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EFFECT OF TEMPERATURE ABUSE ON RAW MATERIAL QUALITY AND STORAGE LIFE OF HOT SMOKED MACKEREL (*Scomber scrombrus*)

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ABSTRACT

The aim of the study was to analyse the effect of temperature abuse on quality and storage life of hot smoked mackerel processed using an improved smoking chamber. With this intent, headed and gutted frozen Mackerel (*Scomber scrombrus*) were thawed and divided in two experimental groups, one kept in ice and the other at room temperature for 36 hours before processing. The fish were hot smoked and thereafter each group further divided into two subgroups that were stored at room temperature and chilled conditions. To determine quality and the storage life of the products, samples were evaluated using sensory, physical properties, chemical and microbiological methods. Initial samples upon thawing were also evaluated for comparison. Results in general show that the quality of raw material, handling and the storage conditions plays an important role in determining the quality of the final product. According to sensory evaluation as well as microbiological results, the storage life of smoked mackerel stored at room temperature is 7 days; on the other hand, the well handle guaranteed storage life of up to 21 days. After 7 days of storage the abused product reach log 8/g of total plate count which is above the limit of human consumption. The lipid degradation analysis combined with sensory analysis gives information that can be used in evaluating the quality and storage life of smoked fish. To ensure the consumption of safe and high quality smoked fish, it is important to strictly follow the cold chain requirement for handling, processing and storage after processing to assure good quality of the final product.

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1 INTRODUCTION

1.1 Background

In Mozambique, the artisanal fishing is one of the most important socio-economic activities carried out in the coastal zone providing low cost animal protein for over two-thirds of the population living in the coastal zone or around large bodies of inland waters. It offers direct employment to more than 334,000 people mainly fishermen, collectors, divers, fishing supplies traders, processors, carpenters and naval mechanical (IDPPE 2007). In 2011, the fisheries sector contributed approximately 3% of gross domestic product and more than 188 thousand tons of different fish, representing an economic contribution of 475 million U.S. dollars (Ministério das Pescas 2012).

The number of fishermen in Mozambique engaged full-time in all types of marine fishing is estimated to be around 140,000 of which 97,000 are artisanal fishermen. The total number of people directly and indirectly involved in the marine artisanal fishery alone is around 350,000; the figure includes fishermen without a vessel, boat crews and land-based support workers. Semi-industrial and industrial fishermen are about 650 operating 30-40 licensed vessels. This is in addition to several thousand recreational and sport fishermen also operating in the line-fishery sector (Ministry of Fisheries 2013).

The marine resources are mainly crustaceans (shrimps, prawns, crayfish, lobster, crab), dermersals and pelagic fishery (groupers, snappers, flounders, tuna, sharks, mackerel, sardines and others small pelagic fish), octopus, squid, clams, mussels, oysters, and other resources. The inland resources are mainly fin fish (kapenta, ussipa, tilapia, catfish, tiger fish, carpa) and shrimp.

Fish processing in Mozambique traditionally involves a number of different methods, and some are done together. These include smoking, freezing, salting and sun-drying. At the industrial level, shrimp is frozen on board fishing vessel for export, while smoking and sun-drying are mostly practices at artisanal and small scale levels for regional and domestic markets. Sun-drying, and salting and drying are the two main processing methods used for fish preservation. Salting and drying is used for squid and fish of all sizes, and also for fish of second-grade quality. This methods of processing (salting and drying, and sun drying) are more common in the northern and central Mozambique, whereas smoking and fish freezing are predominant in the north and south. Lack of cold storage facilities usually forces people to rely on the traditional processing methods of smoking and sun-drying.

Currently, thousands of rural households in the world and particularly in developing countries have been plagued by hunger and extreme poverty. Mozambique is no exception. Poverty has remained constant over the period 2002-2008, estimated at 54.7%, of which about 80% is associated with problems of low food intake and nutrition (Ministério da Saúde 2011). To minimize the problems related to poverty and food insecurity and nutrition, the Government of Mozambique in its Action Plan for Poverty Reduction (PARP) 2011-2014 highlighted several strategies to contribute to the well-being of rural communities and increase availability of food for the population. Some of these strategies have particular emphasis on increasing agricultural production and fishing productivity and impacting the supply of food to contribute to food security and poverty reduction (GoM 2011). One of the challenges posed to the fisheries sector as outlined in the Fisheries Master Plan II approved for the period 2010-2019 is to increase the current global fisheries production estimated at about 188,000 tons/year. This measure is aimed at strengthening the sector's contribution and improving the food security of the population

(Ministério das Pescas 2011). Increasing the availability of fish to the population depends not only on increased catches but also on reducing post-harvest losses in artisanal fishing.

To the extent of the above challenge and in order to make their contribution in increasing production, the fisheries sector defined several lines of activities for the artisanal fisheries subsector. Among them stands out the transfer and dissemination of improved techniques to the artisanal fish processing sector in order to reduce post-harvest losses and increase the availability of fish for domestic consumption. During the rainy season, smoking of fish has been a major preservation techniques employed by artisanal communities to preserve the quality of the fish. But this has mostly been done with use of rudimentary techniques such as smoking under open fire which to some extent affects the quality and safety of the fish. Therefore an introduction to a prototype of a new combined solar dryer flue and smoking cabinet for the fishing communities in Mozambique may possibly contribute to reduction of post-harvest losses and improve quality of fish sold at the local market. Consequently, it will be contributing to the food security and nutrition in addition to improving the income of artisanal fishermen in Mozambique.

The aim of this project is therefore to study the principles of the new smoking cabinet designed and built by MATIS[1] by evaluating its use by the artisanal fisheries communities in Mozambique to smoke and drying fish. The knowledge of this technology will be transferred to Mozambique and contribute to reduced post-harvest losses and improve the quality of fish sold at the local market. The adoption of this technology will reduce the quantity of wood used for hot smoking and therefore contribute to reduction of deforestation in sub-Saharan Africa.

The main objective is to study the effect of pre and pro handling of mackerel and determination of the products storage life under abused (room temperature) and chilled storage conditions. The specific objective of this study are:

i. To determine raw material quality (sensory, microbiological, chemical and physical characteristics) of mackerel previously stored on ice and at abused temperature (20 to 24ºC) for 36 hours.
ii. To conduct hot smoking of mackerel, using the improved smoking cabinet.
iii. To conduct storage life study of hot smoked air packed mackerel stored chilled (0 to 5ºC) and at room temperature (20 to 24ºC) using sensory, microbiological, chemical and physical characteristics.

[1] MATIS: Laboratory Icelandic Food and Biotech Research & Development, Iceland

2 LITERATURE REVIEW

2.1 Fish handling

Fish is a very perishable product. The process of decomposing of fish begins right after its capture by the action of enzymes and bacteria of the normal flora of the fish and putrefactive (Huss 1995). Once captured it is important that the fish is protected from direct action of sunlight and commencing immediately the process of delaying the spoilage of fish. This can be done through the use of ice in individual devices to retard and/or reduce the rate of enzyme activity and multiplication of bacteria responsible for speeding up the fish decomposing.

In many African countries, including Mozambique, many artisanal fishermen are unable to practise proper handling of fish on board after catch. Most often, after the fish is caught it is left on the surface of the vessel and exposed to sunlight. Artisanal fishermen do not use ice on board the boats to cool down the catch and other cold chain facilities that allow fresh fish storage from capture to landing (Odoli *et al*. 2013). All these factors contribute to the quality deterioration of the fish for further processing.

Drying and smoking are efficient and cheap methods for food preservation which has received the most wide-spread and enthusiastic publicity. It enhances the resistance of high humidity products to the degradation by decreasing their water activity. In developing countries, fish smoking and sun drying as a method of fish preservation have been used over the years to increase the shelf life of fish and to add flavour. The practices are common in artisanal fish landing sites that are far flung from infrastructure like roads, electricity for refrigeration, and ready market. Over the years, the traditional fish processing by smoking and sun drying has had weaknesses hence making the methods unpopular with changes in time. One of the problems associated with fish smoking and sun drying has been the hygiene conditions during processing and use of poor quality fish as raw material. The traditional smoking ovens are often marred by complaints of too much wood fuel utilization. The method uses much labour, and because of frequent turning of the fish it ends up with poor quality, burnt and breakable fish products with low market value.

2.2 Smoking of fish

Smoking or curing is a traditional preservation method which combines the effect of four treatments, brining, drying, penetration of smoke components (phenols and acids) and heat (Doe 1998). The application of these four treatments, mainly the smoking temperature and the way the smoke is delivered into the fish muscle, results in various types of smoking process that are; hot smoking, cold smoking, liquid smoking and electrostatic smoking (Wheaton and Lawson 1985).

Hot smoking takes place at temperatures of 70-80°C resulting in cooking of the fish, whereas, cold smoking takes place at temperatures below 30°C (Arason *et al.* 2014). In Africa, the “smoked - dry "processing is the advisable method applicable in artisanal fishing communities. The smoking can be done by using various types of devices, such as improved smoking house type "Chorkor”, "altoona" and "drum" which can easily be used by fishing communities. The smoking house has the advantage of improved smoking as it allows smoking of large quantities of fish in a short time and is also economical in terms of the amount of wood used. Hardwoods (e.g. the hose), dry grass, external and internal coconut shells are most suitable materials for fish smoking.

The hot smoking process consists of three steps. The first is pre-drying which is carried out at a temperature of 30 to 40°C in the smoking house or outside the smoking house. The smoking and partial cooking is the second step done at temperatures of 40 to 60°C to give fish the colour and characteristic odour. The third and last step consists of cooking and smoking of the fish undertaken at a temperature of 70-100°C including a smoke. After smoking, drying is carried out. Drying is smokeless and time required depends on the desired level of dryness. Even though the most smoked fish are frozen immediately after smoking, drying is necessary to achieve the characteristic texture of smoked fish. Furthermore, drying has a small but important effect on keeping quality; for example wet patches on the surface of smoked fish are likely to become sour during subsequent chilled storage. Drying after smoking is mainly done to reduce the water activity in order to reduce or even stop microbiological growth and reduce the enzyme activities.

The hot smoking procedure is as follow: at the beginning of the smoking process the temperature inside the smoking house should be 30°C, the air inlet should be half to three quarts open. This procedure helps to pre-dry the surface of fish at the same time depositing smoke on the fish. The smoking period is about 15 minutes to 1 h (Storey 1982, Horner 1997). The smoke going through the chamber is diluted with air and the fire burn is slow, so that it doesn't burn the fish. With the inlet air fully closed all the air is drawn through the damper to the fire. Thus the fire burns more strongly, causing the initial high flames. If the temperature is too high with rapid air flow, the fish surface becomes sealed off, trapping the moisture inside and causing casehardening (Horner 1997). Then more wood is added inside the firebox to increase the temperature inside the chamber to 50-60°C. The air inlet is reduced to a quarter open. This step is done for about 15 minutes. The last step is done for 40-45 minutes and the air inlet is completely closed. At this step the temperature inside the chamber should be around 80°C (Storey 1982). More wood is added if needed in order to increase the temperature inside the chamber.

2.3 Factors affecting the quality of hot smoked fish

After smoking process the smoked product acquires a typical appearance and flavour of smoking and the surface layers are impregnated by aldehydes, phenols and aliphatic acids found in smoke. The hot smoking process increases the shelf-life of fish as a result of the heat, compounds in smoke absorbed by the fish, the salt used during the brining before processing and the drying after smoking which decrease the water activity (aw) in the fish (Horner 1997, Doe 1998). However, the quality of smoked fish can be affected by many factors such as the initial quality of raw material, and the storage conditions after processing.

2.3.1 Raw material

The conditions of raw material are a very important factor for the quality and shelf life of the final product (Oehlenschläger and Sörensen 1997a, Horner 1997, Doe 1998; Alasalvar 2011, Arason *et al.* 2014). Many factors can affect the quality of raw material before processing: the season of catching, the fishing method, the storage conditions and the handling before processing. The catching season affect the chemical composition of fish, particularly the lipid content of fish muscle. (Arason *et al.* 2014).

If the fish is not fresh or is of low quality before processing, the final product quality is compromised. Fish smoking/processing will not improve the quality of the final product if the raw material was not good before processing (Oehlenschläger 2014). Most poor quality smoked

products are results of poor handling before and after processing (Oehlenschläger and Sörensen 1997a). Some artisanal fishers use fish processing as a remedy for the fresh fish that has not been marketed and is not of good quality. Logically, the final quality of the processed fish will not be good. In that case it is important to follow a cold chain in order to increase the storage life and maintain the quality of fish before and after processing.

2.3.2 Storage conditions

The storage conditions after smoking is very important in order to maintain the quality of the smoked fish. After smoking the product remains perishable and it is important to store products under cold conditions in order to reduce bacteria growth and extent the shelf life. Smoked fish that have lost 11% weight after smoking and can be edible for about 6 days during storage at 20°C. On the other hand, cold storage at -30°C of smoked fish can maintain the quality for 6 months (Storey 1982).

2.4 Methods to analyse the quality and storage life of hot smoked fish

2.4.1 Sensory evaluation

The sensory evaluation of fish is a scientific discipline used to suggest, measure, analyse and interpret human reactions to characteristics of food perceived through the senses of sight, smell, taste, touch and hearing (Martinsdóttir *et al.* 2008). Is used for quality control of seafood and seafood products, determination of shelf life, consumer studies, product development and for regulatory purpose (Oehlenschläger 2014).

This is a method widely used, but not the only one that can be used by the consumer. In some cases, it's common in the local markets that the consumer purchases the product before making assessment for its quality using their sense organs. In sensory evaluation, the consumer evaluates the smell, the colour, the appearance and taste of the product.

Smoked fish has a distinctive and attractive smell, a bright and attractive feature brownish yellow colour and distinctive flavour. Due to the presence of these attributes, the smoky flavour can mask unwanted smells that indicate loss of quality to the consumer such as the spoilage, butyric acid and the TMA odours and flavours which are indicative of decomposing fish, and other undesirable characteristics.

A well- smoked fish must be whole and well-presented and not brittle, with a dark surface due to the action of smoke during smoking.

2.4.2 Physical properties

One of the physical properties commonly used to determine the quality of smoked fish is final yield obtained after processing. Smoked fish with raw material of good quality brings good yields compared to those processed from poor raw material quality. The determination of the final yield is a very important factor for the artisanal fishermen, since they are interested in obtaining good yields and high profits.

The colour measurement is an instrumental method used for quality assessment of seafood. The colour of food is not stable, as it changes with increasing spoilage. Colorimeters are tristimulus devices used for measuring colour. The devices make use of red, green, and blue

filters that emulate the response of the response of the human eye to light and colour (Oehlenschläger 2014).

2.4.3 Microbiological Methods

Seafood poisoning and diseases of bacterial origin have received high attention and methods are available to detect the micro-organisms or their toxins. There are two basic classical approaches for detection of the presence of any given micro-organism in a food product: direct plating from the food onto a selective agar for resuscitation followed by plating onto a selective agar medium (Martinez 2005)**.**

Martinez (2005), noted that a part from classical methods, membrane filtration techniques, automated electrical techniques, immune-magnetic beads, immunological techniques and the molecular techniques based on the use of PCR for detection of DNA sequences for specific bacteria are now applied. However the conventional and classical methods are widely applied for monitoring of changes in safety and quality of food products. Microbiological methods allow enumeration of the total count and putrefactive bacteria that affect the quality of the product, and are of interest to public health (Huss 1995).

Fish processing does not improve the quality of the product, but slows down the proliferation of bacteria. During storage of fish the bacteria may find good condition for rapid growth in products that are not of good initial quality.

The sensory evaluation and the microbial analysis can be correlated to determine the quality and shelf life of smoked fish. Capell *et al.* (1997), noted that in case of using the correlation existing between the growth of bacteria and spoilage, the total count of bacteria may be used to predict the time of rejection by the panellist. According to Huss (1995), the point of microbiological rejection is when total count reach log 8 (cfu/g) and specific spoilage organisms (SSO) are constituting a higher proportion of the flora.

2.4.4 Chemical Methods

TVB-N (Total Volatile Basic Nitrogen), are substances encountered in marine fish after having passed the initial phase of freshness and are responsible for the fishy odour and flavour and can be used as a good spoilage indicator for quality assessment in the fish (Oehlenschläger 2014). TVB-N content accounts for the formation of TMA, dimethylamine, ammonia and other basic nitrogenous compounds associated with seafood spoilage (Huss 1995). The limit of TVB-N for human consumption regulated by EU is in category a: 25mg of nitrogen/100 g of muscle, for category b: 30 mg of nitrogen/100 g of muscle and for category c: 35 mg of nitrogen/100 g of muscle (Oehlenschläger and Sörensen 1997b; Oehlenschläger 2014). Chemical methods are also indicators of determining the quality of smoked fish and how it can be affected. The proximate composition gives an indication of how the fish processing can affect the final quality of the product by determining the fat content, the protein and water in fish.

2.4.5 Lipid degradation

Naturally the lipids of fish are highly unsaturated and the total content varies among and within different species of fish. The approximate fat content in lean fish such as cod and haddock is less than 1% whereas the value of more than10% in fat had been reported in fish like herring and mackerel (Love 1982, Undeland 1997, Oehlenschläger 2014). Fat fish store the fat in the flesh and under the skin, while lean fish store it in the liver (Love 1982). Unsaturated fatty acids which exists in high proportion in fish fats are subject to attack by atmospheric oxygen, leading to deterioration changes, especially in fatty fish (Sohn and Ohshima 2011).

The lipid oxidation process starts when molecular oxygen attacks unsaturated fats, through a series of reactions where it takes part as reactants and intermediates and finish with formation of primary oxidation products (hydroperoxide expressed as the peroxide value), the secondary oxidation products are thiobarbituric acid-reactive substances (TBARS) and the tertiary products (Hobbs 1982, Undeland 1997, Rustad 2010, Sohn and Ohshima 2011). The peroxide value (PV) is used as an indication of the degree of oxidation that has taken place and is mainly used to determine the primary oxidation of lipid in fish. The hydroperoxide break down and with further oxidation give a variety of substances, some responsible for the rancid flavour and others effects (Hobbs 1982, Rustad 2010). The PV is expressed in milliequivalent of iodine per kilogram of lipid or as millimolar of peroxide per kilogram of lipid (AOCS 1995). Peroxides are very in-stable and are rapidly transformed in secondary oxidation products. The determination of PV should be accompanied by determination of secondary products of oxidation. The determination of thiobarbituric acid-reactive substances (TBARS) is a common method to determine the secondary product oxidation (Rustad 2010).

The formation of free fat acid is a result of hydrolysis of the two main fish lipids, the triglycerides (TG) and phospholipids (PL) by enzymatic reaction of lipases and phospholipases respectively (Undeland 1997, Huss 1995). The amount of free fat acids increases considerable during storage. The increment is more prominent in ungutted than in gutted fish probably because of the involvement of digestive enzymes. Triglyceride in the depot fat is cleaved by triglyceride lipase originating from the digestive tract or excreted by certain microorganisms (Huss 1995).

2.5 Atlantic mackerel

In Mozambique the raw materials used for the production of hot smoked fish are mainly small pelagic fishes and fish from in land waters such us cat fish, tilapia, tiger fish and others species. To carry out this experiment and in order to have similar products, Atlantic mackerel was chosen as raw material. The Atlantic mackerel (*Scomber scrombus*) (Figure 1) is a small pelagic fish that can be found in Iceland and is normally sold in the local market.

The quality of raw material before processing is an important factor in determining the product quality and yield. There are several factors that can affect its quality such as the time of year when the fish is caught, the catching method used and the storage conditions until processing takes place.

Figure 1: Atlantic Mackerel (Scomber scrombus).[2]

[2]Source:*http://www.fisheries.no/ecosystems-and-stocks/marine_stocks/fish_stocks/atlantic_mackerel/#.UxSyx_l_uSo*

3 MATERIALS AND METHODS

3.1 Experimental design and sampling

The study was done in two phases at Matis, Reykjavík, Iceland January to March 2014. Phase 1 henceforth referred to as pre-trial was carried out to determine optimum salt concentration in brine solution to attain 5% salt content in fish muscle upon smoking. Whereas, phase 2 henceforward referred to as the main study was carried out to determine the effect of abused temperature during handling and storage on smoked mackerel.

Mackerel (*Scomber scrombus*) used in the study (pre-trial and the main study) was caught on 28thJuly 2013 by a purse seine net in South-East of Iceland, and processed by Síldarvinnslan hf (SVN). After catch, fish were kept on-board in tanks at -1.2°C before transportation to the company for processing (de-heading and gutting) on 30thJuly 2013.Thereafter fish was packed in block of 22 kg each, frozen and stored at -18°C. Prior to the study, fish was transported within 7 hours in refrigerated truck set at -15 to -18°C to MATIS (laboratory Icelandic Food and Biotech Research &Development, Iceland) and stored at -18°C until the day of experiment.

3.1.1 Pre trial

Before start of the main experiment, a pre-trial was performed to determine the salt content needed in the brine solution and time needed for the brining process, in order to reach 5% of salt content in the smoked fish. In pre-trial study, fish was immersed in brine solution with two different salt (NaCl) concentration (18% and 24%) in the ratio of 1l:1 (brine: fish). Fish was sampled at different time intervals (0, 2, 4, 6, 8, 20, 24h), and at each sampling point two fish were taken randomly and determined separately for salt content. The obtained fish at sampling were smoked and salt content determined in the end product (smoked fish). Additionally, water activity of the smoked fish was also evaluated.

3.1.2 Main study

The design for the main study was done as presented in Figure 2, and sample groups used are as illustrated in Table 1. After receiving the raw material, the fish was weighed and samples collected to determine the quality and degree of freshness using sensory evaluation, microbiological, colour and chemical analysis. To explore the effect of temperature abuse before processing fish samples were divided in two treatments groups.

Table 1: Experimental design and sample group definition.

Group/treatment	Handling conditions (36h)	Processed	Storage conditions	Sampling days
A	Room temperature	Not	_	Raw material
C	Chilled	Not	_	Raw material
Aa	Room temperature	Hot smoked	Abused	0,2,4,7
Ca	Room temperature	Hot smoked	Abused	0,2,4,7
Ac	Chilled	Hot smoked	Chilled	0,7,14,21,28
Cc	Chilled	Hot smoked	Chilled	0,7,14,21,28

In the first treatment (Group A), fish sample was kept at room temperature (20 to 24°C) during 36 hours before processing to have the temperature abused lot. This was done to imitate the real conditions of fish handling before processing by artisanal fish processors in Mozambique.

In the second treatment (Group C), fish were stored on ice in the ratio of 1:2 (fish/ice), for 36h before processing to maintain the quality.

3.1.3 The hot smoking process

Blocks of frozen mackerel was removed from the freezer for air thawing at 0-5ºC. The thawing process was done for17h overnight. Thawed fish were divided in two experimental groups; one was stored with ice and another at room temperature during 36h before processing. After storing, fish were trimmed by removing fins and making small cuts in the skin in order to prepare the fish for the next step of processing. After trimming, fish were washed and introduced into full brine with 24% salt content for 20 h. After brining, the fish was washed in light brine solution with 10% salt content in order to remove the salt on the surface of the fish. Then fish was put on drying racks to drain the excess water. Then arranged on smoking racks and prepared for the hot smoking by using the improved smokehouse designed and built by MATIS (Figure 3). Smoke was produced from wood. The processing time in the kiln was divided into three stages: preliminary drying, a partial smoking and full heat smoking.

In order to retain the quality of the fish during smoking process it was important to control the temperature inside the chamber and inside the fish. During the smoking process the temperature inside the smoking cabinet was measured using thermometer (*teste 926 thermometer* AG, Germany). Moreover, the temperature of the fish was also recorded using temperatures loggers placed inside the fish muscle before smoking onset.

After smoking the two groups were further subdivided into two each for storage at room temperature and chilled. From group A, one subgroup was stored at room temperature (treatment Aa) and counterpart chilled (treatment Ac). From group C, one subgroup was stored at room temperature (treatment Ca) and counterpart chilled (treatment Cc) as shown in Table 1. Prior to storage at aforementioned conditions, fish was allowed to cool and dry at 25˚C for24 hours after smoking. After cooling fish were air packed in individual bags with two fishes in each.

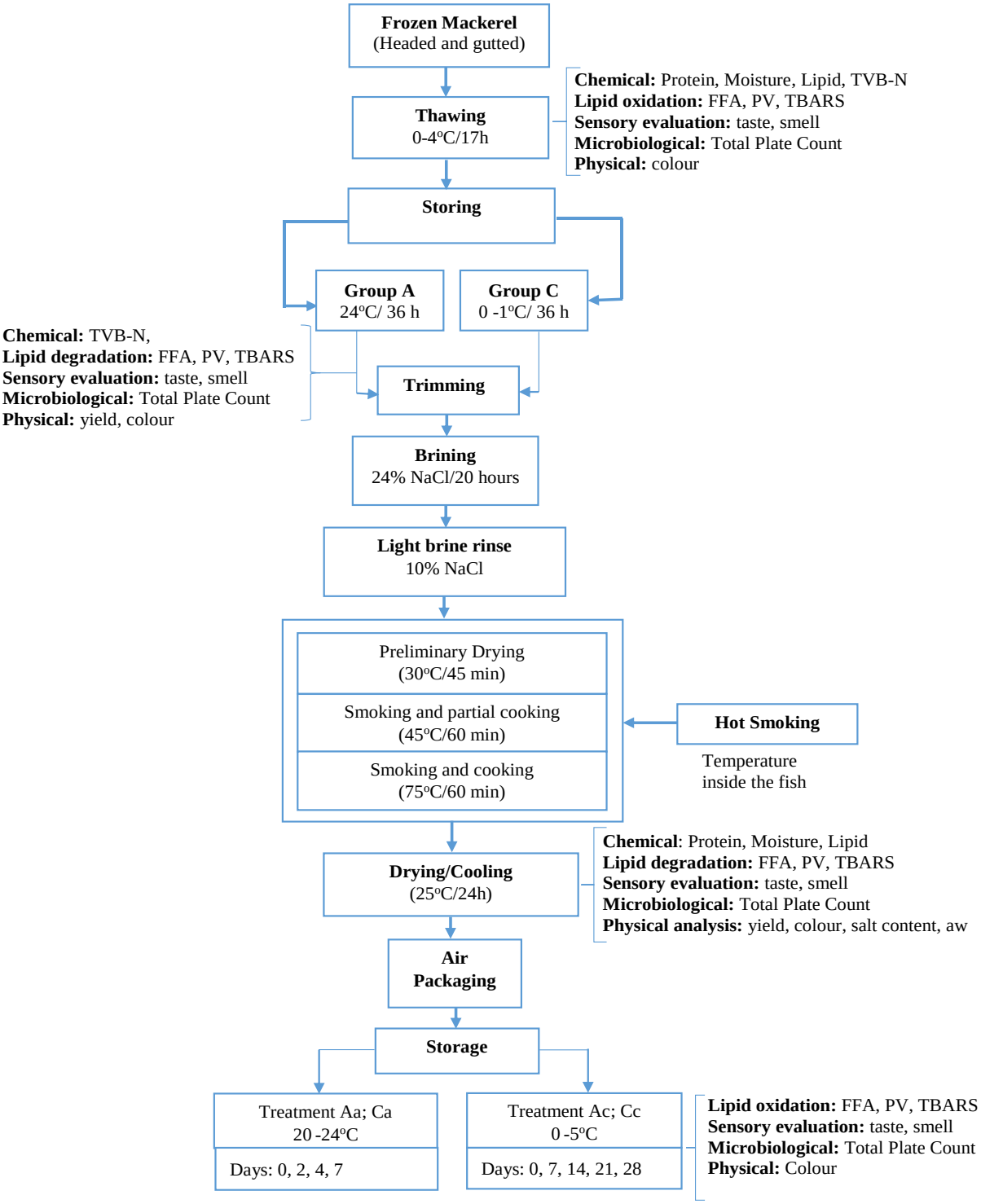

Figure 2: Experimental layout of producing hot smoked mackerel.

Figure 3: The smoking house designed by MATIS.

The groups for storage at room temperature were kept at 20 to 25°C ambient and chilled ones at 4-5ºC. Samples stored at room temperature were analysed every two days until the end of the storage life while the cold storage samples were analysed after every 7 days. Each sampling day, four fish pieces from each group were taken for sensory evaluation and two fishes for determination of Total Plate Count, colour, free fatty acids (FFA), peroxide value (PV) and thiobarbituric acid-reactive substances (TBARS). For the smoked fish stored at room temperature sampling was done on day 0, 2, 4 and 7), whereas for the chilled stored sampling was done on day 0, 7, 14, 21 and 28.

3.2 Evaluation methods

3.2.1 Sensory evaluation

Sensory evaluation for raw and hot smoked mackerel was carried out by 8 to 9 trained panellist all members of Matis sensory panel familiar with a descriptive analysis (DA) procedure as described by Meilgaard *et al.* (1999). For the raw fish sensory evaluation was performed to determine the sensory attributes and quality of raw material before processing. The sensory quality of hot smoked mackerel was evaluated on each sampling day. Prior to sensory evaluation, chilled samples were brought to room temperature for at least 30 minutes for sensory evaluation session. Fish loins were cut into small pieces of about 4-5 cm long and 3-4 cm wide. The pieces were placed in small aluminium boxes coded with three digit random numbers and covered with a lid.

The panellist used unstructured scale from 0 to 100% (Stone and Sidel 1985) to describe the intensity of odour and flavour sensory attributes for smoked mackerel. Each panellist evaluated duplicates of samples in a random order for each group. A computerised system (FIZZ, version Version 2.47B, 1994-2012, Biosystémes, France) was used for data recording. Sensory evaluation was stopped when most panellists detected the spoilage odour and flavour (a score of 20 for half the panellist number was used as limit).

3.2.2 Microbiological method

Fish were analysed in duplicate per group using two polled samples per replicate. The duplicates were analysed separately observing strict hygiene to prevent cross contamination. Twenty five grams of mince flesh were mixed with 225 ml of cooled Maximum Recovery Diluent (MRD, Oxoid) in stomacher bag to obtain a 10-fold dilution. Blending was done in stomacher for 1 minute. Successive 10-fold dilutions were done as required. Aliquots were plated in triplicate on Iron Agar (IA) as described by Gram *et al.*, (1986) with the exception that 1% NaCl was used instead of 0.5% with no overlay. In all counts pour plate technique was used. Enumeration of TPC was performed after 2-3 days incubation at 22°C. Analysis were done on day 0, 2, 4, and 7 for groups stored at room temperature and, day 0, 7, 14, 21 and 28 for chilled stored.

3.2.3 Chemical methods

The proximate composition of fish was done to determine the moisture, lipid and protein content in the fish samples.

The water content was calculated as the loss in weight during drying at 105°C for 4 h (ISO, 1983 according to Bao *et al*. 2007). Results were expressed as percentage of wet weight.

Total lipids (TL) were extracted from 25 g samples (80±1% water) with methanol/chloroform/0.88 % $KCl_{(aq)}$ (at 1/1/0.5, v/v/v) according to the Bligh and Dyer (1959) method. The lipid content was determined gravimetrically and the results were expressed as grams lipid per 100 g wet muscle.

Protein: Protein was determined by Kjeldahl method. The organic matter was digested by sulphuric acid in the presence of a catalyst. The reaction product was rendered alkaline, then the liberated ammonia was distilled and titrated with hydrochloric acids (ISO 2005).

Total volatile basic nitrogen (TVB-N): The total volatile base nitrogen (TVB-N) was determined according to the method described by Malle and Poumeyrol (1989). TVB-N was measured by steam distillation (Struer TVN distillatory, STRUERS, Copenhagen) and titration, after extracting the fish muscle with 7.5% aqueous trichloroacetic acid solution. The distilled TVB-N was collected in boric acid solution and then titrated with sulphuric acid solution.

3.2.4 Lipid degradation

Free fatty acid (FFA): free fatty acid content was determined by the method from Lowry & Tinsley (1976) with modification made by Bernardez *et al.* (2005) based on complex formation with cupric acetate-pyrimidine, followed by absorbance reading at 710 nm (UV-1800 spectrophotometer, Shimadzu, Kyoto, Japan). Results were expressed as g FFA/100g lipids.

Peroxide values (PV): Peroxide values was determined using the ferric thiocyanate method described by (Santha and Decker, 1994) for muscle samples and other heterogeneous samples. The absorbance were read at 500 nm (Sunrise Microplate Reader, Tecan AustriaGmbH, A-5082 Grödig, Austria) and the results were expressed as mmol lipid hydroperoxides/kg of sample.

Thiobarbituric acid-reactive substances (TBARS): Thiobarbituric acid-reactive substances were measured by method of Lemon (1975) with modifications. A 5.0 g sample washomogenised with 10 ml of 7.5% trichloroacetic acid (TCA) usingan Ultra-Turrax homogeniser (Kika Labortechnik, T25 basic, Staufen,Germany) at 2400 rpm for 10 s. The homogenate was centrifugedat 5100 *rpm* for 20 minutes at 4°C (TS-25 centrifuge).A mixture of 0.1 mL of supernatant and 0.9 mL of 0.02 M thiobarbituricacid solution was mixed in 1,5 ml eppendorfs and then heated in a water bath at 95ºC for40 min. Then samples were cooled down on ice and 0.2 ml were placed in microplate for absorbancereading at 530 nm (Sunrise Microplate Reader, Tecan AustriaGmbH, A-5082 Grödig, Austria). The results were expressed asmmoL of malomaldehyde diethylacetal per kg of sample and calculated using a standard curvepreparedwith 100 times dilution of the stock solution (TEP=malomaldehyde diethyl acetal=MDA eq.).

3.2.5 Physical properties

Water activity: An Aqua Lab water activity meter was used to measured water activity (a_w) of the fresh and dried samples. About 2 g of samples were put into the instrument and a_w was measured automatically after starting the program.

Salt content: the salt content of the smoked mackerel were determined by weighing 5g of sample into the extraction bottle, 200ml of deionised water was added and shaken using the shaker for 50 minutes. 20ml of nitric acid was then added to 20ml of the supernatant and titrated with silver nitrate (AOAC 2000).

Colour measurement: the intensity of the flesh colour was measured by using the Minolta CR-300 chromameter (Minolta Camera Co., Ltd; Osaka, Japan) in Lab system with CIE Illuminant C. The instrument records the **L** (lightness), **a** (redness) and **b** (yellowness) values on CIELAB colour scale. Five positions (two close to the head, two in the middle and one close of the tail) above the lateral of the fillets (n=4) were measured. The average **L**, **a** and **b** values of ten measurements for each fish were used to calculate the mean and standard deviation.

Yield: The yieldfor each processing step for production of hot smoked mackerel was calculated according to the formula (Bao *et al.* 2007):

$$Processing\ Yield = \frac{W_{processed}}{W_{raw}} \times 100(\%) \quad \text{Equation (1)}$$

$$Smoking\ Yield = \frac{W_{Smoked}}{W_{raw}} \times 100(\%) \quad \text{Equation (2)}$$

$$Dried\ Yield = \frac{W_{dried}}{W} \times 100(\%) \quad \text{Equation (3)}$$

$W_{raw}$is the weight of rawmaterial;
$W_{procesed}$ is the weight of raw materialbefore processing;
W_{smoked} is the weight of smoked fish before drying;
W_{dried} is the weight of smoked fish after drying.

3.3 Statistical Analysis

The mean values of descriptive analysis (DA) attributes scores, microbial counts and physical-chemical parameter changes were plotted separately against storage time using Microsoft excel (2013).To see if samples were significantly different,t-Test and Linear Regression were also done using Microsoft Excel (2013). To investigate the effect of storage conditions on the quality of hot smoked mackerel,the obtained sensory data were analysed by General Linear Model (GML).Analysis of variance (ANOVA) for sensory descriptive analysis (DA) datawere performed in the statistical program NCSS 2000 (NCSS, Utah, USA).The program (ANOVA) calculates multiple comparisons using Duncan's test to determine if sample groups are different. Significance level was defined at 0.05 (α=0.05).

4 RESULTS AND DISCUSSIONS

4.1 Pre study

The results of pre brining study shows that as the time progressed, the salt concentration/content increased in whole mackerel reaching approximately 5% after 20h and 24h under 24% and 18% brine solution accordingly (Figure 4). The brining time depends mainly upon two factors, the size of the fish and the fat content.

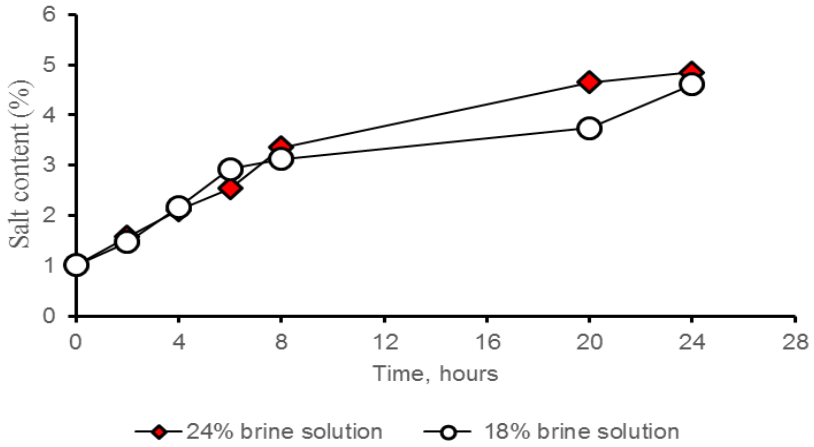

Figure 4. Evolution of salt content in whole mackerel brined in 18% and 24% brine solution for up 24 hours.

The proportion of salt in the fish increased slightly after smoking because of dehydration due to drying. After smoking, the salt content of mackerel muscle was 4.85% and the water activity was 0.87 in 24% brined group. Whereas, the 18% brined mackerel recorded salt content and water activity of 4.61% and 0.93 respectively. According to Arason *et al.* (2014), salt content less than 20% in brine solution has minimum effect on the protein conformation in fish muscle. However, water activity plays an important role in food preservation. Rahman and Labuza (2007), noted that pathogenic bacteria grow is inhibited when the water activity is below 0.85-0.86.In present study, the water activity of fish brined with 24% salt content was more close to this value, therefore the salt concentration used in the present study for brining was 24%.

4.2 Main study

4.2.1 The hot smoking process

Figure 5 shows the temperature profile versus time during hot smoking. During the smoking process the highest temperature in the fish muscle reached around 60°C for 45 minutes. This is in agreement with findings by Hobbs (1982), who reported that during hot smoking the temperature inside the fish during hot smoking needs to achieve 60-70°C for 30 minutes or longer. It's important to attain that temperature and time during smoking to kill most of the normal spoilage bacteria.

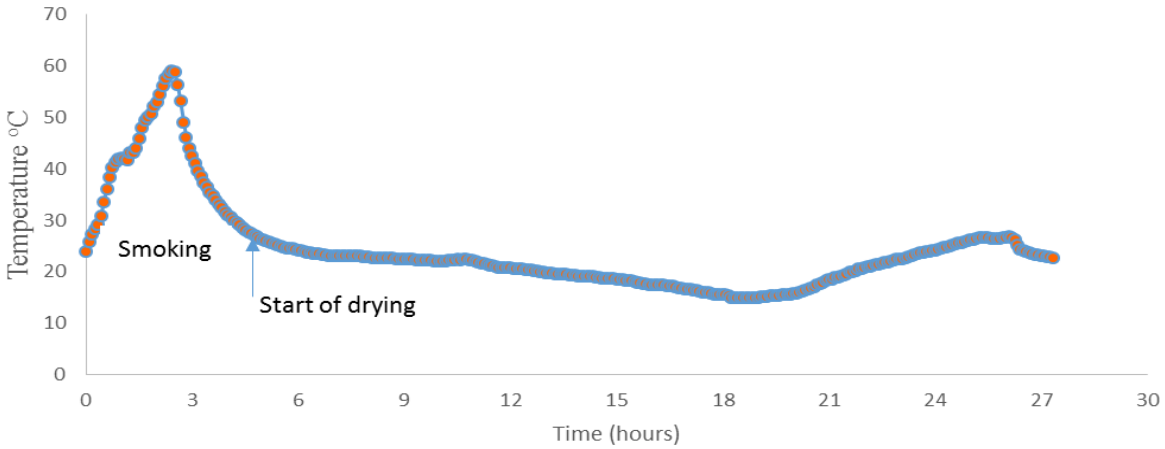

Figure 5: Temperature profile inside the fish during the hot smoking and drying process (n=10 loggers).

During the pre-drying and smoking period the temperature was around 20 to 40°C in the first hour. In the second period of smoking the temperature was around 40 to 60°C. As expected it was observed that at the end of smoking process the temperature started to decline. On ending the smoking process, the drying process was initiated. However, in the current experiment the drying of fish was done inside the smoking house for 24 hours at temperature of about 24°C (Figure 5).

4.2.2 Temperature profile during storage

After processing the hot smoked fish samples were stored at (4-5°C) and at room temperature (20-25°C) to determine the storage life of products (Figure 6). During the storage life study, sensory evaluation, yield, colour measurement, microbiology, chemical and lipid degradation were done in order to determine the quality of smoked fish with storage time.

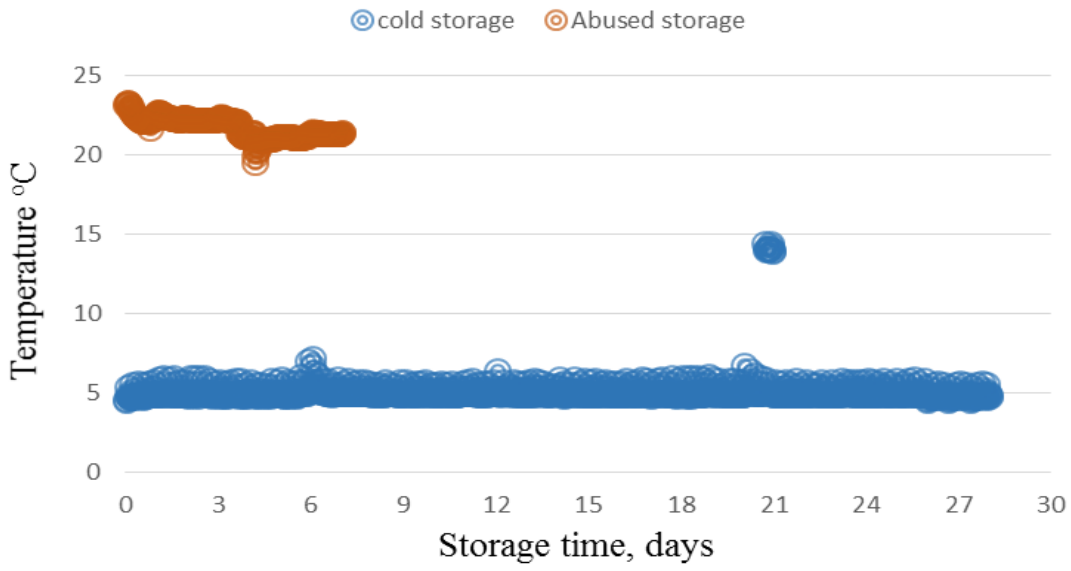

Figure 6: Average temperature during storage of smoked mackerel. Cold storage (n= 5 loggers); room temperature (n=5 loggers).

4.2.3 Sensory evaluation

Before processing, the two experimental groups were subjected to sensory evaluation to determine the quality of raw material. The negative and positive attributes of odour, flavour and texture used to determine the fish quality are shown in the Figures 7, 8, and 9.

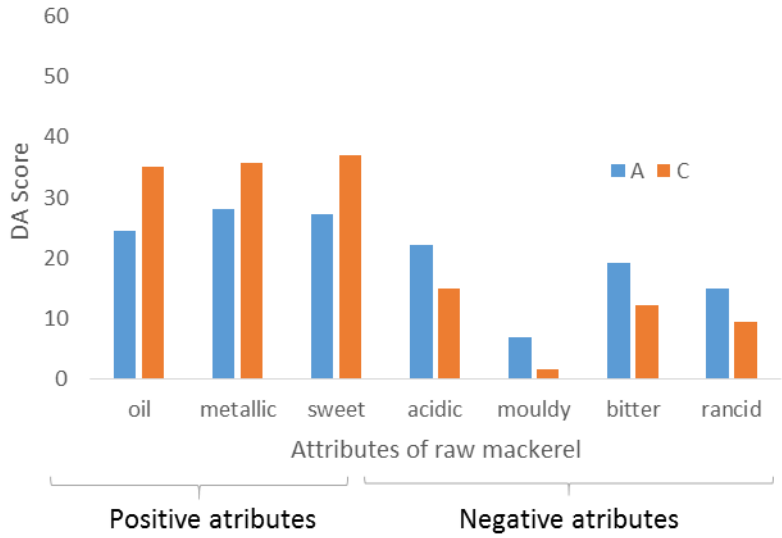

Figure 7: Flavour of raw material (Descriptive Analysis (DA) score: 0-100). A= Fish stored at room temperature (abused) and C= Fish stored on ice (chilled).

The figure shows that the two experimental groups were different before processing. The raw fish stored in ice (group C) had high score for positive attributes compared to counterpart stored at room temperature (group A). The flavour of group C was more oil and sweet than for group A ($p<0.05$). On the other hand, the experimental group A has high score compared with group C. The flavour was more mouldy ($p<0.001$), bitter, acid and rancid ($p<0.01$).

In terms of odour the group C was more oil and sweet ($p<0.01$) and metallic ($p<0.05$) if compared with the group A (Figure 7 & 8). The odour score within the two experimental groups were not significantly different, but the mouldy and butyric odour was more noticeable in the group A compared with the group C, with ($p<0.01$) and ($p<0.001$) accordingly.

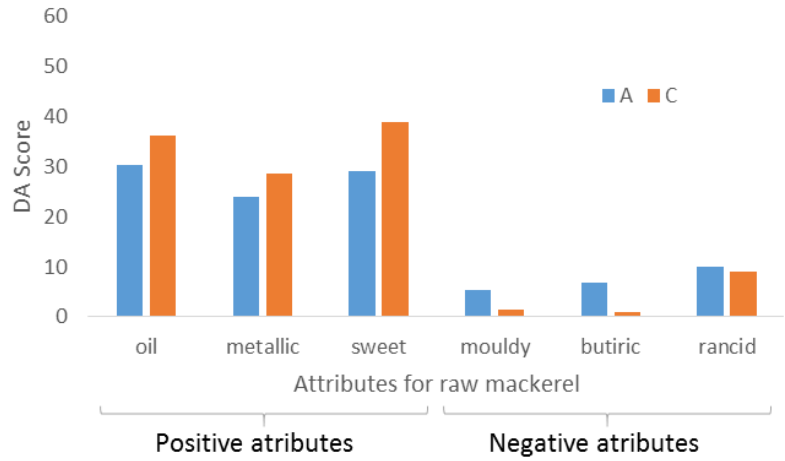

Figure 8: Odour of raw fish (Descriptive Analysis (DA) score: 0-100). A= Fish stored at room temperature (abused) and C= Fish stored on ice (chilled).

In terms of texture the two experimental groups were more soft, juicy and tender and the difference between both was not significant. As regards the negative attributes the fish stored in ice were mushier than the fish stored at room temperature. The sticky texture was higher in the group A than the group C.

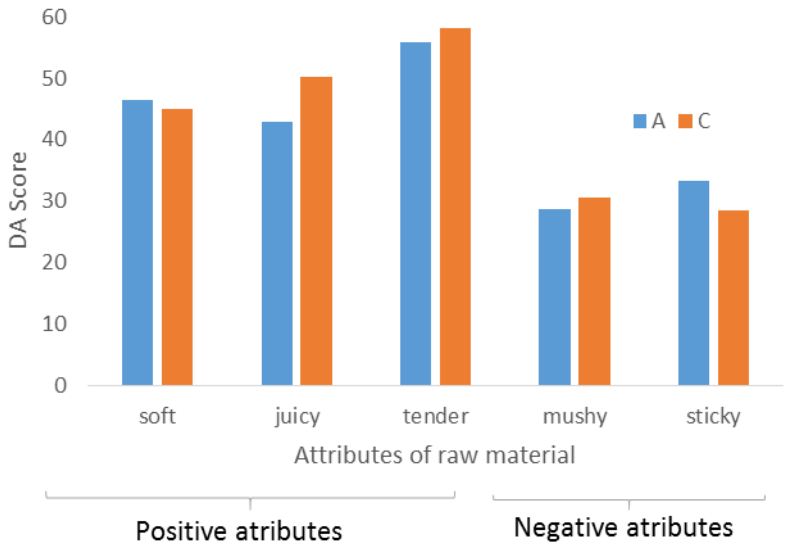

Figure 9. Texture of raw fish (Descriptive Analysis (DA) score: 0-100). A= Fish stored at room temperature (abused) and C= Fish stored on ice (chilled).

The sensory evaluation of raw mackerel shows that at the beginning the two experimental groups were significantly different (Appendix 2). The odour and flavour attributes shows that the fish stored at room temperature (group A) prior to processing was characterised by spoilage quality attributes compared to the one stored in ice (group C). The acidic, rancid and mouldy attributes for flavour and odour detected by panellist was more evident in group A, indicating that the bacteria and mould growth was higher and lipid degradation initiated. Huss (1995), noted that during ambient storage a slight lower level of 10^7-10^8 cfu/g is reached in 24 hours

and the development of free fatty acid in herring stored at different temperatures was high in the group stored at +12˚C.

Changes in rancid and spoilage attribute odour and flavour during storage of smoked mackerel evaluated by sensory panel are presented (Figure 10 and 11). The rancid and spoilage odour was more prominent in the temperature abused fish stored at both room temperature (Aa) and chilled (Ac). The rancid odour indicates lipid degradation while the spoilage indicates the bacteria and mould growth. The temperature has positive effect in retarding lipid degradation and spoilage of fish. The fish stored at abused condition (high temperature) before processing and thereafter stored at chilled temperature, the storage time was extended at evidenced by longer days to rejection (Ac). On the other hand, after 7 days of storage, the mackerel stored at room temperature (Aa) before and after processing was rejected implying end of storage life based on sensory results.

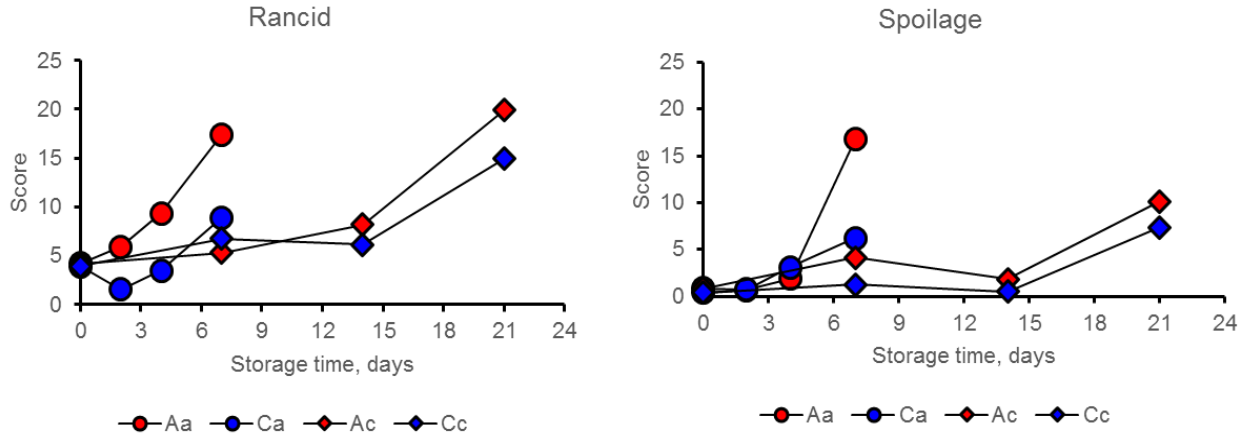

Figure 10: Changes in odour attributes during storage of hot smoked mackerel (score: 0-100). (Aa: abused, abused; Ca: chilled, abused; Ac: abused, cold; Cc: chilled, cold).

Figure 11 shows changes in flavour of smoked mackerel stored at room and chilled temperature as well as appendix 4 and 5. The rancid flavour was more evident in the experimental group Aa and Ac, both from raw material abused before processing. The spoilage flavour was not good indicator for the panellist to determine the storage life of smoked mackerel. This probably is because the smoke flavour is strong and can mask the spoilage flavour and other undesirable flavour.

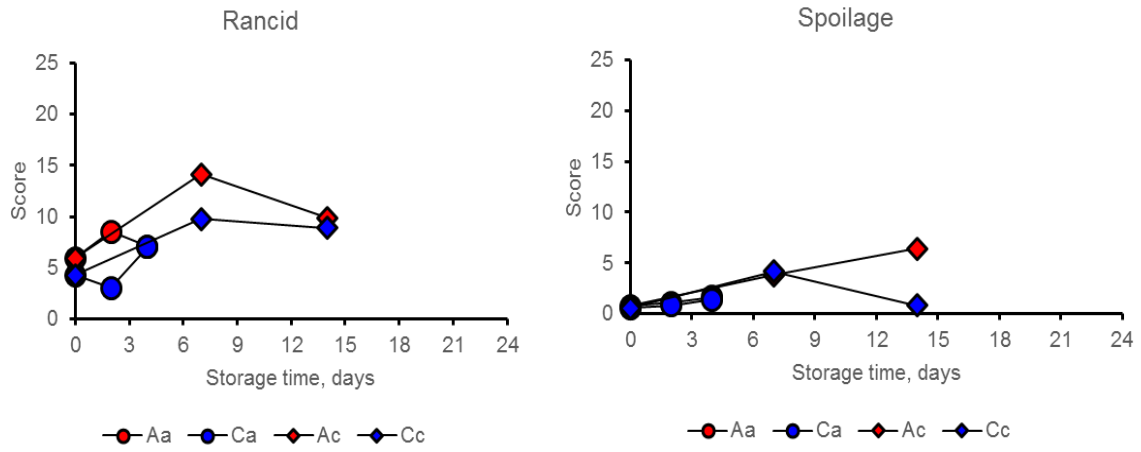

Figure 11: Changes in flavour attributes during storage of hot smoked mackerel (score: 0-100). (Aa: abused, abused; Ca: chilled, abused; Ac: abused, cold; Cc: chilled, cold).

4.2.4 Microbiological analysis

The total counts in raw fish before smoking were log 5.86 CFU/g and log 3.65 CFU/g in the group A and C respectively. The results of total count during storage time are presented in Figure 12. As expected, the results shows that the bacteria growth in group A (Aa and Ac), which was stored at room temperature before processing, was higher than group C (Ca and Cc) stored in ice before processing. The difference between the two experimental groups was statistically significant at all sampling points ($p < 0.05$), with the exception of day 4.

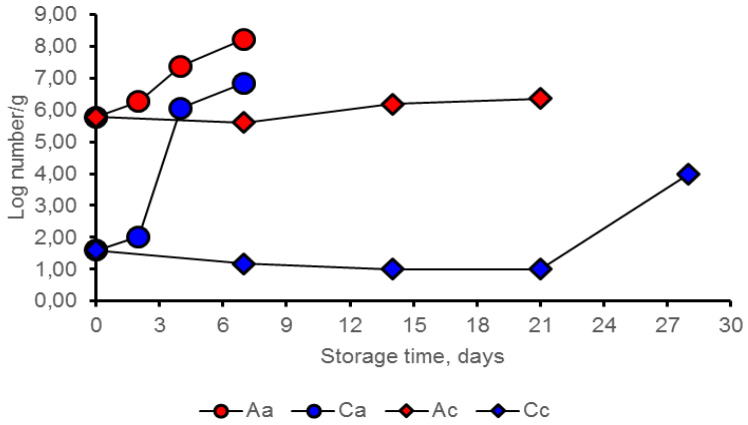

Figure 12. Growth of bacteria (total count at 22˚C) during storage of hot smoked mackerel. Aa: abused, abused; Ca: chilled, abused; Ac: abused, cold; Cc: chilled, cold.

After hot smoking, an extended lag phase (delayed growth) of bacteria was observed in mackerel stored under cold conditions. This phenomenon could be attributed to cold shock on the microbes. However, from day 21 high microbial growths was evident in Cc group probably

because of re-establishment or succession by cold loving bacteria that had started growing at this stage. On the other hand the results shows that the cold storage doesn't improve the quality of initial temperature abused group. The abused group after processing still recorded higher bacteria counts at the beginning of chilled storage (log 6 CFU/g) though the counts didn't change much during storage. Comparing the abused and chilled experimental groups storage under cold conditions results in low bacterial growth that were statistically different from room temperature stored groups ($p<0,05$). The storage life of smoked mackerel stored at room temperature was 7 days. This conforms to findings by Storey (1982), who found out smoked fish that have lost 11% weight during smoking remain edible for about 6 days stored at 20°C.

4.2.5 Chemical analysis

The TVB-N level, moisture and Protein content in raw and smoked mackerel are presented in the Table 2.

Table 2: The chemical analysis of mackerel before and after processing.

	Experimental group	Moisture (%)	Protein (%)	TVB-N (mgN/100g)
Raw material	A	60,30 ± 4	19,15 ± 3	22,55
	C	55,85 ± 4	19,65 ± 3	15,70
Final product	A	48,55 ± 4	21,40 ± 3	26,40
	C	49,65 ± 4	20,00 ± 3	20,80

Group A= fish stored at room temperature before processing.
Group C= fish stored on ice before processing.

The smoking process reduced significantly the moisture content in fish. This reduction corresponds to 11.75% and 6.2% for the experimental group A and C respectively.

The protein content in smoked mackerel increased by 2.25% and 0.35% for A and C accordingly. This probably because of dehydration during the smoking process.

The TVB-N formation increased in both groups before smoking. The total volatile basic nitrogen (TVB-N) in in the experimental group C raw fish was 15.70 mg N/100g and after smoking it reached 20.80 mg N/100g, corresponding 32% of increment. Although this increment, the fish was rather fresh before processing in contrast to the experimental group A which was stored at room temperature before processing and had an initial TVB-N value of 22.55 mg N/100 and after smoking it rose to 26.40 mg N/100 indicating 17% of increment. This value indicates that the experimental group A raw fish was of compromised quality prior to processing. This results are in agreement with Goulas and Kontominas (2004).

4.2.6 Lipid degradation

Peroxide value (PV)

The peroxide value recorded in the raw material was 0.46 µmol/g and 0.43 µmol/g in the experimental group A and C respectively. The Figure 13 shows the change in peroxide value during storage of smoked mackerel. After hot smoking this value reduced in both experimental groups stored at room temperature and at chilled storage. At the beginning of storage time, the peroxide value was around 0.15-0.20 µmol/g in both groups. The results show that the hot smoking process has an effect on the formation of lipid oxidation. The effects may be associated with the antioxidant components in wood smoke. Horner (1997), noted that during the smoking process, there is a deposition of phenolic antioxidant substances, which delays autoxidation (and rancidity) of the unsaturated fish lipids. The results found in this study was similar with Adeyemi *et al.* (2013) were found increasing of peroxide value during storage of smoked mackerel at room temperature.

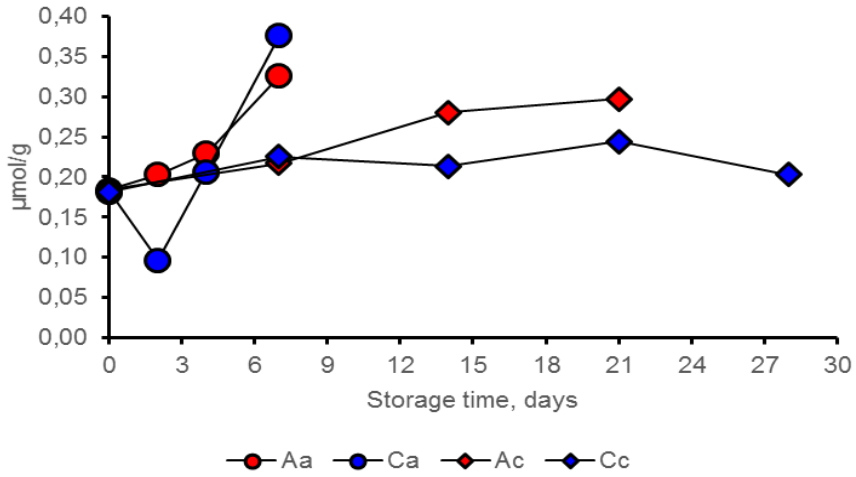

Figure 133. Change in peroxide value (PV) during storage of hot smoked mackerel. (Aa: abused, abused; Ca: chilled, abused; Ac: abused, cold; Cc: chilled, cold).

From day 0 to day 2 the PV reduced in group (Ca) and started increasing from day 2 to day 7 reaching 0.38umol/g at the end of storage life. This increment was probably because of the formation of secondary oxidation products which start immediately when the first oxidation products cease. The production of hidroperoxides products was more stable and at lower level in the fish stored chilled (Cc). The same trend was observed in the abused fish stored chilled. According to Huss (1995), the temperature affect the lipid degradation. Lower temperature reduces the lipid degradation with time.

The result of formation of Thiobarbituric reactive substances (TBARS) is shown in the Figure 14. Before processing the TBARS content in the raw fish was 1103.69 ± 99.79µmol/kg and 1270.89 ± 171.89µmol/kg in group A and C respectively. After smoking the level of TBARS reduced probably because of antioxidant effect of smoke applied during smoking. During storage the TABRS content increased because of reaction of lipid oxidation.

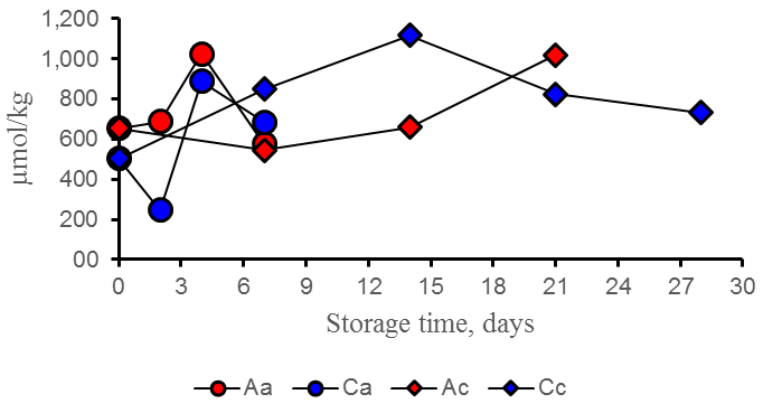

Figure 144. Changes in Thiobarbituric reactive substances (TBARS) during storage of hot smoked mackerel (Aa: abused, abused; Ca: chilled, abused; Ac: abused, cold; Cc: chilled, cold).

Lipid content variation during storage in hot smoked mackerel is shown in the Figure 15. The results shows that lipid content in raw mackerel 20.91 % in group A and 21.54 % in group C. was After smoking the lipid content reduced.

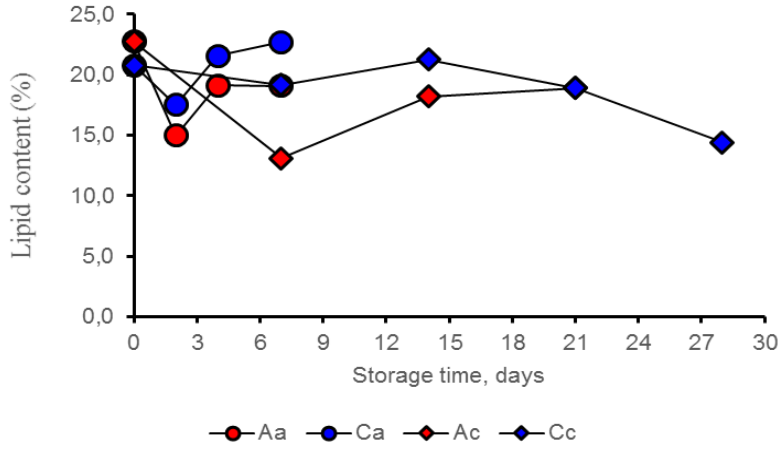

Figure 155. Lipid content variation during storage of hot smoked mackerel (Aa: abused, abused; Ca: chilled, abused; Ac: abused, cold; Cc: chilled, cold).

Free fatty acid (FFA)

The free fatty acid in the raw material was 3.1 g FFA/100g Lipid for the experimental group A and 2.0 g FFA/100g Lipid for the group C. The Figure 16 trends shows that after smoking the percentage of free fatty acid didn't reduce significantly. However, two days after the storage onset, the free fat acid started increasing. This result is in agreement with similar study made by Huss (1995), about the development of free fatty acids in herring at different temperatures.

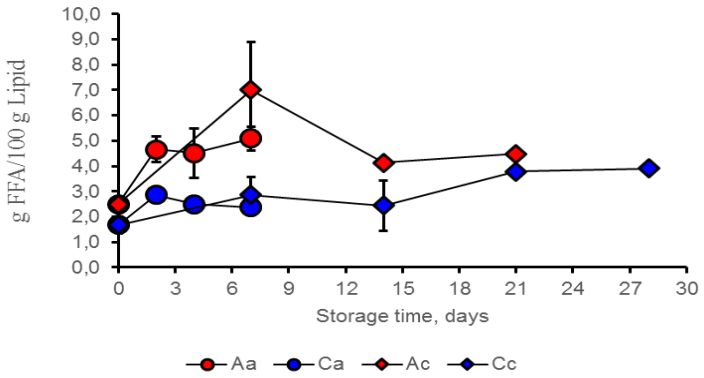

Figure 166. Changes in free fatty acid (FFA) during storage of hot smoked (Aa: abused, abused; Ca: chilled, abused; Ac: abused, cold; Cc: chilled, cold).

4.2.7 Physical properties

Water activity and salt content

After smoking the water activity was 0.944±0.001 and 0,951± 0.004 in the experimental group A and C respectively. The salt content was 4.95±0.11 and 3.97±0.13 in the experimental group A and C accordingly.

Colour

Results of colour measurement in smoked mackerel stored at cold temperature are illustrated in Table 3. The lightness (L) of raw material was 50.4 ± 1.and after smoking the **L** value increased then started reducing until the end of storage.

The **a** values prior to processing were 2.97 ± 0.72. After Smoking it reduced except day14 after which it increased slightly then reduced at the end. Before smoking the **b** value was 6.89 50.4 ± 0.36. After smoking until the end of storage it increased significantly. Nguyen *et al.* (2001) and Lauritzsen *et al.* (1999), reported similar results and noted that the increases in **b** and **a** value is probably related to increase of lipid oxidation in the heavy salted cod muscle increasing yellow/orange hue whereas blue/green hue decreased. The **a** value describes the intensity in green colour (negative) and in red colour (positive). The **b** value describes intensity in blue colour (negative) and in yellow colour (positive) (Park 1994).

Table 3. The colour measurement during storage under cold conditions (Means± SD, n=4).

Parameters	Experimental Group	Raw material	Final product (storage days) day 0	day 7	day 14	day 21
L	Ac		58,13 ± 4,46	52,17 ± 3,04	47,04 ± 3,88	47,34 ± 1,57
	Cc	50,4 ± 1,34	60,47 ± 6,09	49,67 ± 1,08	50,43 ± 1,17	47,74 ± 3,10
a	Ac		2,47 ± 0,68	2,05 ± 0,73	2,53 ± 0,90	2,98 ± 0,94
	Cc	2,97 ± 0,72	1,97 ± 0,72	1,95 ± 1,10	2,97 ± 0,57	1,14 ± 0,81
b	Ac		8,00 ± 0,28	11,54 ± 0,47	9,39 ± 2,65	10,64 ± 2,87
	Cc	6,89 ± 0,36	8,16 ± 0,54	11,86 ± 0,63	11,35 ± 0,55	12,88 ± 0,60

L=lightness; a=redness; b=yellowness. Ac: abused, cold; Cc: chilled, cold.

The Table 4 shows results of colour measurement of smoked mackerel stored at room temperature. The L value before smoking was 47.79 ± 2.60. After smoking (on day 0) the value was high compared to raw material. After storage the **L** value of smoked mackerel stored at room temperature reduced with time until the end of storage life. Whereas, the **a** value for raw material was 2.074 ± 0.57. After smoking it increased for both groups stored at room temperature until the end of storage life. The b value prior to processing was 5.78 ± 0.63. However, after smoking and during storage it increased significantly in both experimental groups. This increment is probably related to lipid oxidation as reported by Nguyen *et al.* (2001) and Lauritzsen *et al.* (1999).

Yield

The yield results during production steps for hot smoked mackerel are presented in the Table 5. In general, the quality of raw material before processing affected the yield. The experimental group A stored at room temperature before processing had lower yield compared with the experimental group C stored in ice. Horner (1997) and Doe (1998) reported that during smoking and drying the fish weight reduces caused by dehydration due to heat. The moisture content after smoking reduced by 11.75% and 6.2% for the experimental group A and C respectively. Probably this was the reason for lower yield in the group A compared with group C, as possibly during fish spoilage protein breakdown may have resulted to reduced water holding capacity leading to low yield.

Table 4. The colour measurement during storage at room temperature (Means ± SD, n=4).

Parameters	Experimental Group	Raw material	Final product (storage days) day 0	day 4	day 7
L	Aa	47,79 ± 2,60	58,13 ± 4,46	51,63 ± 1,26	45,02 ± 1,98
	Ca		60,47 ± 6,09	50,48 ± 2,78	48,69 ± 2,77
a	Aa	2,074 ± 0,57	2,47 ± 0,68	1,65 ± 0,44	3,12 ± 0,53
	Ca		1,97 ± 0,72	3,25 ± 0,74	3,99 ± 0,70
b	Aa	5,78 ± 0,63	8,00 ± 0,28	11,54 ± 0,49	12,03 ± 0,98
	Ca		8,16 ± 0,54	11,37 ± 0,57	11,99 ± 0,52

L=lightness; a=redness; b=yellowness. Aa: abused, abused; Ca: chilled, abused.

Table 5. The yield of hot smoked mackerel.

	Group A		**Group C**	
	Weight (Kg)	**Yield (%)**	**Wheigh (Kg)**	**Yield (%)**
Raw material	18,10	100,00	38,20	100,00
Processing	15,50	85,64	34,62	90,63
Smoking	12,94	71,49	31,85	83,38
Drying	12,04	66,52	27,80	72,77

Group A= fish stored at room temperature before processing.
Group C= fish stored on ice before processing.

The results show as well the importance of observing cold chain in all steps of fish processing in order to have a good yield. High yield brings good profits to the fish processors. Comparing the yield in each step of producing for hot smoked mackerel, the results show that in both groups the weight loss was higher after processing compared to the earlier two steps (smoking and drying). This result gives an indication of the initial quality of processed fish purchased by the company. That means if the processor has high loss after processing, he should complain to the company about the quality of raw material mainly after processing.

5 CONCLUSION

The shelf life of smoked mackerel is affected by the quality of raw material and storage temperature after processing. According to sensory evaluation, the storage life of abused products was 7 days. On the other hand, the well-handled (chilled) fish had 21 days of storage life.

The lipid degradation analysis combined with sensory analysis gives information that can be used in evaluating the quality and storage life of smoked fish. During storage when the oxidation and enzymatic reaction occurring in lipid content of fish is evaluated, obtained data can be used as indicator of spoilage in smoked fish. This data combined with sensory evaluation indicates the rancidity odour and flavour.

Among the physical properties of smoked fish, the yield, salt content and water activity are the most important parameters to analyse during handling and processing for smoked products in regard to artisanal fishery. Yield results shows that the poor handling respectively affects the produce. Salt content in brine solution plays an important role in keeping the quality of smoked fish, however in the study the final product had about 5% salt content which is high for some consumers. To get good profits for the fisherman, handling and processing should take into account both preservation and wholesomeness of the products.

The microbial analysis indicates that processing doesn't improve quality of poorly handled product. Before smoking, the abused group had high bacteria counts. After smoking, the total count reduced although not significantly but compromising the storage life of abused fish. After 7 days of storage the bacterial level was at the allowable limit for consumption indicating the end of storage life, and the sensory panel detected spoilage related attributes on the same day. This means that the artisanal fishermen without cold chain equipment to preserve their catch can have the harvest processed and kept for up to 7 days, from catching until the end of chain. Whereas, if good handling prior to processing is adhered to, better quality smoked fish products with extended storage life of about 21 days can be realised.

In general the results of this study indicates that the good handling procedure along the processing steps produced smoked fish that retained good quality up to 21 days storage. It is therefore worth emphasising the importance of following a cold chain to increase the storage life and in maintaining the superior quality of smoked fish products.

6 RECOMMENDATIONS

Similar study should be carried out to determine the quality and storage life of smoked fish, by using less salt content in brine solution and with increase in time for drying or by using different method for drying. On the other hand, studies should be carried out as well in order to determine the quality and storage life of smoked fish comparing lean and fat fish.

The government of Mozambique should continue encouraging the promotion of rural extension programs in fisheries communities with emphasis in transferring of improved technology for fish processing. Within this trainings fishermen should be encouraged through training programs about the importance of use ice during handling and storage of fish in order to extent the storage life of fish.

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APPENDIX

Appendix 1. Sensory vocabulary for cooked fresh mackerel loin.

sensory attribute	short name	scale	definition
ODOUR			
fresh oil	O-oil	none || much	Fresh fishoil odour
metallic	O-metallic	none || much	Metallic odour
sweet	O-sweet	none || much	Sweet odour
mouldy	O-mouldy	none || much	Mouldy odour
butiric acid	O-butiric	none || much	Butiric acid, smelly feet
rancid	O-rancid	none || much	Rancid odour
FLAVOUR			
fresh oil	F-oil	none || much	Fresh fishoil flavour
metallic	F-metallic	none || much	Metallic flavour
sweet	F-sweet	none || much	Sweet flavour
acidic	F-acidic	none || much	Acidic, sour flavour
mouldy	F-mouldy	none || much	Mouldy flavour
bitter	F-bitter	none || much	Bitter flavour
rancid	F-rancid	none || much	Rancid flavour
TEXTURE			
soft	T-soft	firm || soft	Softness in first bite
juicy	T-juicy	dry || juicy	Dry: draws liquid from mouth. Juicy: releases liquid when chewn
tender	T-tender	tough || tender	Tenderness when chewn
mushy	T-mushy	none || much	Mushy, porridge like texture
sticky	T-sticky	none || much	Glues together teeth when biting the fish.

Appendix 2. Mean value for sensory of cooked fresh mackerel.

Sensory attribute		A	C	p-value
O-oil	**	30	36	0,007
O-metallic	*	24	29	0,098
O-sweet	**	29	39	0,002
O-mouldy	**	5	2	0,005
O-butiric	***	7	1	0,001
O-rancid		10	9	0,512
F-oil	**	25	35	0,004
F-metallic	*	28	36	0,015
F-sweet	**	27	37	0,001
F-acidic	**	22	15	0,007
F-mouldy	***	7	2	0,000
F-bitter	**	19	12	0,003
F-rancid	**	15	9	0,002
T-soft		46	45	0,709
T-juicy	ms	43	50	0,087
T-tender		56	58	0,560
T-mushy		29	31	0,591
T-sticky		33	29	0,189

ms (marginal significance, p = 0,05-0,10); * (p < 0,05); ** (p < 0,01); *** (p < 0,001)

Group A= fish stored at room temperature before processing.
Group C= fish stored on ice before processing.

Appendix 3. Sensory vocabulary characterizing spoilage in smoked mackerel.

sensory attribute	short name	scale	definition
ODOUR			
butiric acid	O-butiric	none || much	butiric acid, smelly feet
rancid	O-rancid	none || much	rancid odour
spoilage sour	O- sour	none || much	spoilage sour odour
TMA	O-TMA	none || much	TMA odour (trimethylamine)
spoilage	O-spoilage	none || much	other spoilage odour, describe in comment line
FLAVOUR			
bitter	F-bitter	none || much	bitter flavour
rancid	F-rancid	none || much	rancid flavour
spoilage sour	F- sour	none || much	spoilage sour flavour
TMA	F-TMA	none || much	TMA flavour (trimethylamine)
spoilage	F-spoilage	none || much	other spoilage flavour describe in comment line

Appendix 4. Sensory attributes for smoked mackerel stored chilled (0-5^{o}C).

Group	O-butiric	O-rancid	O- sour	O-TMA	O-spoilage	F-bitter	F-rancid	F- sour	F-TMA	F-spoilage
Day 0										
Ac	6	4	1	1	1	12	6	3	1	1
Cc	3	4	2	1	0	8	4	2	1	1
p-value	0,000 ***	0,872	0,523	0,358	0,001 ***	0,040 *	0,450	0,757	0,811	0,425
Day 7										
Ac	7	5	6	2	4	21	14	11	2	4
Cc	5	7	3	1	1	17	10	5	1	4
p-value	0,347	0,581	0,007 **	0,342	0,010 *	0,366	0,245	0,037 *	0,466	0,885
Day 14										
Ac	12	8	4	3	2	21	10	14	7	6
Cc	9	6	1	2	1	18	9	3	4	1
p-value	0,011 *	0,358	0,037 *	0,653	0,244	0,333	0,813	0,006 **	0,606	0,031 *
Day 21										
Ac	19	20	11	1	10					
Cc	13	15	10	2	7					
p-value	0,010 **	0,227	0,662	0,492	0,325					

Appendix 5. Sensory attributes for smoked mackerel stored at room temperature (20-25^{o}C).

Group	O-butiric	O-rancid	O- sour	O-TMA	O-spoilage	F-bitter	F-rancid	F- sour	F-TMA	F-spoilage
Day 0										
Aa	6	4	1	1	1	12	6	3	1	1
Ca	3	4	2	1	0	8	4	2	1	1
p-value	0,000 ***	0,872	0,523	0,358	0,001 ***	0,040 *	0,450	0,757	0,811	0,425
Day 2										
Aa	4	6	2	2	1	17	9	1	2	1
Ca	4	2	1	2	1	9	3	1	1	1
p-value	0,593	0,051	0,001 **	0,933	0,812	0,003 **	0,016 *	0,503	0,600	0,525
Day 4										
Aa	7	9	3	2	2	15	7	3	1	2
Ca	4	4	2	1	3	12	7	3	1	1
p-value	0,170	0,035 *	0,551	0,027 *	0,639	0,373	0,982	1,000	0,205	0,884
Day 7										
Aa	17	17	18	3	17					
Ca	6	9	6	1	6					
p-value	0,003 **	0,081	0,012 *	0,008 **	0,093					