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Quality assessment of hot smoked Capelin (*Mallotus villosus*) and Redfish (*Sebastes mentella*)

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ABSTRACT

Redfish and capelin were hot smoked by using an isolated cabin, designed by Matís. Performance of the cabin was monitored by quantifying the amount of firewood used, monitoring temperature and relative humidity (RH). All the samples were smoked and some were then dried by hot air from the fan, after that they were packed in open air plastic bags and stored at room temperature (≈23°C) and temperature of 2-4°C for 26 days while monitoring their quality changes. Chemical properties were used to monitor deterioration of lipid by quantifying the amount of free fatty acids (FFA), peroxide value (PV) and thiobarbituric acid reactive substance (TBARS). Smoked samples and smoke-dried samples after smoking stored at room temperature were less stable compared to samples stored at 2 – 4 °C. The difference in between smoked and smoke-dried samples stored at room temperature could not be established however stability of the smoked and smoke-dried samples were observed in samples stored in a cold room. Drying time should also be extended beyond 2 hours and air should be fired-heated in the kiln as the combustion process lowers the O_2 concentration in the air which inhibits oxidation of lipid in the product. It is highly recommended to fit in a cap on top of the cabin as it offer equal distribution of temperature in the cabin. Determination of the shelf life of the smoked product should also include microbial and sensory evaluation analysis.

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1 INTRODUCTION

FAO (2007) current fisheries production levels directly consumed by human in the country stands at 351,127 tonnes annually which accounts to 7 Kg/year per capital consumption while only 4,680 is being produced for animal feed and other purposes. Fisheries primary sector employs about 171,793 people while a secondary sector provides employment to about 2,000,000 people. In 2005 it contributed 324.21 million USD to the national GDP.

According to FAO (2007), the following are the main fishery area in Tanzania; Marine territorial waters (Shellfish and finfish), Marine Exclusive Economic Zone-mainly fin fish – tuna and tuna-like species. Nile perch (Lates niloticus) from Lake Victoria and sardines and from Lake Tanganyika (Stolothrissa tanganicae and Limnothrissa miodon) and four Centropomids species which includes *Lates Stappersi* which is of great commercial importance.

Fish is a food product which can easily get spoiled, it needs to be processed immediately in order to slowdown/stop spoilage process. Processing fish involves primarily the application of preservation techniques in order to retain quality and increase shelf life (FAO, 2001). Some of the procedures may include sorting, grading, gutting, deskinning, filleting and trimming. Furthermore, other processing procedures such as thermal processing (cooking, smoking etc.) can be applied to make product edible, to increase the price of the product on the market or to protect product against different spoilage and pathogen microorganisms (Thrane, Nielsen, & Christensen, 2009).

It is universally known that fresh water fish does not get spoiled rapidly as compared marine fish (FAO, 1997) due to a chemical difference which limits the off odours produced by fresh fish. This offers a great potential in terms of processing to the current Lake`s pelagic catches which are normally landed fresh, without ice which has a negative impact on the quality and value of fish. Minor improvements on the current processing methods will offer great potential to improve livelihoods of people without adding pressure to the fishery (UNDP/GEF, 1994) as the processed product can be transported any distance or kept for more than few hours.

In Lake Tanganyika fishermen sell the catch to women normally, who proceed to dry it on the ground. Van de Knaap (2014) found in a last frame survey conducted on the shores of the Lake Tanzanian side that there were over 11,000 fish processors who directly gets involved in a the sector. A popular method of processing sardines fishery for *Stolothrissa tanganicae* is spreading the fish on the on the ground and let it dry by sunlight. When it comes to smoking is done by using open fire and mostly to *Lates* spp. Smoking and smoking are among methods used to reduce water activity and create an environment unfavourable to the growth of microorganisms. Water is a key medium for most chemical and physical reactions and interactions in food, therefore control of freedom of water to move or interact with other ingredients is the key to product stability, chemical reactions during processing and storage, and growth of microorganisms (Pigott & Tucker, 1990).The “drying fields” being used around the lake are covered with small stones (rather than just sand) which reduces the amount of sand that is picked up by the fish (UNDP/GEF, 1994). There is always a constant contact between a newly spread sardines with sticky oils from the previously dried fish which is a probable source of contamination to the product being dried as the drying fields are always open and in contacts with animals, air and human being therefore making them susceptible to contamination. During raining seasons or cloudy weather, fishes being dried always gets spoiled sometimes to an extent of not being good for human consumption. This results in low market value, low shelf life and high post-harvest loses as a result of breaking spoilage of

the incomplete dried fish. This results into a product of low quality and therefore hampering their net profits. As stated in UNDP/GEF (1994) in normal weather conditions it takes about 24 to 36 hours for the fish to sun dry suitably there after it is collected and marketed in nylon sacks of an average weight of 70Kg.

Any fish which is found in the Lake can be smoked, this has led to establishment of traditional open fire smoking kilns in all villages where there is a large landings of *Lates stappersii* (UNDP/GEF, 1994). Local processors normally bend the fish into a cycle with a tail through the gill covers without descaling and gutting them, there after they are put through poles and smoked on a direct fire for 18 to 24 hours. The smoked fish is normally very dark in colour and brittle due to high soot content in smoke and uncontrollable temperatures.

Traditional smoking kilns made up of mud or clay bricks are found in almost all fishing villages along the Tanzanian part of Lake Tanganyika. They are normally operated by one or two fish processors. The fish is normally arranged on the top of the kiln with an open fire at the bottom. Smoke and fire is in direct contact with the fish and the operators are exposed to the fire and smoke as well. The operators need to continually attend to the fire and fish during operation. The final stage of either involves reducing the amount of fire wood or if the weather is good, taking the fish and spreading it on the ground for final drying. Sometimes the fish are put on the bare ground and sometimes grass mats are used. The risk of contaminating the product is high, not only because of unhygienic handling but also because of flies and birds

The current challenge existing in Lake Tanganyika is it that, fishermen do not carry any ice when going out for fishing as the infrastructures for ice production is not available and not only that even processing procedures are not hygienic at all. This was also indicated by Reynolds *et al*.,(1999) who found that there were no industrial processing facilities on the Tanzanian side of Lake Tanganyika so processors dealing with Clupeids and juvenile *L. stappersii* either sell them fresh or sun-dry at most local landing sites. While adult *L. stappersii* and other larger fish are sometimes smoke-dried by local processors before sale by using an open fire.

Hot smoking is the most hygienic processing method to be done in Tanzania as it involves high temperatures which is capable of killing most of the pathogenic specific spoilage bacteria in fish. Regrettably the way it is being performed is not appropriate as the open fire method results into a products of low quality as it excessively gets burned which is probable method of (Codex Alimentarius, 2015) imparting high concentrations of poly cyclic aromatic compounds (PAH) which are always embedded in the smoke particles and are known to be cancer causing compounds.

2 AIM OF THE STUDY

This research was aimed at improving performance of a newly designed drying kiln for fish, and preparation of fish before smoking/drying in preparation for introduction to Lake Tanganyika, Tanzania. The main focus is the upcoming project (TAFIRI-MATIS) whose main aim is to improve people's livelihoods (fish processors) while conserving the environment in which they live .i.e. by making sure the fish is being dried in an environment which is hygienic) and reducing the amount of firewood used for hot smoke drying. The main objective was to examine a potential effect of two stage process (i.e. smoking and smoke-drying) in smoking cabin, establish performance of the

cabin by evaluating the quality characteristics of the smoked capelin (*Mallotus villosus*) and redfish (*Sebastes mentella*).

The specific objectives were:

- To establish quality differences (i.e. microbial, chemical and physical) between capelin and redfish after hot smoking process and drying.
- To determine the shelf life of the smoked fish packed in open air clear plastic bags and stored at different temperatures i.e. cold room 2 – 4°C and room temperature ≈ 23°C.
- To determine the performance of the smoking kiln and suggest the improvement to be made to the existing smoking kiln in order to increase its efficiency before adoption by local Tanzanian communities.

3 MATERIAL AND METHODS

3.1 Materials

Smoking Cabin: Improved wooden smoking kiln was used for hot smoking experiment (i.e. smoking and smoke-drying) performed in Iceland at Matis Laboratories. The main parts (Figure 1) of the smoking kiln includes; metal barrel which holds fire, metal cap which distributes heats and traps smoke particles and racks where by fishes are arranged for drying. Bannerman (2014) described that hot smoking in the kiln usually takes place in three stages; a preliminary drying period at 30°C, during which the skin is toughened to prevent subsequent breakage, a smoking and partial cooking period at 50°C and a final cooking period at 80°C. The total time, and the proportion spent at each stage, will depend on the species, its size and fat content, and the kind of product required. On the other hand air inlet and outlets vents located at the burner and above the smoking kiln/cabin respectively needs to be controlled in order to control the amount of smoke and heat into the smoking cabin. This ensures optimum smoking, cooking and drying time to the product as it ensures appropriate temperatures for cooking and killing pathogen bacteria while maintaining quality of the product. As the smoking process progresses the fish tends to change colour and appearance from (Bannerman, 2014) jelly like appearance, juicy stuffs no longer coming out of the muscles and attained a golden brown colour it can be considered perfectly cooked.

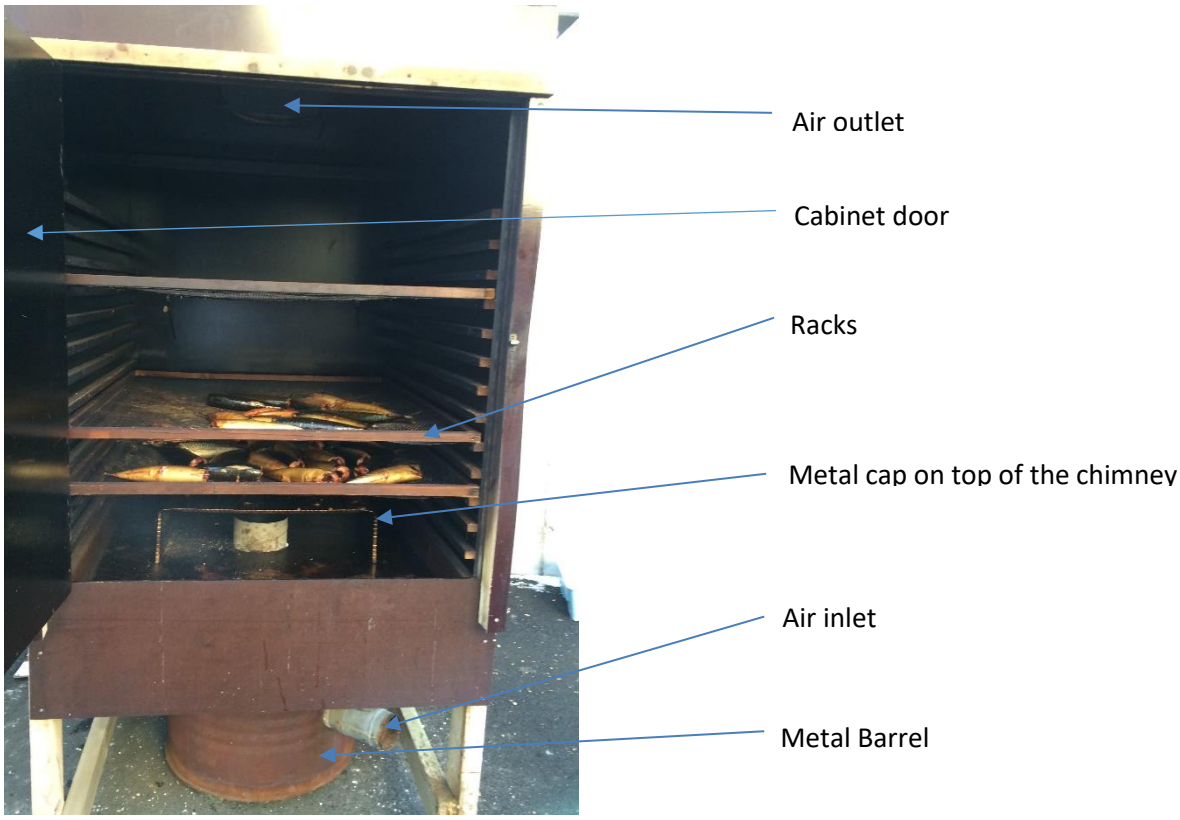

Figure 1: Hot smoking cabin main parts

Fish: Frozen redfish (*Sebastes mentella)* and capelin (*Mallotus villosus)* caught in Icelandic waters were used in this experiment. Red fish was purchased from Brim Sea Food Company while capelin was bought from SVN Company. Redfish was caught on November 2014 de-headed, gutted and block frozen on board at -25 °C. Capelin was caught on March 2014 and block frozen (22 Kg) on board at -25°C. Capelin (*Mallotus villosus)* is known to be a fatty while the redfish (*Sebastes mentella*) is lean. The choice of species was based on the fact that in an annual cycle pelagic species of the Lake Tanganyika they become fatty when food is in abundance in the Lake. So in an indirect way this experiment provides a rough picture of the kiln use throughout the year if adopted by the Lake residents.

3.2 Experimental design

Pre-trials: The experiment started by doing pre-trial smoking of the capelin fish. Thawing was the first stage at 2-4°C and brined in a salt solution of 15% for two hours. Dripping was done at -1 to1°C overnight (18-20 hour) and smoked in the following day.

Main experiment: Frozen redfish and capelin were thawed at 2-4°C overnight. Redfish were split open cleaned and weighed while some were just cleaned without split opening them. All of them were brined for an hour and followed by dripping for 18-20 hours at 2-4°C. After thawing capelin

were washed and weighed. There after brined for 0.45 hour followed by dripping for 18-20 hours at 2-4°C. Brining was done by preparing a salt solution of concentration of 15% and dipping the fish into a salt solution at a ratio of 1:1 between fish and salt solution. Summary of the whole experiment is shown in a flow chart below (Figure 2).

Smoking: The freshly brined samples were smoked in a cabin each species differently while monitoring the temperatures, humidity, time and amount of firewood used. Temperature and humidity was recorded by using data loggers while fire wood was weighed before being put into the cabin. The burner holding the firewood was made up of a metal barrel with a chimney going into up into the wooden cabinet. On top of the chimney a cap of almost 15 x 60 inches was placed and above it the fish were arranged for on racks for drying. During smoking the temperature in the cabin fluctuated depending on the amount of firewood and state of the control doors. Some brined redfish were smoked whole (i.e. not split open) for water activity experiments. One local fish processor and Kigoma district fisheries officer were interviewed in order to provide us with estimated amount of firewood being used to smoke *Lates* species. The smoked fish were divided into two groups' i.e. just smoked and smoke-dried by species. Each group from each species was air dried by using an electric fan in the same cabin. Air was blown through the same chimney hole for two hours.

Sampling: Immediately after brining, smoking, and drying sampling was done for laboratory analysis. The freshly smoked and smoke-dried samples were used in open air shelf life experiments i.e. packed into plastic air bags and left open. The unsealed bags were placed in a box and stored at room temperature ≈ 23°C and cold room 2-4°C. With room stored samples the sampling frequency was shorter as compared to the cold room stored samples (see Table 1 below).

Table 1: The table below shows sampling and analysis points (highlighted in different colours) of various samples stored at cold room (2-4 °C) and room temperature (≈ 23°C)

Sampling Time (Day)	0	4	8	14	15	26
Sample Type						
Fresh brined Redfish						
Fresh brined Capelin						
Smoked & dried Redfish						
Smoked & Undried Redfish						
Smoked & dried Capelin						
Smoked & Undried Capelin						

Key

Sampled immediately afterbrining

Room temperature stored samples

Cold room stored samples

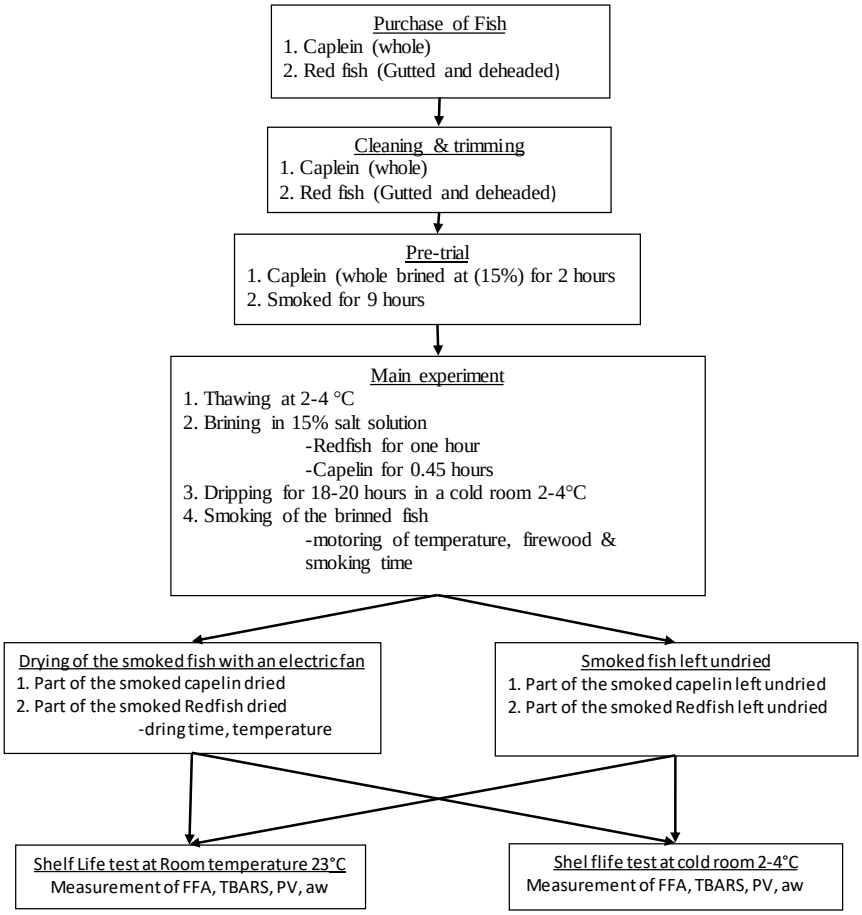

Figure 2: Flow chart showing experimental design.

Non-sensory methods were also applied in evaluating the quality of the fresh and smoked fish as they were cheaper and quicker as compared to sensory where by a trained panel is required.

3.3 Analytical methods

Microbial evaluation: their activities plays potential role in limiting the shelf life of fresh and smoked fish, proper quantification of the total viable counts (TVC) at various temperatures is used as an acceptability index in standards, guidelines and specifications (Olafsdóttir, *et al.*, 1997). In this experiment fresh and smoked fish samples were analysed while 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 (as described in MATIS lab protocol). 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*.,(1987) 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 3 days incubation at 23°C. Analysis was done on fresh samples and day 0 smoked samples.

Kiln performance evaluation: Relative humidity (RH), temperature were monitored during its operation by using temperature loggers (Ibutton) and humidity sensors (HOBO). Amount of fish (Kg) produced at the end depends on time of smoking and amount of firewood/heat energy being used during the whole process. Therefore time and amount of firewood were monitored.

Chemical methods: Analyses were carried out to brined raw fish and smoked samples moisture, lipid and protein content.

The water content was calculated as the loss in weight during drying at 105°C for 4 h, ISO 6496:1999.

Total lipids (TL) in fresh brined and hot smoked fishes extraction 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 & Dye, 1959) method. The lipid content was determined gravimetrically and the results expressed as grams lipid per 100 g wet muscle which were later used to analyze Free Fatty Acids (FFA).

Protein: in fresh brined sampled was determined by Kjeldahl method. The organic digested by Sulphuric acid in the presence of a catalyst. The reaction product was rendered alkaline, then the liberated ammonia by distillation process and titrated with hydrochloric acids (ISO, 2005)

Total volatile basic nitrogen (TVB-N): Samples raw and hot smoked and stored different temperatures were used in this experiment in order to determine TVB-N. Steam distillation method was used as explained by (Malle & Poumeyrol., 1989). 50g (modified form 100g) of the raw and smoked fish exposed in different temperatures on particular days were placed in a blender then 100ml(modified from 200ml) of 7.5% aqueous trichloroacetic acid solution was added and the mixture homogenized. The mixture was then filtered through a Whatman filter paper number 3 (6µm pore size), 25 ml of the filtrate transferred into a distillation flask followed by addition of 10% NaOH. Steam distillation was performed using Kjeldahl method (Struer TVN distillatory, STRUERS, Copenhagen). TVB-N was collected under a condenser in a beaker containing solution of 10 ml of 4% boric acid and indicators (0.04 ml of methyl red and bromocresol green). Steam distillation was done for 4 minutes until final volume of 50 ml is obtained in the beaker (40ml of distillate). The boric acid solution turned green when alkalised by total volatile bases during the distillation process. The alkalised solution then titrated with sulphuric acid solution (0.0324N) by using 0.05ml graduated burrete. Complete neutralization was obtained when the colour turned pink on addition of a further drop of sulphuric acid.

TVB-N (mg N/100g) was calculated by using this formula: $\frac{\frac{14mg}{mol}\times a\times b\times 300}{25ml}$

Where a: ml of sulphuric acid
b: Normality of sulphuric acid

Lipid degradation: two distinct reactions which are oxidation and hydrolysis of lipids occurs in fish muscles which shows quality deterioration which leads to unpleasant (rancid) taste and smell which leads to formations of the FFA, PV and TBARS.

Free fatty acid (FFA): free fatty acid content was determined by a method from (Lowry & Tinsley, 1976) with modification made by Bernárdez *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 expressed as g FFA/100g lipids.

Peroxide values (PV): Peroxide values were determined using the ferric thiocyanate method described by (Shantha & 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 will be homogenised 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 centrifugedat 5100 *rpm* for 20 minutes at 4^{o}C (TS-25 centrifuge). A mixture of 0.1 mL of supernatant and 0.9 mL of 0.02 M thiobarbituricacid solution will be mixed in 1.5 ml eppendorfs and then heated in a water bath at 95^{o}C for 40 min. Then samples cooled down on ice and 0.2 ml and placed in microplate for absorbance reading at 530 nm (Sunrise Microplate Reader, Tecan AustriaGmbH, A-5082 Grödig, Austria). The results will be expressed as mmoL of malomaldehyde diethylacetal per kg of sample and calculated using a standard curve prepared with 100 times dilution of the stock solution (TEP=malomaldehyde diethyl acetal=MDA eq.).

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 2g 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 capelin and redfish was determined by weighing 5g of each 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).

Yield: The yield for each processing step for production of hot smoked capelin and redfish were calculated according to the formula:

$$Processing\ yield = \frac{Wbrined}{Wraw}\ x\ 100\ (\%) \text{.....Equation (1)}$$

$$Smoking\ yield = \frac{Wsmoked}{Wbrined}\ x\ 100\ (\%) \dots\dots\dots\dots\dots\dots Equation\ (2)$$

$$Tota\ yield = \eta\ processing\ x\ \eta\ smoking\ x\ 100\ (\%) \ldots\ldots Equation\ (3)$$

Where:

W_{raw} is the weight of raw material;

W_{brined} is the weight of raw material after brining and dripping;

W_{smoked} is the weight of smoked fish before drying;

3.4 Data analysis

Data were analysed by using Ms excel 2013, figures drawn by using Sigma plot 10, 2007 © Systat Software Inc. Analysis of variance (one tailed) was also done and probability level was set at p=0.05.

4 RESULTS

4.1 Pre-trials

The smoked product was salt tested by two individuals eating the smoked product. It was advised that brining time should be reduced to 0.45 hours in the real experiment as salt in the smoked product felt like was above 5% which was too high.

4.2 Kiln performance

Performance of the smoking kiln was observed by measuring the amount of wood used, smoking time and temperature distribution within the cabinet system. Whole capelin and split open redfish were used in this experiment. The ambient weather condition was snowing and raining and temperature and relative humidity (RH) ranged between 1.91 and -1.56°C and 63.10 to 100% respectively,

The temperature differences was monitored at various points in the smoking cabinet during the smoking process, lower, middle and upper (Figure 3). No difference was observed between the three levels (ANOVA, $F_{2, 135} = 3.06$, $p = 0.78$). The maximum temperature in the cabin was 98 °C while it was 50°C in the in the fish muscles. However, the measurements showed also that the heat was lost during the smoking process (Figure 3) to the surrounding air. The temperature around the barrel ranged between 3.03 and 41.79 °C. The relative humidity (RH) inside the cabin during the smoking period decreased considerably as the temperature increased compared to outside the of the cabin (Figure 4).The RH outside the cabin ranged from 63.10 to 100% while it ranged from 52.81 to 10.45% inside the cabin during smoking. During the drying process in the final 2 hours the RH ranged from 99.36-100.24% to 9.74-12.27%.

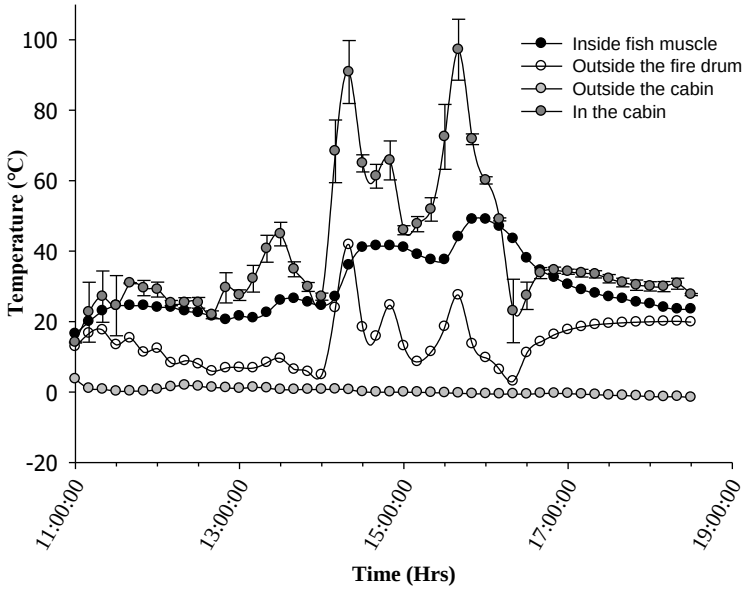

Figure 3: Temperature fluctuation outside the cabin, inside the cabin, in the fish muscles and around the metal burner

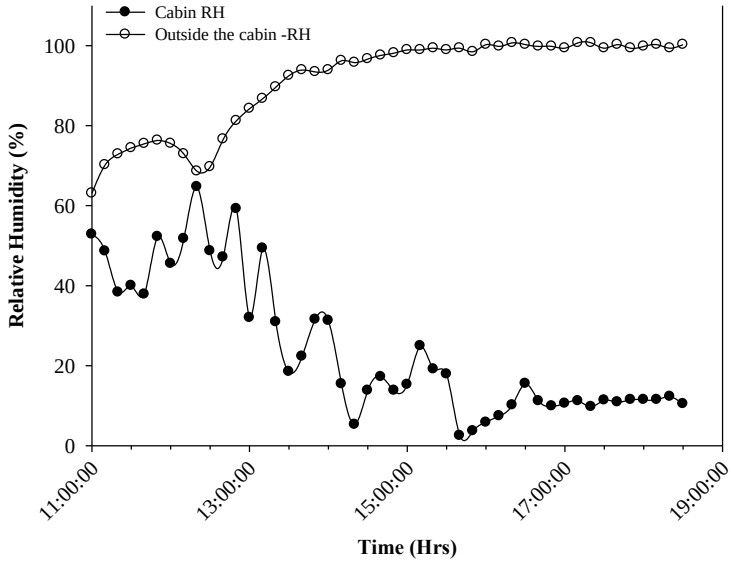

Figure 4: Change in relative humidity (RH) as a function of temperature through time (Hours) in a hot smoking cabin

The amount of firewood during this experiment (Figure 5A) used to smoke a kilogram of redfish and capelin was found to be 0.6 kg which is less than what is currently being used by local fish processors along the shores of Lake Tanganyika ranging from 0.7 to 1.0 kg. The cabin capacity is 60 kg of fish but during this experiment it was loaded with 35.5 and 22.7% of its capacity of redfish

and capelin at a time, still its performance was good compared with local processing methods by using the same amount of firewood. Smoking time (Figure 5 B) of redfish was the highest 4.5 hours when compared with that of capelin and *Lates* spp which was 1.75 and 3 hours respectively.

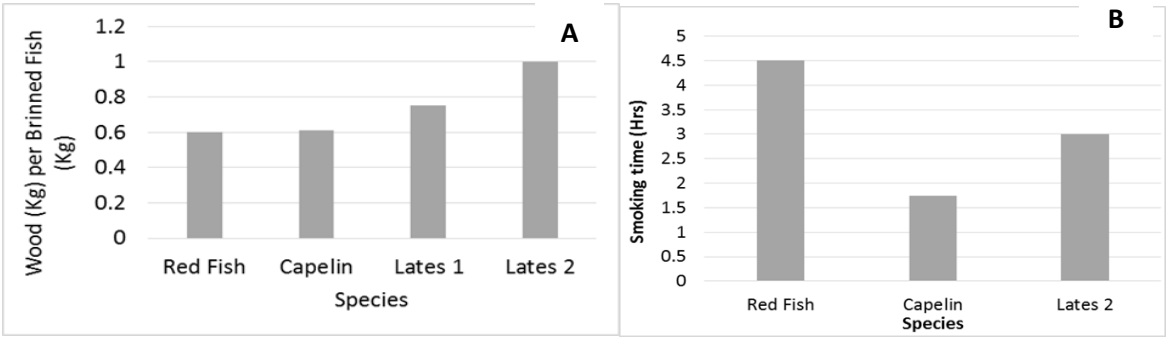

Figure 5: The amount of firewood (a) used in smoking fish and time (b) involved in smoking the fish, Lates 1 and 2 the figures have been obtained by interviewing local fish processors and District fisheries officer of Kigoma respectively, Tanzania.

The smoked products were tested for the water activity (Figure 6) and what we found is that the water activity for the split opened redfish was 0.9615a_w while the un-splited had 0.9828 a_w. Fresh capelin had higher water activity as compared to the smoked ones which had around 0.9500 a_w, generally water activity of smoked fish was less as compared to fresh ones and not much difference was observed between smoked and smoke-dried fishes.

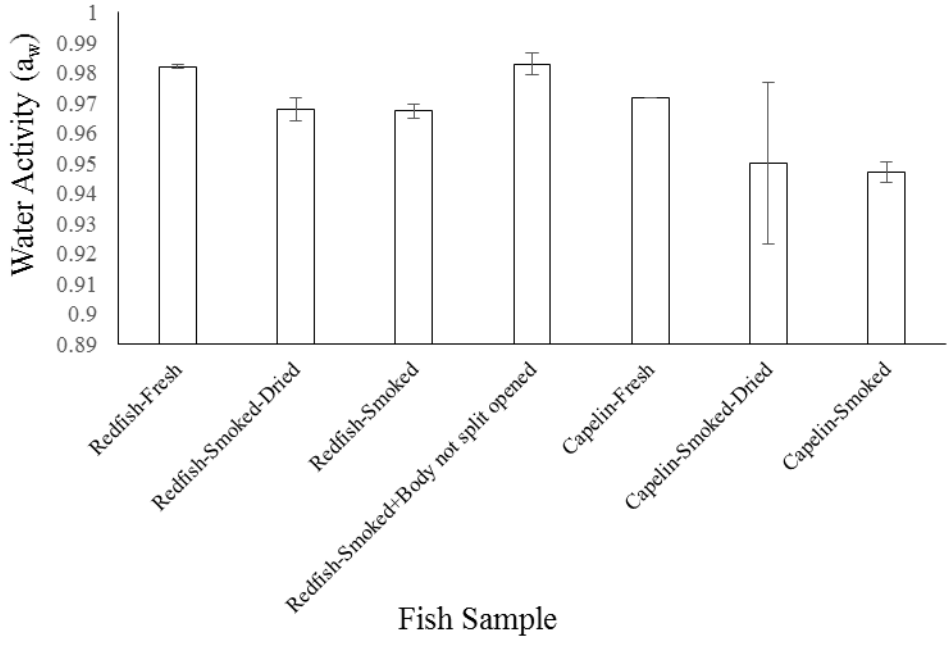

Figure 6: Water activity levels in the muscles of fresh Redfish and smoked ones in different forms

The brining and smoking cabin (Figure 7 and Table 2) played a potential role in reducing the water content of the smoked product which led to increase in salt content of the smoked products. Redfish and capelin salt content increased from 1.63 3.1 to 3.10-4.95 respectively. TVC from fresh redfish muscles was also reduced from 3 counts to < 1 Log_{10}cfu/g counts in the smoking process.

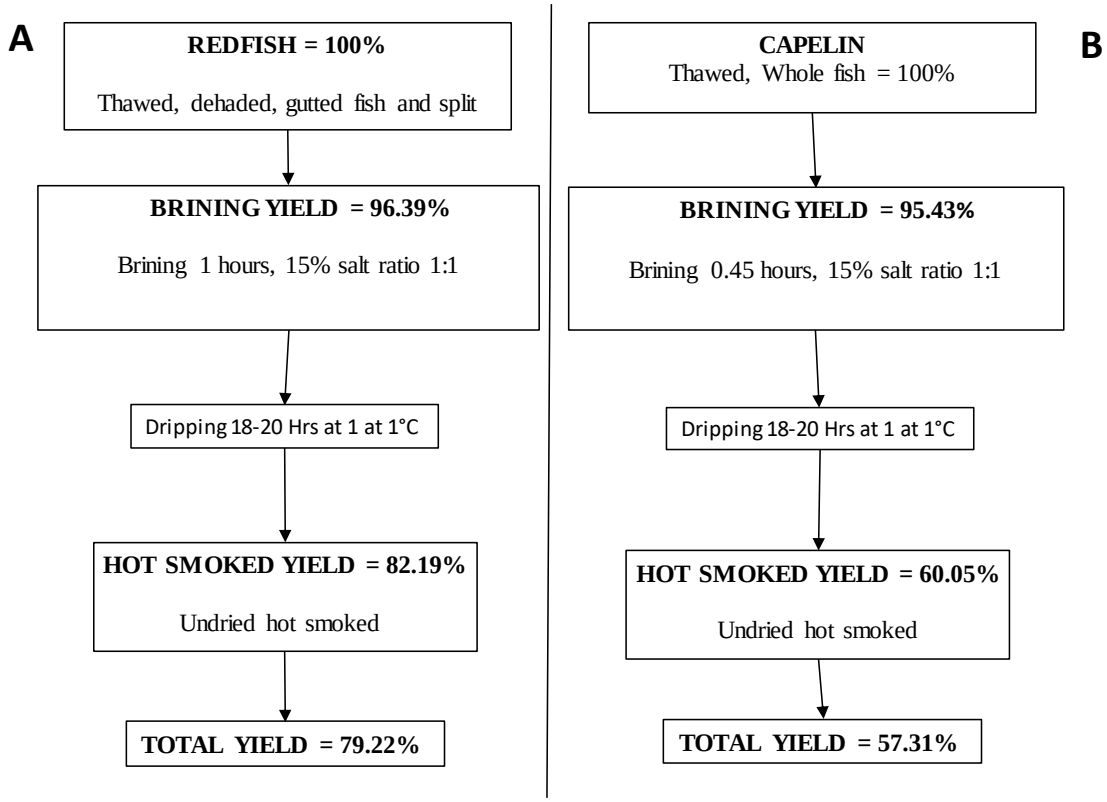

Figure 7: Yield during brining and hot smoking of split open redfish and capelin

Table 2: Change in total viable counts of microbes (TVC) incubated at 22°C and salt concentration after smoking process

Sample Type	Water content (%)	Salt Content (%)	TVC (Log_{10}cfu/g) at room temperature-day 0	TVC (Log_{10}cfu/g) at cold room temperature-day 14
Fresh brined redfish	73.7	1.63	3.0	-
Fresh brined capelin	72.4	3.10	-	-
Smoked Redfish-Dried	68.45	2.70	< 1.0	< 1.0
Smoked Redfish	69.7	3.10	< 1.0	< 1.0
Smoked Capelin-Dried	53.15	4.95	< 1.0	< 1.0
Smoked Capelin	59.6	4.30	1.3	< 1.0

4.3 Chemical Analysis

Protein content of fresh brined redfish and capelin was 18 and 13% respectively (Figure 8). Peroxide values (PV) for fresh brined redfish and capelin was 0.01 and 0.12 µmole/g while Thiobarbituric acid-reactive substances (TBARS**)** were 0.015 and 0.08 µmole/g (Figure 9a and 9b respectively).

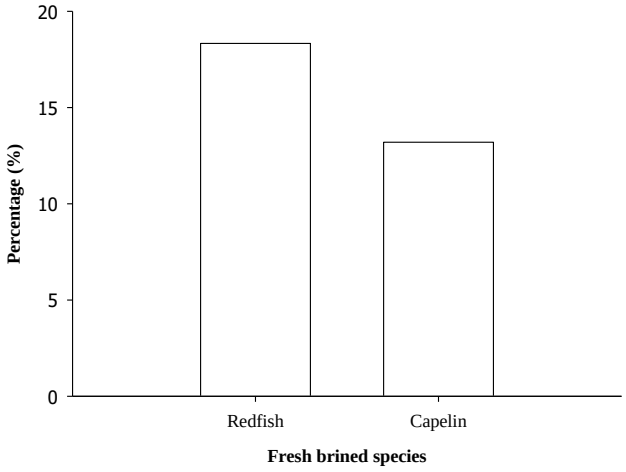

Figure 8: Protein content of fresh brined redfish and capelin

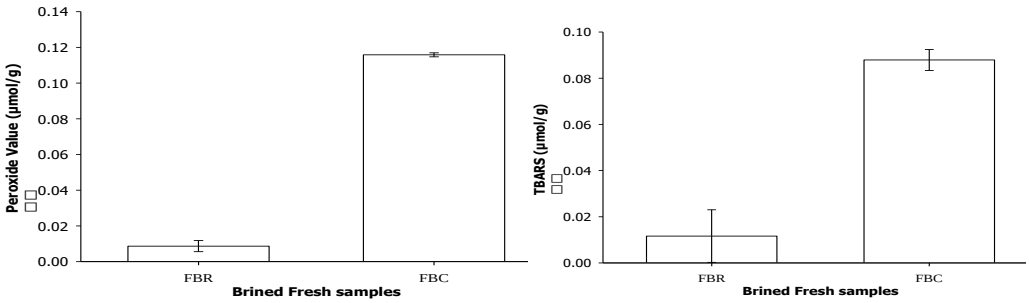

Figure 9: Peroxide values (PV) and TBARS of fresh brined redfish (FBR) and capelin (FBC)

TVB-N (Figure 10); for fresh redfish was 11.0 mg N/100g. After smoking and smoke-drying the fresh brined samples (day 0=after smoking) the values of TVB-N for Smoke-dried redfish, Smoked redfish, smoke-dried capelin and smoked capelin stored at room (Figure 10) temperature went up to 20.45, 16.60, 23.70 and 20.60 mg N/100g respectively on day 4 and stayed stable up to day 8 and then increased progressively to 33 mg N/100g on day 15. Smoked redfish at room temperature on day fifteen got completely spoiled so samples could not be analysed. Samples in the cold room (Figure 11) were stored for a total of 26 days the TVB-N values for Smoke dried-redfish, Smoked redfish, Smoke-dried capelin and Smoked capelin kept on increasing (Figure 10) from day 0 to day 14 (22.6, 22.3, 27.5 and 27.2 mg N/100g). On day fifteen the started to drop down to 21.5, 21.8, 21.8 and 21.0 mg N/ 100g.

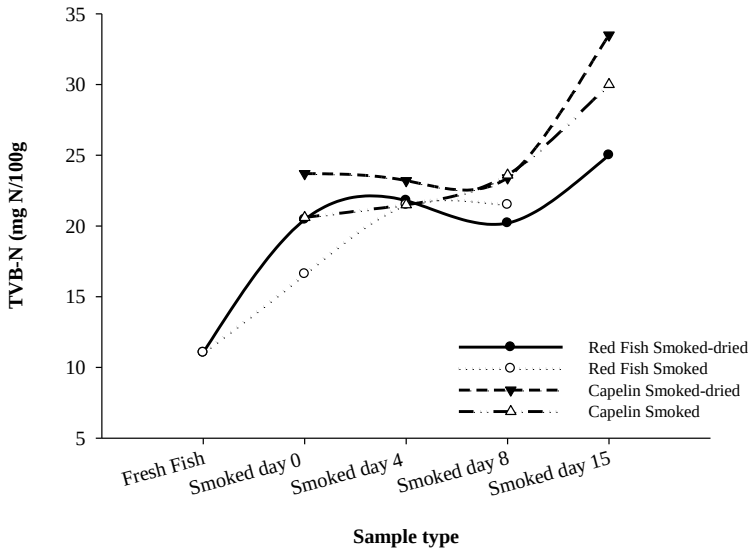

Figure 10: Change in TVB-N (mg N/100g) values of smoked Redfish and capelin stored at room temperature (≈23°C)

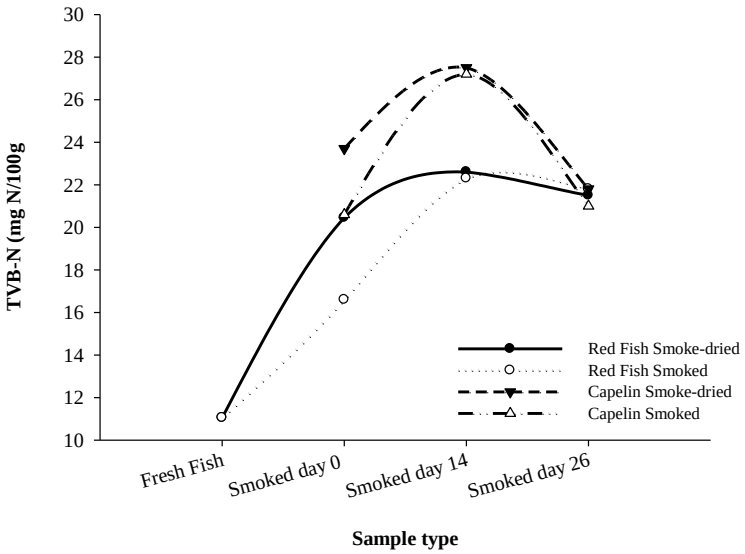

Figure 11: Change in TVB-N (mg N/100g) values of smoked Redfish and capelin stored in a cold room temperature (2-4°C)

Peroxide values (Figure 12A) in smoked and smoke-dried redfish; smoke-dried and smoked stored at room temperature they decreased to less than 0.01µmol/g with storage temperature and finally rose up again on day 8 while those samples which were stored in cold room their values (smoked samples) increased to almost 0.04 µmol/g and went down to almost 0.01 µmol/g. The smoked and smoke-dried redfish sample in the cold (Figure 12A) room was increasing gradually. Both smoked-dried and smoked capelin samples stored at room (Figure12B) temperature between day 0 (0.01 µmol/g) and day 4 (0.12 µmol/g) the rate of formation of peroxide values was higher as compared to the rate of decomposition so the concentration of PV increased up whereas between day 4 and 8 the concentration was decreasing and later increased to almost 0.3 µmol/g. during the whole storage period smoke undried samples had less PV values as compared to smoke dried ones. Samples of capelin stored at cold room had progressive increase in peroxide values attaining a highest value at the end of the storage and not much difference was observed between dried and undried samples.

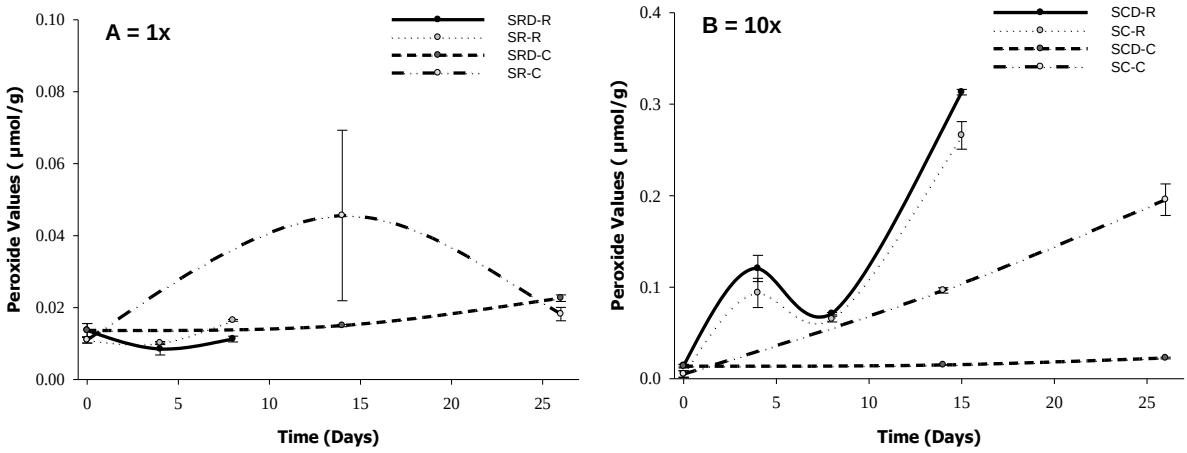

Figure 12: Changes in peroxide values (PV) over storage time of the smoked redfish-dried (SRD), smoked redfish (SR), Smoked Capelin Dried (SCD) and Smoked Capelin (SC) stored at room temperature (R) and cold room (C)

There was a constant (Figure 13A) increase in rate of formation of secondary decomposition products (TBARS) in the smoke-dried redfish stored at room temperature while that of smoked reduced from almost 0.005 µmol/g towards zero values and after day 4 it rose up to 0.008 µmol/g. Redfish samples stored in a cold room; the concentration of the TBAR kept on reducing from day zero and gradually increased to higher levels on day 26th. At the beginning the dried redfish was having higher values of TBAR in the cold room and finally undried sample ended up having higher value. TBARS in capelin (Figure 13B) of smoke-dried were higher as compared to the smoke values at the beginning up to the end, the same scenario was observed with samples which were stored in the cold room. Generally TBARS in capelin were ten times higher as compared to the redfish.

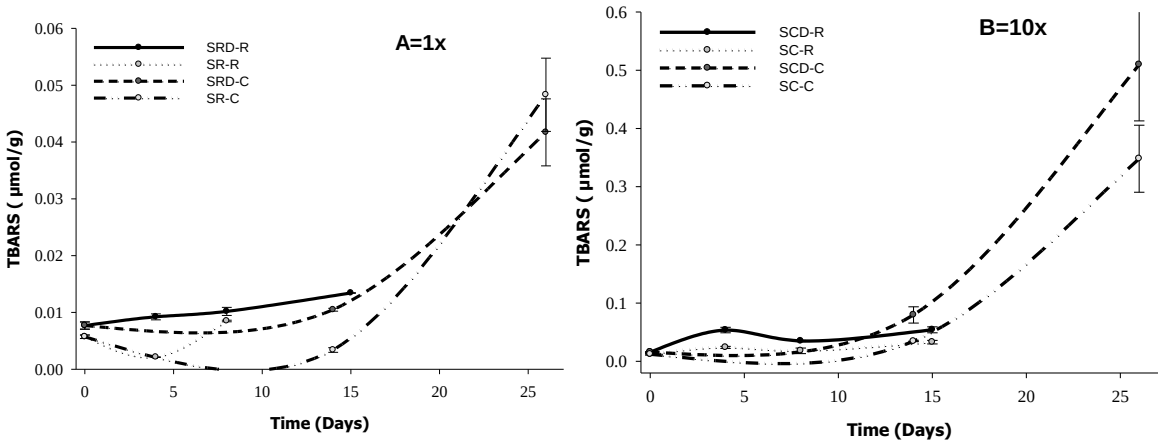

Figure 13: Changes in Thiobarbituric acid-reactive substances (TBARS) over storage time of the smoked redfish-dried (SRD), smoked redfish (SR), Smoked Capelin Dried (SCD) and Smoked Capelin Undried (SC) stored at room temperature (R) and cold room (C)

Fresh brined samples of redfish and capelin had 4.0512±0.2017 and 4.0520±0.1276 g/100g Lipid of free fatty acids (FFA) before they were smoked. After smoking the redfish the smoke-dried samples decreased in FFA content as compared to smoked samples (Figure14a), during storage the FFA values of smoke-dried and smoked redfish stored in room temperature (Figure 14a) were not stable, for the dried samples FFA kept on increasing from day 0 up to day 8 where by it remained stable thereafter up to day fifteen while for the smoked it decreased on day 4 and late went up. With the smoke-dried and smoke capelin at room temperature values were also fluctuating, the smoke-dried samples at first increased in FFA up to day 4 and later went down on day 8 and thereafter it remained more or less stable. In the smoked samples of capelin stored at room temperature the concentration went up from day 0 and decreased a bit on day 15. Cold room stored samples also kept on increasing their FFA values whereby if compared with room temperature samples up to day 14 they were still below the room temperature values.

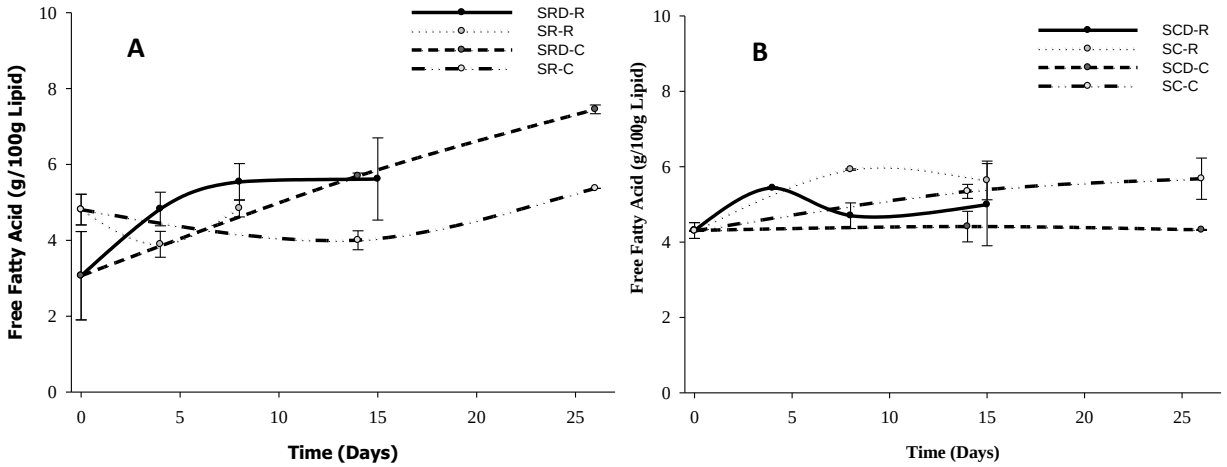

Figure 14: Changes in free fatty acid during storage of the smoked –smoke-dried redfish (SRD), smoked redfish (SR), Smoked Capelin Dried (SCD) and Smoked Capelin (SC) stored at room temperature (R) and cold room (C)

5 DISCUSSION

There are several factors which influence drying of fish during sun drying/ hot smoking. These includes; its thickness, surface area, fat and water content in the muscles. Surrounding environment relative humidity, pressure, temperature/heat and speed of air passing through the dried product are also important factors to be considered (Hilderbrand-Jr, 2001). In this study it was found that the water content of brined redfish and capelin used as raw materials in this experiment was measured and found to be 73.70 and 72.4 % respectively which is known to be held within protein structures of fish muscles. The high water content and size of redfish led us to dry the fish in two forms i.e. whole and split opening. The split opened group which were thin and higher surface area resulted into a lower a_w as compared to un-splitted ones.

Water in the fish muscle cannot be expelled so easily unless external factors are applied, heat change and brining being one of them. In this experiment brining was engaged and had a positive

impact by reducing the initial weight of both redfish and capelin, this is in agreement with Thorarinsdottir *et al*.,(2003) who found that brining causes partial dehydration by increasing rate of water diffusion out of the cod muscle during brine salting. Salting also effectively prevents the growth of both spoilage and pathogenic bacteria (Goulas & Kontominas, 2005). Further positive dehydration effect of brining is explained by Jittinandana (2002) who found that dehydration of trout fillets was influenced by brine solution where by inherent muscle water migrated from muscle to high brine solution and it further has (Lauzon, 2009) protective effect on specific spoilage organisms (SSO) in super chilled air packed fish.

The yield results from brining and dripping provides potential of using less amount of fire wood during hot smoking, fish brining along the shores of Lake Tanganyika is not a very common practice but it is expected to be introduced along with the new smoking cabin technology. It has been revealed from the wood calculations above that currently the amount of fire wood being used to smoke a kilogram of fish by local processors in Lake Tanganyika is far high as compared to what was used during this experiment.

Temperature distribution within the hot smoking cabin was almost equally on all parts, this is an improvement if compared with (Huong, 2014) who used the same cabin before and found that the temperature was high at the middle and on top of it while at the bottom was always low during the smoking process. Putting the metal cover/cap on top of the chimney had a significant effect on distribution of heat within it, this helps in the drying process as it ensures equal smoking and drying process of fish arranged in the racks. Users will not be required to frequently shift the fish racks from bottom to up and vice-versa. It is further known that many chemical compounds are formed during smoking, (Bailey & Dungal, 1958) these includes polycyclic aromatic hydrocarbons (PAH). According to (Codex Alimentarius, 2015) particles in smoke are estimated to constitute 90% and PAH are particulate bound, so increase in distance of particle travel, use of filter or any obstacle towards their direction of travel has an impact in reducing their concentration. The smoking cabin as of its current design provides these options. The current findings explains that much temperature is lost to the surroundings instead of being transferred into the wooden cabinet and cook/dry the fish as a result it leads into the prolonged cooking time. Insulation of the kiln (metal barrel and the chimney) / use of fire resistant insulated materials such as clay bricks in building the fire holding part of the system would improve performance of it as it will trap the temperature being lost and minimize the cooking time and the amount of fire wood used to will be lowered.

There was a major reduction in number of microbes in smoked redfish, even after storage in the cold room still the microbes did not grow up. Doe (1988) this could be due to cooking and preservative effect of smoke i.e. heat, phenols and acids bound on the fish muscles during smoking process. Though the raw materials were of very good quality as the microbial counts were below 3 and 1 Log_{10} cfu/g for the fresh brined redfish and capelin before smoking. These values were below recommended levels (European Commission; Health & Consumer Protection Directorate General, 2012), still the hot smoking cabin managed to reduce the counts to < 1 Log_{10} cfu/g after smoking process.

The maximum attained muscle temperature during smoking in our experiment was 58 °C and the lowest water activity values of 0.95 a_w in all smoked fish samples. The lowest value of water was obtained after drying the capelin fish for two hours by using an electric fan with a heater embedded in it, with red fish it did not give much difference probably the drying time was not enough and the

size to volume ratio of redfish was low so needed more drying time. These values are okay for cold storage of products but for the purpose of adoption of this technology to the shores of Lake Tanganyika the following options are suggested. Temperature in the cabin needs elevated by putting more firewood during time of smoking so as to get rid of *Listeria monocytogenes* which is known to be pathogenic and temperature resistant up to 60°C, (Huss, Ababouch, & Gram, 2004) they proposed to hot smoke the fish product by more than 2 minutes at above 70 °C and reach a $0.92a_w$. A water activity ($0.92a_w$) value of less than the proposed will be of great help as we have already seen that there are no refrigeration facilities currently available in the villages bordering the Lake this can also be achieved by extension of drying time, practically by opening the upper vents of the cabin so that to allow the smoke move out as heat only is deeded at drying stage. Split opening of the fish before brining and smoking is also advised as it has proved to be effective in providing more surface area for the drying, this has been established by water activity data generated by this experiment.

Chemical and microbial analyses of the fresh samples showed that the samples which were used in this experiment were of good quality as the Total Volatile Nitrogen Bases (TVB-N) were below the recommended maximum levels of 35 mg of nitrogen/100 g (COMMISSION REGULATION (EC) No 1022/2008, 2008) while microbes were also below 5 Log_{10}cfu/g (European Commission; Health & Consumer Protection Directorate General, 2012). Progressive increase in TVB-N at room temperature stored samples signifies continuous deterioration of the smoked fish while at cold room temperature the values kept on increasing but not at high rate and went down after day 14, the mild decrease at cold room temperature cannot be explained while at room temperature it is thought the samples were releasing nitrogen bases but still they were still below the recommended levels in terms of concentration. Microbial levels on the room temperature stored samples were not analysed but those stored at cold room were still within the acceptable range up to day 14 of storage. Microbial analysis if was done could have explained this as the change in TVB-N concentration is (Goulas & Kontominas, 2005) directly related to microbial spoilage.

Karlsdottir, *et al*., (2014) Established the quality of the processed and unprocessed fish by looking at formation and breaking of main products of lipid oxidation which are PV and TBARS. The PV values are known to be a result of peroxidation process. Fresh fish and smoked fish on day 0 used in this experiment were within the acceptable limits. Upon storage the PV values keeps on changing and giving out the off odour and off flavour which is a sign of quality deterioration. According to Karlsdottir *et al*., (2014) TBARS values measures secondary products of lipid oxidation (normally from peroxidation process) and always used in detecting rancidity of tissues. Samples stored at room temperature were quite unstable as they followed oscillating pattern of PV. This showed that there were more generation of rancid flavour in samples stored at room temperature as compared to samples at cold temperature which throughout the experiment were stable. Smoked/dried samples were attaining high TBARS values as compared to just smoked ones. This showed oxidative effect caused by the in pumped air from the electric fan so use of heated air passed through fire could have better result as it will be having less oxygen due to combustion process.

Capelin stored at room temperature had higher enzymatically catalysed lipid oxidation and fluctuating FFA values as compared to cold room stored capelin and redfish which were throughout stable and increase in the FFA values was not as high-pitched as room stored samples. The difference between fresh brined, day zero smoked and dents in room stored fish could be

(Karlsdottir, *et al*., 2014) drip loss during smoking and storage as oil was melting and falling down or into the storage bags.

6 CONCLUSION

The smoking cabin performed well in terms of amount of fire wood being used for smoking as less amount of firewood was used per kilogram of fish as compared to open fire being performed by locals in Tanzanians residing along the lake shores. It also reduced expressively microbes which were available in the redfish. In terms of quality no differences could be established by this experiment between dried and undried samples of fish which were stored at room temperature, the drying time was not enough to show the differences. The Smoke-dried samples stored in a cold room were more stable than the just smoked ones. Most likely the shelf life of room stored samples might have ended up between day 4 and 8 as breaking of secondary and tertiary lipid oxidation products was observed while the cold room stored samples were stable up to day 26 no breaking of secondary and tertiary product was noted. It was difficult to clearly establish the shelf life of the stored products based on chemical results only.

7 RECOMMENDATIONS

For the purpose of technology adoption to the shores of Lake Tanganyika it is recommended to extend the drying time, the two hours drying time during this experiment was not enough to attain recommended water activity of 0.75-0.8a_w which is the most appropriate level to restrict growth and lower any enzymatic activity which would result into spoilage of the smoked product. Local communities should split open the fish before smoking as it offers good chance of attaining lower water activity in the smoked product and less use of fire wood. The newly built smoking cabin should be fitted with cap on top of the chimney as it helps in distributing temperature equally in all parts and reducing smoke particles. Microbial and sensory evaluation should be added in determining shelf life of the hot smoked products. This experiment could be repeated and produce better results by extending drying time and use of hot air passed through fire as it reduces oxidation of lipid by combusting the O_2 available in the air.

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APPENDICES

Table 3: Estimated cost involving this study while table 2 shows implementation plan

Time			2014		2015											
			December		January				February				March			
			Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4
S/No	Main Activity	Description														
1	Proposal Development	Meeting supervisors and discuss the idea														
		Submission														
		Presentation														
		Inputs of the new comments														
2	Experiments/ Data collection	Construction of the smoking kiln														
		Pre-experiment trials-Data collection														
		Sensory evaluation-QIM-Data collection														
		Brining-Data Collection														
		Smoking-Data Collection														
		Proximate analysis-Data Collection														
		Shelf life Experiments-Data Collection														
		Sensory evaluation-QDA-Data Collection														
3	Report development	More literature Review														
		Submission- Reseach progress to UNU-FTP & supervisors														
		Data Analysis														
		Report Writing														
		Submission of Draft report														
		Inputs of the new comments														
		Final Report Submission														
		Presentation of the main findings														

Figure 15: Locally processed Stolothrissa and Lates spp

Figure 16. Smoking Cabin

Figure 17: Capelin smoking process

Figure 18: Raw and smoked redfish