, even faster during ambient storage. This explains the value of 17 mEq for fresh sample . After 5 days, the PV continued to rise through up to day 21. Fresh oil usually has a PV well below 10 mEq/Kg of fat and a rancid taste may be noticed when the PV is between 20 and 40 mEq/Kg (Al- Bulushi et al, 2005). Standards for PV in smoked fish products are still yet to be established. Some suggest 2 mEq/Kg (Weiss,1970) but not for fish oils, others, (Alabi & Sanni, 2003) have reported fresh Soyabean to have a PV of 20 m Eq/Kg.

The highest value of PV here rose to 27mEq and did not affect eating quality.

The fish caught in June were analysed for TBARS . Day 1 in this case was the first day after smoking. No data is available for fresh samples due to small amounts initially available.

TBARS increased from 0.15 mMAD/kg upto 0.28 during 5^{th} day of storage and dropped slightly to 0.23 after 14 days (Table 28). Values of 2 mMAD/kg are given as indicators of spoilage for other oils. Nothing is established for smoked Siganids so the fish can still be considered fresh. During storage, some oil is still in the fish flesh The levels of TBARS are quite low during storage of siganids. Protection against oxidative rancidity has been observed in cooked sardines by Khayat and Schwall

(1983). During smoking, fish is cooked and low levels of TBARS could be due to this protection. TBARS show a maximum then a decline over time (Nair, 1976). Malondialdehye a TBA reactive compound is also capable of cross-linking amino acids through vinyl- amidine linkages and also may cross-link with nuclei bases or may transfer the MDA moiety from one to another thus reduced values.

Lethrinus Lentjan

The fish were caught in March 2005.

PV was determined as well as moisture content (Table 30). The oil content was recorded during PV determination. The gaps were due to insufficient quantities of samples. The oil content rose as storage proceeded from 2% to 10%. At the fresh state, this fish was lean as the oil content was low. The increase in oil content was corresponding to decrease in moisture.

Table 30 PV, moisture and oil content of *Lethrinus* during storage

Day	Peroxide Value (mEq/Kg)	% oil	% moisture
0	41.10±0.27	2.18	
5	30.48±0.30	2.82	48.21±1.84
6	-	2.03	
14	27.66±1.79	3.64	16.25±0.67
21	23.39±9.65	10.60	17.84

The storage period was for 21 days. The PV fluctuated with time. It was a highest at 41.1 mEq when the fish was still fresh and before smoking. The PV however dropped to 30.48 mEq after smoking and on the fifth day of storage. By day 21 PV had dropped to 23.39 mEq/Kg. The higher PV levels when the fish was still fresh was due to the presence of conditions like enzymes system, temperature, oxygen, HUFAs that favour lipid oxidation (Undeland et al, 1999). The drop was due to the unstable nature of the hydroperoxides over time. The levels are not alarming during the period of storage but it leaves one in doubt of when to use PV as an indicator of spoilage of smoked fish. Changes in PV and TBARS values have been studied by (Nair et al, 1976 and Ke et al 1977) in mackerel and sardines. They found that PV reached a maximum after 4 weeks of storage then it decreased. TBA value reached a maximum after 22 weeks then dropped. This trend is however in frozen fish but according to Jones (1963) the model applies to dried fish and smoked fish is dried. Ke et al, (1977) showed that the rate of

oxidation of mackerel lipids during frozen storage is dependent upon temperature and polyunsaturated fatty acids are oxidized faster.

The factors that play an important role in oxidative reaction in fish tissue are nature of the fat i.e. the type of fatty acids, degree of unsaturation, and proportion of phospholipids; Distribution of fat in the body i.e. contact of fat in meat with aqueous solution containing accelerators and inhibitors of rancidity and the orientation of unsaturated fatty acids at an interface; Presence or absence of other chemical compounds in the tissue which may act as accelerators or inhibitors of rancidity regulations, subject to other influential factors such as Ph, chemical environment etc; External factors such as heat, light and UV rays which tend to change the equilibrium of tissue compounds.

Trichinotis bailoni (Caranx)

The caranx were landed in Majoreni in March 2005. Oil and PV were determined during storage (Table 31)

Table 31. Peroxide Value changes during storage of Caranx

Day	Peroxide Value m Eq/Kg	Oil %	Moisture %
0	23.31±	27.6	
5	35.36±0.70	12.05	35±0.76
14	40.25±0.00	14.60	15±0.068
21	66.64±0.000	11.23	16±0.23

This was a fatty fish at the period it was caught. The oil content was 27.6%. The fish was stored for 21 days.

The PV showed a steady increase with days of storage. The PV rose from 23 mEq/Kg to 40.25 mEq/Kg and to 69 mEq/Kg after 21 days of storage. The final levels were rather high (Al-Bulushi et al 2005) has obtained such results. The formation and increasing quantitites of PV is a strong indication for continuos deterioration of the oil (Martin & Harbinson, 1979). In this fish, PV can be of concern because of the fatty nature of the fish. The factors that play an important role in oxidative reaction in fish tissue are nature of the fat i.e. the type of fatty acids, degree of unsaturation, and proportion of phospholipids; Distribution of fat in the body i.e. contact of fat in meat with aqueous solution containing accelerators and inhibitors of rancidity and the orientation of unsaturated fatty acids at an

interface; Presence or absence of other chemical compounds in the tissue which may act as accelerators or inhibitors of rancidity regulations, subject to other influential factors such as Ph, chemical environment etc. External factors such as heat, light and UV rays which tend to change the equilibrium of tissue compounds. Each fish species has a specific PV behavior depending on factors like fat content etc. The higher the fat content the greater the PV formation for some or contribution (Underland et al, 1999). The continuous rise of PV is due to high fat content of the fish. The TBARS were monitored for only 6 days due to lack of samples.

Table 32 Changes in TBARS during storage of Caranx

Day	TBARS m Malondialdehyde/Kg
0	4.11
1	0.45
2	0.35
6	0.30

The TBARS for fresh Caranx was 4.1 m MDA/Kg (Table 32). This was high in the fresh state due to secondary oxidation products produced because of favourable conditions for oxidation. The amount of TBARS was 0.45 and dropped slowly to 0.35 till 0.30 in day 6. TBARS stayed low after smoking and during the short storage period. Temperature interferes with TBARS. Holding the fish at ambient temperatures before smoking is adequate to initiate formation of secondary oxidation products. The decrease in TBARS during storage of Caranx is because the carbonyls are unstable and easily react with other compounds (Undeland, et al 1999). TBARS also react and breakdown so may not accumulate in accordance with rise in PV. The fishing season has a strong influence on the level of oxidation products required to make a rancid smell evident. In lean spawning herring with about 4% fat, Underland et al (1999) found rancidity to develop at PV of 21 whereas in fattier autumn herring having about 11% fat, a PV of 40 had to be reached, and, where the fillets contained an average of 8.6% fat, rancidity was first significantly detected at PV about 4. But for caranx, being fatty at the time of landing, this may not be the case. It is sufficient to say that lipids, TBARS, PV are highly species specific. But a limit for smoked PV and TBARS of fish must be suggested and agreed upon at individual level for each fish along side other parameters for lipid oxidation yet to be determined like Free Fatty acids, acid Value and para- Anisidine value.

Carangoide armatus (Kole Kole)

These were caught in Majoreni in March 2005. They were in storage for 14 days (Table 33).

Table 33 Moisture content of Kole Kole during storage

Day	% Moisture content
0	75.4
1	62.5
5	32.1
9	13.1
14	10.5

The moisture content for fresh Kole Kole was 75.4%. The moisture content declined during storage to 10 %. The period of storage was marred by insect infestation. This made the samples to be kept in the hot sun for 2 hrs a day as a means of driving the insects away. This explains the much lower levels of moisture during storage and this could have affected lipid oxidation significantly. Afterwards of course in later studies a solution was found to the insect infestation problem. This solution to insect infestation is even a bigger step in handling and storage of fish.

Pomadysis multimaculatum

The fish was caught in March 2005. The moisture content reduced from 75.7% in the fresh state to 10.7%. They were also kept in the sun for 2 hours daily to prevent insect infestation.

Pomadysis hasta (Vinego)

This was caught in March and stored for 14 days. The moisture levels dropped from 71.4% for fresh fish to 11 %. The drop in moisture was also due to keeping the fish in the sun to avoid insect infestation. This would affect oxidation products.

Gerres oyena (Chaa)

These were caught in March 2005. The moisture content was finally reduced to 14 % (Table 34) on day 14 of storage after an initially low and unexplained amount of 60% probably due to part of fish taken for moisture analysis: (Fish body composition is heterrogenous)

Table 34 Moisture and TBARS levels during storage of Chaa

Day	% Moisture	TBARS mg MDA/Kg
0	60	0.8
1	40	3.01
5	39.9	1.01
14	14.7	0.95

This fish was also sun dried for 2h to due to insect infestation to drive away insects. The TBARS were low even for the fresh fish with a value of 0.8 m MDA/Kg. There was an increase in TBARS in day 1 to 3 then a drop to 1.01. The storage levels of TBARS remained rather low. The low levels of TBARS when fresh could be due to control of lipid catalysis interactions provided for by the presence of natural antioxidants in the tissue. After slaughter or death of fish, the antioxidant level is generally high and most oxidation is inhibited. However, with time, an array of post mortem changes take place in the tissue that disturbs the delicate balance that initially exists between catalysts and antioxidants (Underland et al, 1999). The lower level of TBARS during storage is due to the unstable nature of carbonyls that react readily with other compounds. TBARS also react and break down so may not necessarily accumulate. At high temperatures during sun drying, oxidation proceeds so fast that whatever is formed be it hydroperoxides or TBARS, breakdown fast as temperatures are also high.

3.10 Outcome of Training in fish smoking in Gazi

Smoking of fish was introduced in Gazi for the first time to community groups. They were not familiar with processes of fish smoking. Results of the fish they attempted to smoke are reported and their subsequent smoking events.

The first training was held in Gazi on 25 th February. The first fish to be smoked included Caesio spp, (Mbono), Barracuda (already reported) and *Lethrinus.*

In the latter day trials, fish were smoked on 25th march and these included Mullet *Siganids* and *Lethrinidae*. The parameters analyzed were TBARS and moisture. The storage period in some cases was less than 4 days. This was attributed to inexperience which was later corrected.

Table 35 Moisture content of Lethrinus caught and smoked in Gazi during storage

Day	% moisture
0	79.5±0.07
1	58.6±0.27
4	35.8±1.52

The moisture content for the fresh fish was 79.5%. with the final content being 35.8%. This amount could still support mould growth (Table 35). The moisture content was high thus storage days were reduced. Packaging was wrong as the fish were kept in a polythene casing during cooling time. The moisture condensed and dropped on the fish creating good environmental for environmental growth. The locals were taught to avoid this in future. They also kept the fire quite high and ended up with a near barbequ

Caesio cunning (Mbono)

The same applied to Mbono whose moisture dropped from 82.5% to 56.1 %. The storage conditions were same as for Lethrinus.

The second attempt was in March. The locals were now a bit familiar with smoking techniques.

Mullet was smoked and stored for 21 days. The oil content was 14% for fresh species. The PV increased steadily from 95% fresh fish to 176 after 21 days of storage (Table 36). The appearance was not quite appealing because too much smoke got in the fish imparting a blackish coloration.

Table 36 Peroxide Value, Oil contents of Mullet fish prepared in Gazi during storage

Day	% oil	Peroxide value mEq/Kg
0	14.0	95.8±0.00
14	13.89	92.0±2.45
21	18.9	176.2±7.34

During this period, PV increased steadily from 95 % in fresh fish to 176% during storage after 21 days. Mullet can be considered to be fatty. The lipid oxidation pattern followed the one for fatty fish like Caranx. The increase in PV though seen, it was not easy to say that after 21 days we reject the fish because of the PV since at the fresh state it was already high any way. Fatty fish could have higher PV values before being spoilt. The fish were also kept briefly in the sun to allow for insects to escape. This could have influenced the PV values.

3.11 Other studies

3.11.1 Drying rates for some selected marine fish during smoking

Table 37 Drying rates for selected fish

Species	Equation
Lethrinus lentjan	2.85-0.192x
Caosio cuning	2.659-0.183x
Sphyraena baraccuda	*2.807-0.317x*
V. seheli	3.034-0.283x

Baraccuda had a faster seemingly faster drying rate because of its thinner stature (Table 37). Other data on drying rate was for information only. Thinner fish dried faster than thicker ones.

3.11.2 Changes in PV during ACTUAL smoking of some marine fish

The trials were only in 2 fish namely V. *seheli*, and Lethrinus. Lentjans (Fig 5 and 6). It was observed that during smoking, the levels of PV reduce with smoking time. Changes in PV are normally reflected via the initiation, propagation and termination steps. At high temperatures and in the presence of oxygen, breakdown of PV is prominent hence the reduced levels. This meant that with temperature rise, the process of propagation and termination proceeds rapidly. This helped to understand events in

the other cycles reported earlier of oxidation during storage where the process of initiation, propagation and termination starts all over again during storage.

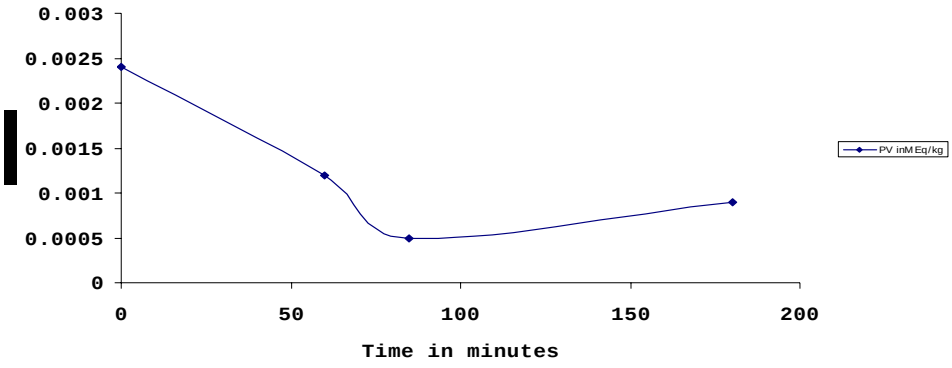

Fig 5. PV changes during smoking of V.sehel

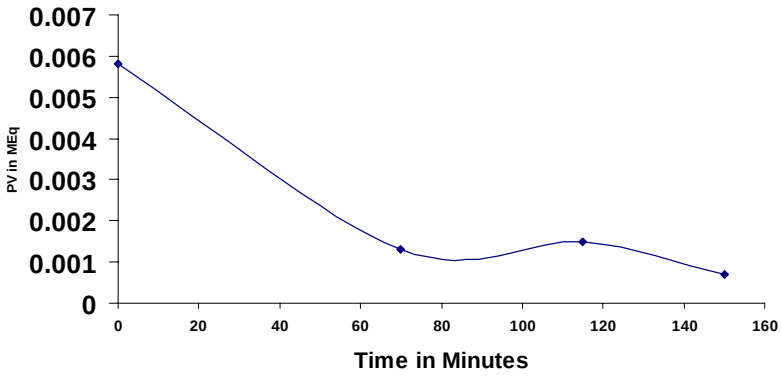

Fig 6 .PV Changes during smoking of *Lethrinus*

3.11.3 Utilization of Wood Fuel by Smoking ovens in Moa

The fuel consumption for the improved smoking oven gave a minimum of twice efficiency compared to the traditional oven and more fish was smoked per unit time (Table 38). This meant that in the long term this improved system of smoking was environmentally friendly.

Table 38 Wood fuel and fish smoked using Improved and Traditional Ovens

	Weight of wood fuel	Number of fish smoked
Traditional method	32.3kg	60
Improved method	15.8kg	130

3.11.4 Instant reaction to traditional and improved smoking methods by fishermen in Moa

The fishermen themselves responded positively to the improved fish smoking method as well as the products produced (Table 39). They admitted lower product quality due to using too much fire that occasionally burns their fish in the traditional oven as opposed to the use of smoke for a longer time in the improved smoking oven.

Table 39 Mean score for attributes for Improved and Traditional fish

Species	Mean	N	Std. Deviation
Clarias (Improved smoking method)	8.56	66	.585
Clarias (Traditional smoking method)	6.45	66	.748
Galeichthys (Improved smoking method)	8.09	66	.575
Galeichthys (Traditional smoking method)	6.30	66	.723
Pappilloculiceps sp_(Improved smoking method)	7.83	66	.483
Pappilloculiceps sp_(Traditional smoking method)	6.06	66	.721
Protopterus (Improved smoking method)	7.76	66	.556
Protopterus (Traditional smoking method)	6.08	66	.771
Total	7.14	528	1.153

There was a significant difference in response for the attribute scores for the traditional and improved smoking systems as confirmed by Krusskal-Wallis test (Chi square 379.648 , p=0.000)

Table 40 Statistical reaction to attribute score

	Attribute score
Chi-Square	379.648
df	7
Asymp. Sig.	.000

a Kruskal Wallis Test
b Grouping Variable: Species

Further tests (Mann Whitney) indicated significant differences between Traditional and improved methods of smoking $p<0.00$

Table 41 Comparison of scores for Traditional Vs Improved smoking methods

Species	Mean Rank	Sig. Difference	Comment
Clarias (Traditional	97.20	.000	Sign. Difference. Better response for Improved method
Clarias (Improved)	35.80		
Galeichthys(Trad.)	97.20	0.000	Sign. Difference. Better response to improved method
Galeichthys (Impr)	35.80		
Pappilloculiceps(T)	97.48	0.000	Sign. Difference. Better response to improved method
Pappilloculiceps (I)	35.52		
Protopterus (I)	96.13	0.000	Sign. Difference. Better response to Improved method
Protopterus (T)	36.87		

3.11.5 Reaction to the improved processing method in Moa – Tana River

After the introduction of the improved smoking oven, they agreed that there was a lot of improvement in quality of the fish smoked, the colour had improved, the weight of the fish was better as it was heavier (their clients complain of lighter fish and over dried fish), the colour of the fish was more appealing, the efforts in turning the fish during smoking was reduced as only tray positions are changed, less smoke went into their eyes, they could attend to other chores while smoking was going on and most important, they used very little wood fuel to smoke a large amount of fish. The cost of wood fuel is reduced and environment risks averted.

3.11.6 New Strategy

One of their new strategies is to try and construct as many improved smoking oven in Moa as possible as they have agreed to embrace wholly the improved fishing oven for smoking of their fish.

3.11.7 Limitations

Whereas we introduced the improved smoking fish system in Moa, the fishermen pleaded not for direct financial assistance but for us to arrange to build more ovens for them in the village. We were also limited by funds but it would be a good idea to get funds and build more smoking oven types in the village of Moa.

3.11.8 Concluding observations

The fishermen in Moa are thus interested in improvement of all quality parameters like appearance and also storage time. They have an interest in learning and incorporating new technology in fish smoking. Fish is caught in large numbers between October to March especially during the dry season when the lake volume is low. In periods of April to July, the lake volume is high as this coincides with the rainy season bringing in flood water. Fish is quite low during this period. If adequate fish is smoked and stored during the glut period, there could be some left for use during the leaner periods.

3.12 Reaction to smoked marine fish in Gazi and Majoreni

The preference in taste was not in doubt. What is wanted is simply awareness and market for smoked marine fish.

CHAPTER 4

4.0 SOLAR DRIED MARINE FISH

4.1 Site selection

For fish drying using the solar tunnel dryer, the site selected was in Gazi area of south coast because the community there had identified with its implementation. It was easier to get locals to help running the solar tunnel dryer once installed.

4.2 Solar Tunnel Dryer construction

4.21 Solar Collector

The solar collector was a tunnel 7 m long, 2 m wide and 0.4 m above the ground. The tunnel height was 300 mm and maximum height at the center was 450 mm above the collector base. The top outer cover was made from two layers of UV (Ultra Violet) treated polythene sheet of 500G (0.5 mm). The base of the collector was made up of a 2 mm thick metal plate painted black for heat absorption and encased in a sand layer for refractory and heat storage purposes. Below the sand layer there was a 5 mm thick wooden layer followed by a 20 mm thick coconut fibre layer, both for insulation purposes. At the bottom were a 2.5mm wooden layer and a 0.5 mm polythene layer for encasing the collector. The sides of the collector were made up of a 2 mm thick metal plate painted black for heat absorption, and lined by a 50 mm thick coconut fibre layer for insulation. At the outer surface the collector walls was a 25 mm thick wooden layer that was painted black to absorb heat. To facilitate the entry of air into the collector a 2m by 0.6 m galvanized sheet plenum mounted with a 40W d.c fan was fixed onto the collector (Figure 1).

4.22 Drying Chamber

The drying chamber was made to be a cabinet 2 m wide, 2 m long and 1.4 m high and 0.5 m above the ground surface. The maximum height of the drier was 1.55 m above the base of the cabinet. The sides of the drier were made from 25 mm thick plywood, which was lined with 0.05 mm galvanized iron sheet for reflection and painted black on the outside for heat absorption. The base of the drier cabinet was made from and lined with 0.05 mm aluminium sheet for heat reflection of heat and ease of

cleaning. A 5 mm thick wooden layer, followed by a 50 mm coconut fibre layer and finally a 2.5 mm wooden layer for insulation, encased the aluminium sheet. The roof and front part of the drying cabinet was made from 4 mm thick glass to allow for solar radiation into the cabinet and ease of inspection during the drying process.

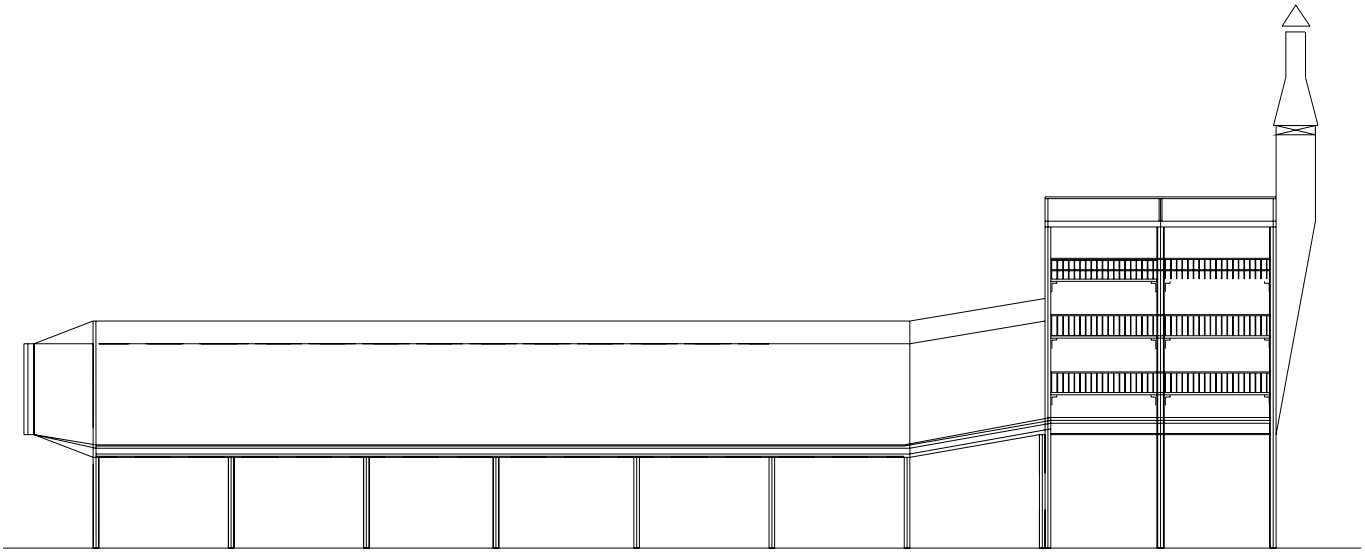

Figure 1. Schematic view of designed tunnel drier

The chamber had three shelf layers for holding twelve wire mesh trays measuring 1 m by 1 m, and spaced 200 mm apart with a maximum capacity of 200 kg of fish. These were accessed from the side of the drier cabinet via hinged doors, which could be opened wide to allow for sliding the trays into and out of the drying cabinet during loading or offloading of fish. At the outlet of the drier cabinet an exit plenum 2m wide by 1.4 m wide and fitted with a chimney 30 mm in diameter and encased with a 40 W d.c fan was fitted to facilitate the removal of moist air from the drying chamber (Figure 1)

4.23. The photovoltaic system

The power supply system for the solar drier was a photovoltaic system consisting of a 100 W solar panel and a 100 Ah deep cycle battery. This power source was used to power two axial 40 W d.c axial fans with a capacity of 0.46 m^3/h that were purchased from a motor vehicle spares dealer.

4.24. The instrumentation panel

The instrumentation panel consisted of a charge controller to control the charging rate in the photovoltaic system and switchgear to control the switching schedule for the d.c. fans. It also had provisions for the installation of sensors and instruments to measure the critical performance parameters for the drier, which include moisture, relative humidity, air temperature and velocity, solar radiation, transmissivity, wind speed, weight, hardness, voltage, and power.

4.25. Handling fish for solar drying process

The fish species that were most dominant were purchased from the local fishermen in Gazi in late November 2005.

They were then sorted out into categories to obtain similar sizes as possible. Their average weights were recorded.

They were then descaled, degilled and eviscerated. They were split open for drying. The fish were then washed thoroughly. They were then salted by mixing with salt at a ratio of 1:10 salt to fish. The fish were stacked in the brine for a period of 16 hours before drying after which they were washed, drained for 1 hour lying at an angle on chorkor like trays to drip. The fish were then transferred to the drying chamber of the solar tunnel dryer and laid on the drying trays in single layers. The drying temperature and humidity was measured inside the drying cabinet every 2 hours and fish sampled for moisture content every 2 hours during the drying period over a 30 hr day drying period continuously. A complete drying period was between 8.30 am to 6.30 pm (10 hrs) everyday for 3 days. Fish samples for determination of biochemical changes during the process of drying were taken every 6 hours continuously during the drying period. Upon completion of the drying process, fish were removed and allowed to cool to ambient temperatures. They were then packed in polyethylene bags and stored in straw baskets that were then transported to the lab in KMFRI. Baseline data was obtained by taking a representative sample for analysis at the beginning of storage and was listed as time zero. Subsequent samples were to be analyzed every 2 weeks for organoleptic trials as well as biochemical tests of PV, TBARS, AV as Free Fatty acids, para-Anisidine Value .This data is however not reported due to time limits and analysis is still going on. A structure simulating traditional fish drying was placed next to the solar dryer and had fish treated the same. Results from the two treatments were compared where data was available.

4.26. Results and Discussion

The moisture loss in the fish samples in the solar tunnel dryer and the traditional rack followed similar patterns of faster drying at the beginning and slowing towards the end of drying (Fig 7a, b, c)

The weight or moisture loss in Siganids in the solar tunnel dryer was from 350 g to 165 g after drying on the first day (8.30 am to 6.30 pm) or 0hr to 10 hr. This weight loss represented 52.85% calculated on the initial fresh weight. The weight loss for Siganids in the traditional drying rack over the same period was from 250g down to 120g representing a 52% weight loss.

The weight loss for Lutjanus spp (Red snapper) in the solar tunnel dryer was from 400g to 250 g after drying on day 1 (first 10 hrs) which was equivalent to 37.5% calculated on the initial fresh weight. The starting weight of the red snapper in the traditional rack was 200g and the weight loss in day 1 was 50%. For Lethrinus spp the weight loss was from 350 g to 210 g and was equivalent to 40% calculated on the initial fresh weight. In the traditional rack with a starting weight of 300g the weight loss during the same period was 40 % (Fig 7a, Fig 7b and Fig 7c). In day 2 represented by 12 hr to 20 hr, there was a reduced weight loss for all the three fish. The % weight loss for Siganid spp based on original fresh weight was 62.6% while in the traditional rack it was 58%. For the Red snapper in the solar tunnel dryer the weight loss was 62.5% while in the traditional rack the weight loss was 70%. For Lethrinus the weight loss was 65.7 % in the solar tunnel dryer while it was 58.3 % in the traditional rack. In day 3 between 22 and 30 hours there was a reduction in weight loss and the % loss differences were lower. The final moisture loss for Siganids in the solar tunnel dryer was 82.80% and in the traditional rack it was 80%. For the Red Snapper the moisture loss in the Solar Tunnel dryer was 68.75% while in the traditional rack it was 70% and it was 68.57% for Lethrinus in the Solar Tunnel dryer and 66.6% in the Traditional rack. The starting weights of fish were always smaller and by inference thinner in the traditional rack. Thinner or smaller fish dried faster than bigger ones. The surface area to volume ratio of smaller fish is normally higher resulting in faster drying rates (Mujaffar and Sankat, 2005). This has not happened despite the fact that the fish in the traditional racks had a greater surface area to volume ratio. This means that the solar tunnel dryer was effective in achieving faster drying rates. Mujaffar and Sankat (2005) working with shark fillets of various thickness showed that the thinner slabs lost moisture faster than the thicker ones. In our study therefore, the solar tunnel dryer is causing more moisture loss because despite utilizing fish bigger in size, there is not much difference in the moisture loss as the drying progresses compared with the smaller sized fish in the traditional rack. This is further confirmed by the drying rates over time (Fig 8a, 8b and 8c). During drying, the moisture loss decreased logarithmically with drying time which means that the fish suffered greater moisture loss at the initial

stage of drying. Other workers have reported such findings (Mujaffar and Sankat, 2005; Sablani et al 2003, Sankat and Mujaffar, 2004). The Siganids, Red Snapper and the Lethrinus in the solar tunnel dryer dried at a faster rate than the ones placed in the traditional rack as per equations on the graphs (Fig 8a, 8b, 8c and table 42). The factors causing this increased drying rate are temperature and humidity. During the drying period in the traditional rack, ambient temperature and humidity did not vary much (Fig 9). The daily temperatures were 30-33 ^{0}C. Such temperatures are not ideal for drying. Mujaffar and Sankat (2005) dried shark fillets at 30 ^{0}C in an oven without air movement and discarded the fish after 16 hr due to spoilage. Another factor was therefore responsible for drying. Humidity was high under ambient conditions ranging at about 60% to 79 %. The only reason for the fast drying in the traditional open rack therefore is because of wind. The rack is located by the sea where wind speed is quite strong.

The lower the humidity the faster the rate of drying (Mujaffar and Sankat 2005). Dryers that give better drying rates have lower humidity and higher temperatures inside the drying units (Sablani et al, 2003). This is the trend shown in the solar tent dryer. Humidity and temperature varied in opposite directions during drying. At peak drying periods between 10. 30 am and 2.30 pm each day or 2hr to 6 hr, 12 hr to 16 hr and 22h to 26 hr temperatures were high and humidity was low. It can be postulated that higher temperatures maintained inside the solar tunnel dryer as a result of insolation on the collector, the subsequent transfer of the heated air by forced convection over the fish coupled with direct radiation into the cabinet dryer and low humidity is responsible for the faster drying of the fish.

The initial moisture content of Siganid spp on fresh weight basis was 73.9 % this dropped to 22.5 % after 3 days of drying. For Lethrinus it was 75.48% when fresh and 12.9% at the end of 3 days No data is available on initial moisture content of fresh Red snapper but the final moisture content was 20.9 % after 3 days drying as well. According to Mujaffar and Sankat (2005), moisture content is significantly affected by drying time. Moisture content of the three fish species during drying inside the solar tunnel dryer is shown in Fig. 10 from which we see that moisture content decreased faster in Siganids then Lethrinus then Red snapper. It is not known whether the lower moisture content rate change in Red snapper was due to its body composition or its quality at the start of drying as it looked slightly deteriorated after brine treatment overnight and it is considered a fatty fish.

Fish contains up to 80% water. When moisture is reduced to 25% wet basis, contaminating agents cannot survive and autolytic activity greatly reduced. However to prevent mould growth during storage moisture must be reduced to 15% (Bala, 2001). Reports by Sankat and Mujaffar (2004) on the other hand also indicate that moisture contents of 20 -40% for dry salted sun dried fish are acceptable. From this study, the final moisture content of the 3 fish species falls within the suggested ranges so it is safe

to say that attaining low moisture values in a short time of 3 days is possible with this solar tunnel dryer. More work however is to continue to optimize the equipment further.

Unfortunately, insect larvae and insect infestation was common in the fish dried in the traditional open rack during drying. This rendered the fish unattractive and the community members rejected the fish and preferred the solar dried fish which had no signs of insect infestation at all. The lack of insect infestation is attributed to the higher temperatures in the solar tunnel dryer during the drying process and the enclosed drying cabinet among others. The solar tunnel dryer produced fish are therefore more hygienic. Visual inspection of the solar dried fish for quality assessment over the sun dried fish in the open rack indicated a more uniform dried fish with an appealing colour better than the fish dried in the traditional rack. Studies that have found such results are by Bala, 2001, Sankat & Mujaffar, 2004, 2005; Sablani et al 2003, Sachithananthan et al (1985), Osei-Opare and Kukah (1989). Control of insect infestation after identification to prevent losses should form the basis of the next study.

The drying rate of fish in the solar tunnel dryer is much faster. The fish is dried to acceptable moisture levels. The fish dried in the solar tunnel dryer were of superior quality devoid of insect infestation and very readily accepted by the consumers in the local community. Storage trials for traditionally processed fish was not carried out further as the villagers had rejected the fish due to insect infestation.

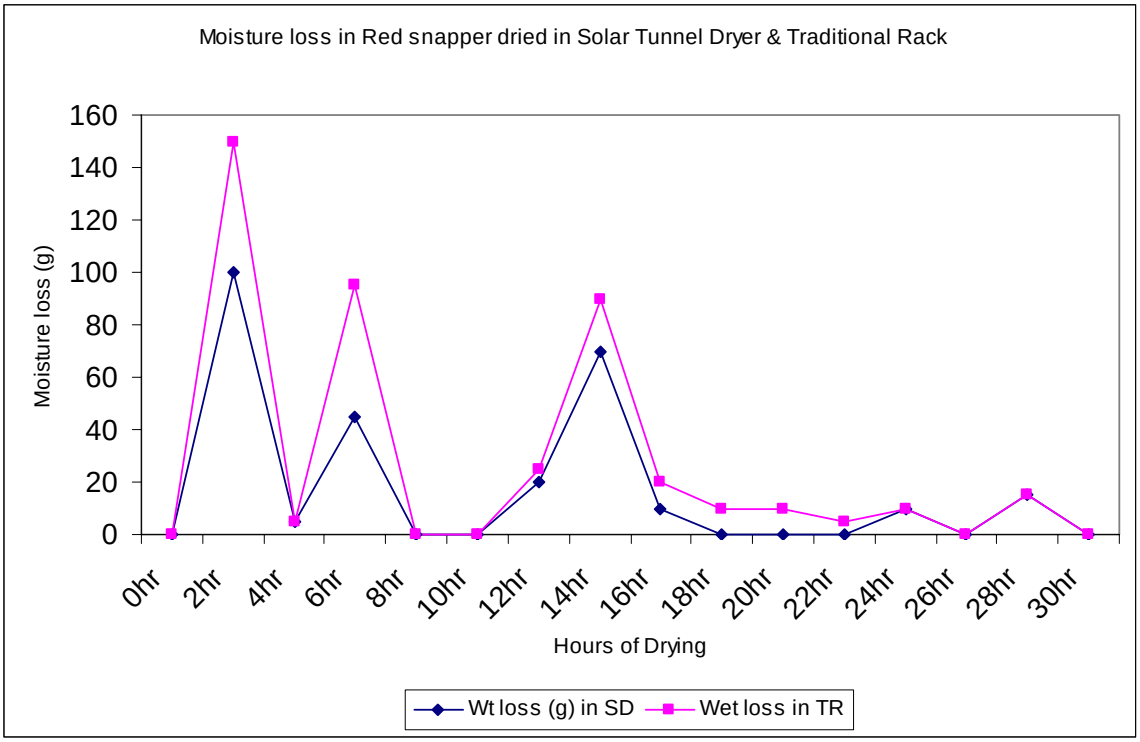

Fig 7 a

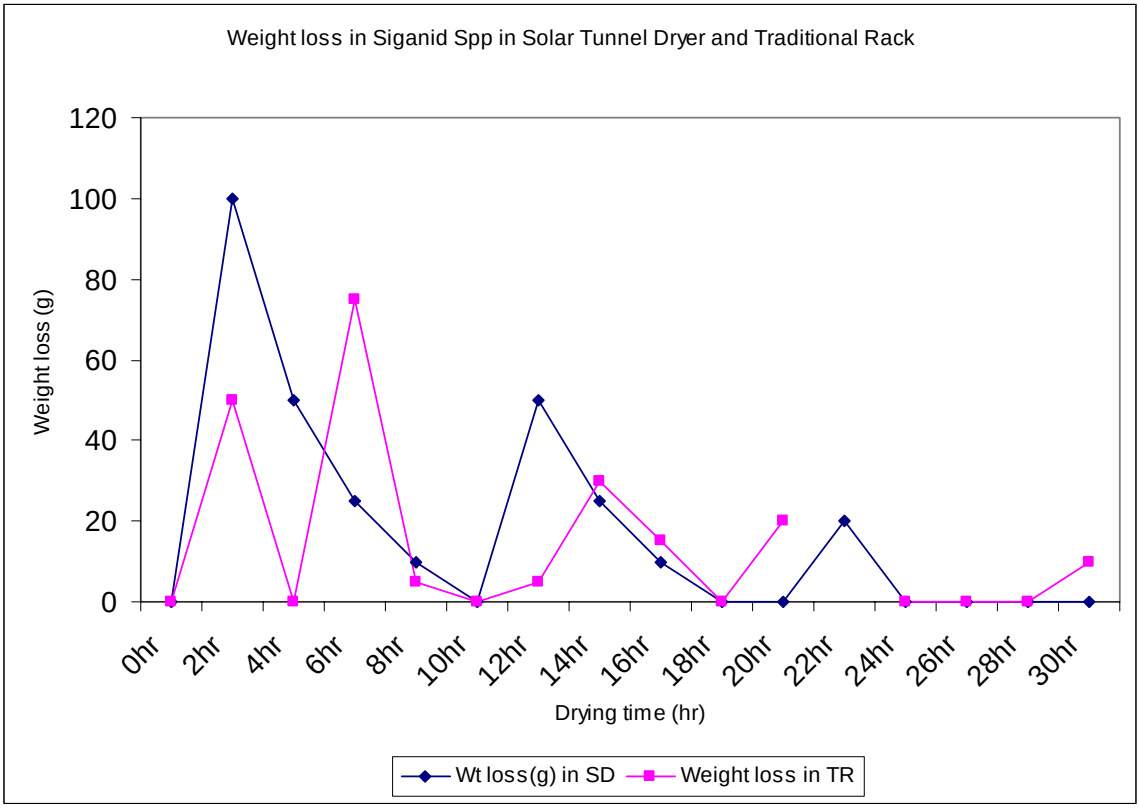
Weight loss in Siganid Spp in Solar Tunnel Dryer and Traditional Rack
120
100
80
60
40
20
0
Weight loss (g)
0hr
2hr
4hr
6hr
8hr
10hr
12hr
14hr
16hr
18hr
20hr
22hr
24hr
26hr
28hr
30hr
Drying time (hr)
Wt loss(g) in SD
Weight loss in TR

Fig 7b

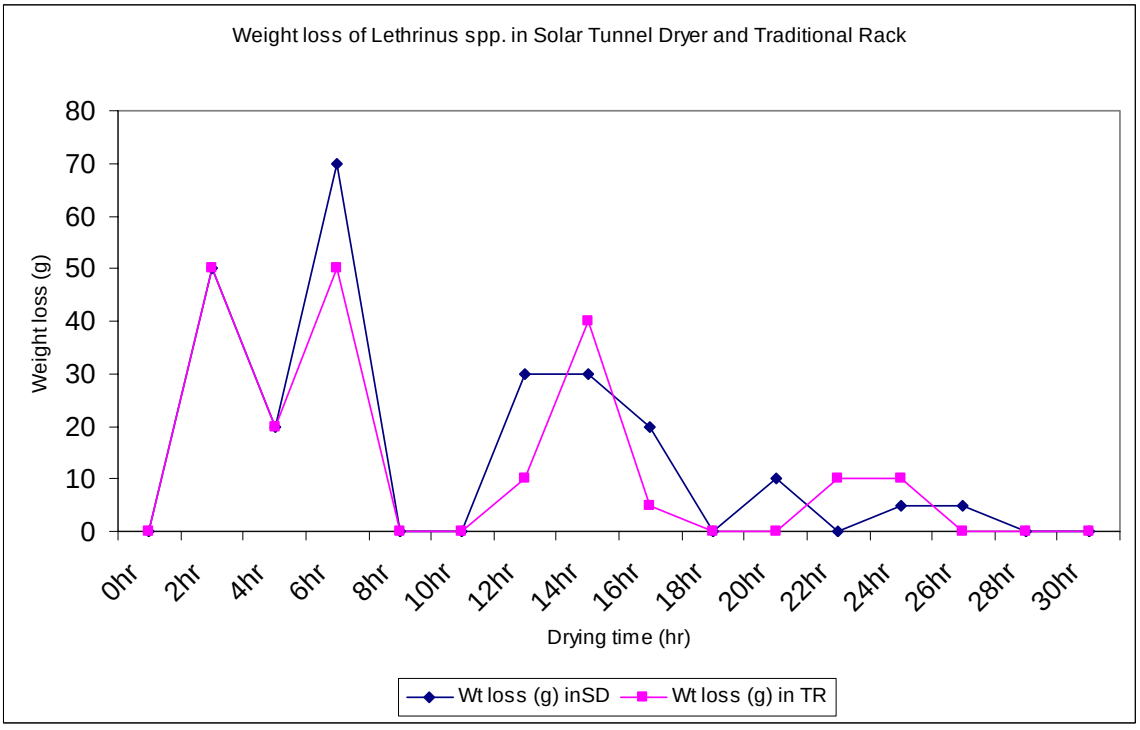
Weight loss of Lethrinus spp. in Solar Tunnel Dryer and Traditional Rack
80
70
60
50
40
30
20
10
0
Weight loss (g)
0hr
2hr
4hr
6hr
8hr
10hr
12hr
14hr
16hr
18hr
20hr
22hr
24hr
26hr
28hr
30hr
Drying time (hr)
Wt loss (g) inSD
Wt loss (g) in TR

Fig 7 c

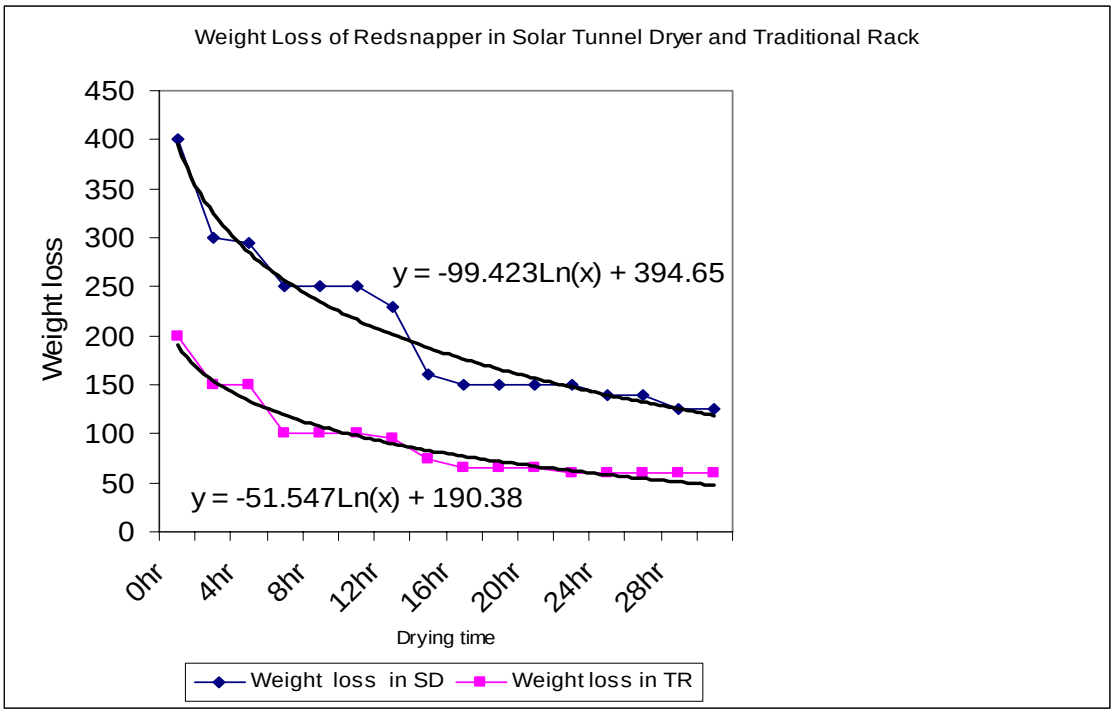
Weight Loss of Redsnapper in Solar Tunnel Dryer and Traditional Rack
Weight loss
450
400
350
300
250
200
150
100
50
0
y = -99.423Ln(x) + 394.65
y = -51.547Ln(x) + 190.38
0hr
4hr
8hr
12hr
16hr
20hr
24hr
28hr
Drying time
Weight loss in SD
Weight loss in TR

Fig 8a

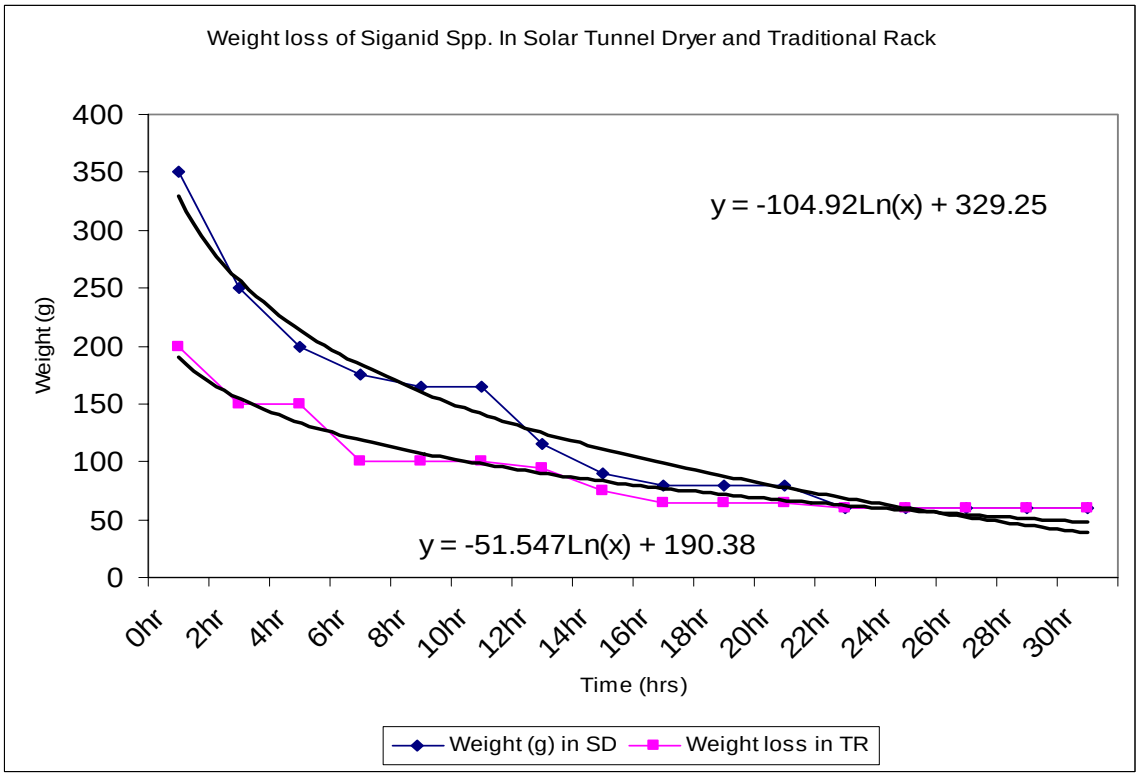
Weight loss of Siganid Spp. In Solar Tunnel Dryer and Traditional Rack
Weight (g)
400
350
300
250
200
150
100
50
0
y = -104.92Ln(x) + 329.25
y = -51.547Ln(x) + 190.38
0hr
2hr
4hr
6hr
8hr
10hr
12hr
14hr
16hr
18hr
20hr
22hr
24hr
26hr
28hr
30hr
Time (hrs)
Weight (g) in SD
Weight loss in TR

Fig 8b

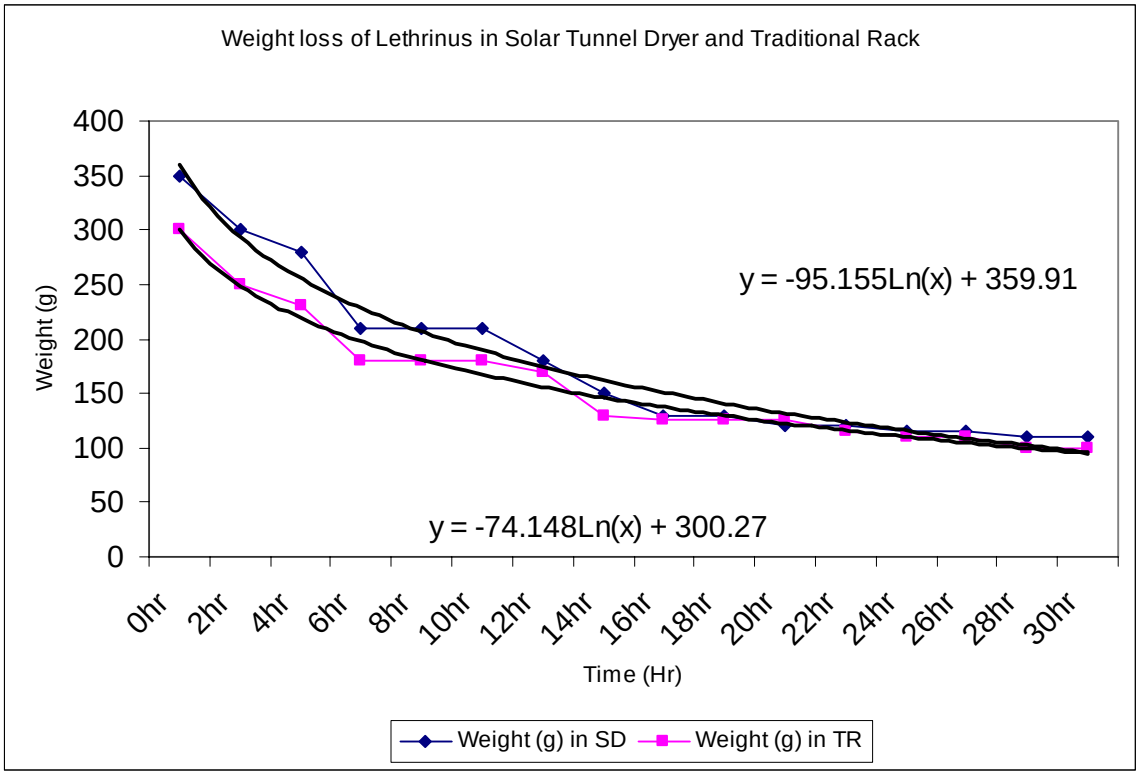

Fig 8c

Table 42. Drying Equations for Siganids, Red snapper and Lethrinus in Solar Tunnel Dryer and in Traditional Rack

Siganids in Solar Tunnel Dryer	y = -104.92lnx
Siganids in Traditional rack	y = -51.54lnx
Red snapper in Solar Tunnel Dryer	y = -99.423lnx
Red snapper in Traditional rack	y = -51.547lnx
Lethrinus in solar Tunnel Dryer	y = -95.155lnx
Lethrinus in Traditional rack	y = -74.148lnx

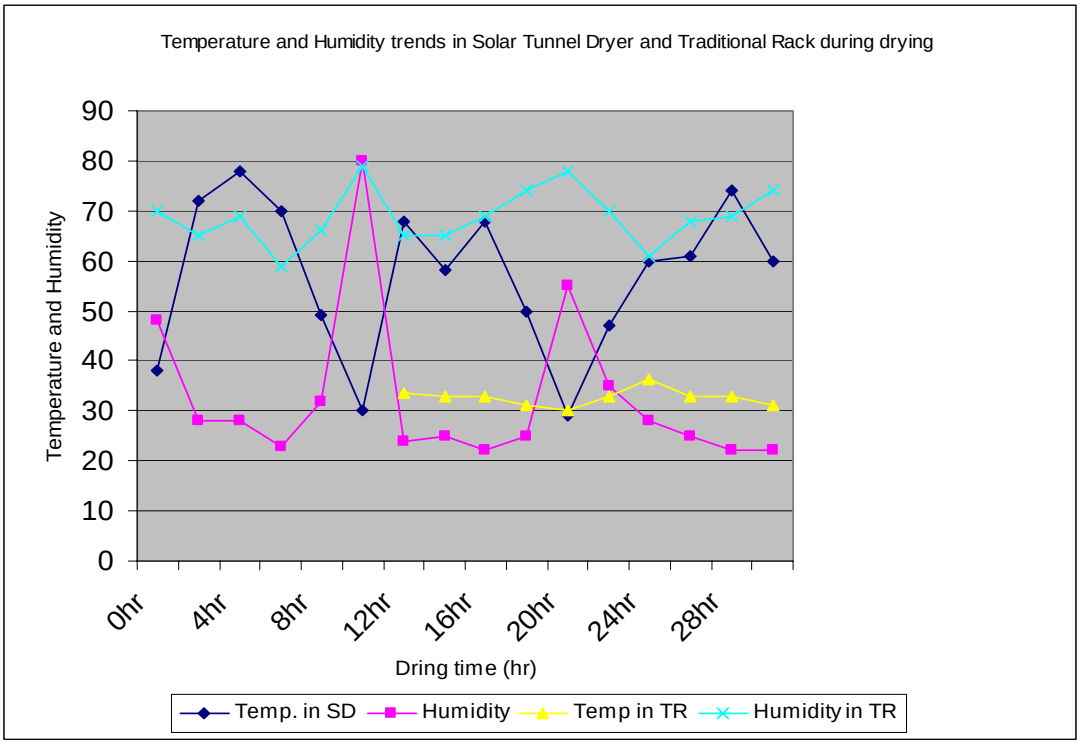
Temperature and Humidity trends in Solar Tunnel Dryer and Traditional Rack during drying
Temperature and Humidity
90
80
70
60
50
40
30
20
10
0
0hr
4hr
8hr
12hr
16hr
20hr
24hr
28hr
Dring time (hr)
Temp. in SD
Humidity
Temp in TR
Humidity in TR

Fig 9

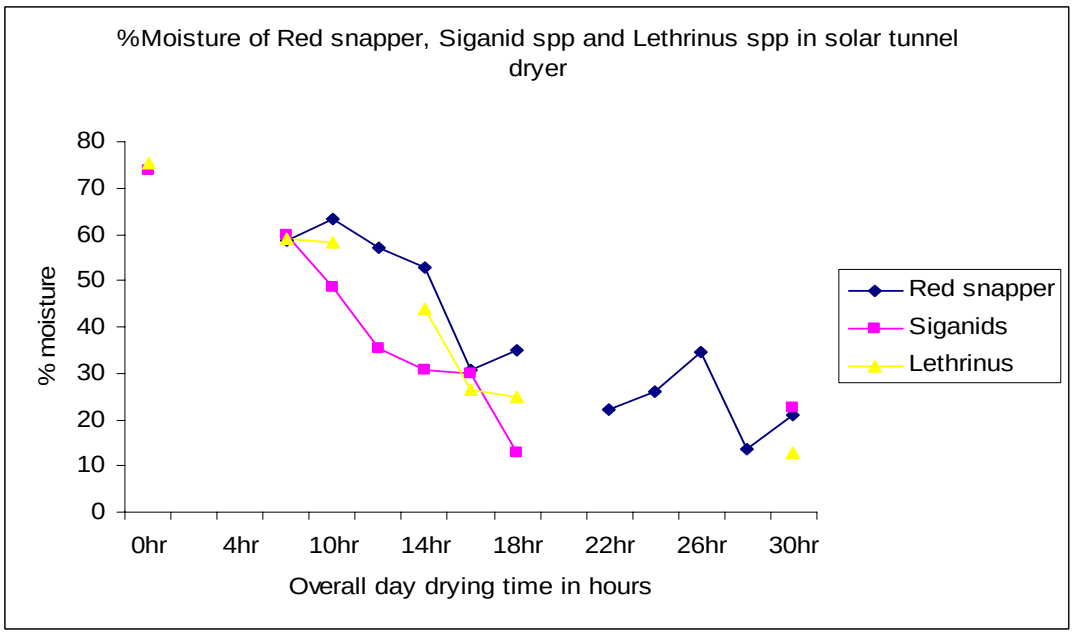
%Moisture of Red snapper, Siganid spp and Lethrinus spp in solar tunnel dryer
% moisture
80
70
60
50
40
30
20
10
0
0hr
4hr
10hr
14hr
18hr
22hr
26hr
30hr
Overall day drying time in hours
Red snapper
Siganids
Lethrinus

Fig 10

5.0. Conclusions

1) Peroxide Value and Thiobarbioturic Acid Reactive Substances as one of the monitors for lipid Oxidation are species specific in smoked fish and vary with season and may not be useful indicators in smoked fish spoilage
2) Storage period for fish during smoking is species specific
3) Wood fuel consumption is much lower in improved oven than in traditional oven
4) More fish per unit time is smoked in improved oven than in traditional oven
5) There is strong preference for use of the improved smoking oven in Moa and the constructed one is currently over used.
6) Taste for smoked marine fish is appealing for most fish and should be market tested further
7) Storage period for smoked fish is at least 14 days from organoleptic perception (fried fish takes 3 days).
8) Awareness for smoked marine fish potential is lacking
9) All smoked marine fish are tasty though P. *hasta and* Red snapper are tastier
10) The drying rate of fish in the solar tunnel dryer was faster than in the traditional rack
11) The fish dried in the Solar tunnel Dryer reached acceptable moisture levels
12) It took 3 days to dry the fish in the solar tunnel dryer
13) The fish dried in the solar tunnel dryer was of superior quality

6.0. Emerging issues

1. Post harvest losses during storage due to insect infestation
2. Awareness for and marketing of smoked marine fish
3. Use of different TREE species to check effect on quality of fish

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