THE INFLUENCE OF DIFFERENT SMOKING METHODS ON THE QUALITY AND STABILITY OF SMOKED REDFISH (*Sebastes norvegicus*)

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ABSTRACT

Hot smoking is a traditional method for preserving fish in Angola, but the quality of the final product is still unsatisfactory. The aim of this study was to examine new smoking technology, which could benefit the rural areas of Angola, using redfish (*Sebastes norvegicus*) fillets and testing two different smoking methods (Bradley and cabin kiln smoker). After smoking, redfish was air packaged and during storage period the samples were divided in two experimental groups, room cold storage (0-4) °C and room temperature (15-20) °C for both smoked redfish fillets. Yield was 76.32% and 61.48% for Bradley smoker and cabin kiln smoker respectively. The research results indicated significant difference in yield, and Total Plate Count (TPC) for all study groups ($p<0.05$). Significant difference was observed between storage days and color (lightness, yellowness and redness) ($p<0.05$). Total volatile basic nitrogen (TVB-N) was stable for all samples except for Bradley smoked fillets. Storage room temperature (104.7±6.08) and microbiological load was changed from 5 log(cfu/g) to 9 log(cfu/g). The level of PAHs in smoked fillets produced in cabin kiln was higher than Bradley smoker.

Keywords: *Smoked fish, cabin smoker, TBARS, smoking methods, PAH, water content, yield*.

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1 INTRODUCTION

The demand for fish and seafood products has consistently increased during the recent years since fish protein is a major animal protein consumed in many parts of the world. Seafood is a very perishable product and processing is therefore necessary to assure safety and prolonged shelf life of seafood (Blackwell, 2014). Traditional processing methods of seafood were originally developed to preserve fisheries products by either lowering the water activity (W_a) and/or which points the growth of spoilage bacteria. In addition, preservation was also carried out by applying salt and/or smoke components or other preservative compounds with antibacterial activity to increase shelf life and improve safety of such products (Köse, 2010).

In the modern world, fish provides 16% of total animal protein consumed globally (FAO, 2016; Foline, 2011). Though perishable, fish is an important food stuff, especially in developing countries, due to its high protein content and nutritional value of unsaturated fatty acids and affordability by the masses when compared with beef (Adeyemi, 2013), poultry, pork (FAO, 2016, Idah, 2013) and egg. Fish and fish products are of more importance in low-income and food deficit countries, accounting for 24% of total animal protein consumed (FAO, 2016). Its nutritional properties have been highlighted in several studies showing that fish contains important micro-nutrients (riboflavin, iron and calcium) and fatty acids, such as omega-3, all of which are important for human health, particularly during childhood (FAO, 2016).

Fish meat currently has a great market potential, because its product matches consumer preferences for; nutrition (rich in proteins and polyunsaturated fatty acids), sensory (pleasant, soft and characteristic taste), convenience (easy preparation or pre-ready), and economic aspects (with affordable prices) (Ferreira *et al*., 2002).

One of the conservation processes of aquatic products is smoking (Bellagha, 2007). Fish smoking is one of the oldest methods of preservation (Stlyhwo, 2005; Muratore, 2005; Yanar, 2006; Coban, 2013), giving a characteristic flavour and colour to the product and increasing its shelf life (Frank, 2014). When, selecting a preservation method appropriate to developing countries in relation to the raw material and the quality of the final product must be determined/investigated (Cardinal *et al.*, 2001; Ferreira *et al*., 2002; Souza *et al.*, 2005).

Smoke is the product of incomplete combustion of wood and consists of numerous individual components, namely, aldehydes, ketones, alcohols, acids, hydrocarbons, esters, phenols, ethers, etc. These components are transferred to the smoked goods by deposition on their surface and subsequent penetration into their flesh (Guillen, 2002; Goulas, 2005). For this reason, the exportation of smoked fish is becoming increasingly stringent due to the emergence of food safety and agricultural health standard, along with the fact that buyers keep changing their requirements, offer new parameters for food safety (Gbolagunte, 2012).

Smoking fish in Angola

Angola has a coastline of about 1,650 km. Two diverging currents namely, the Angola current with its warm water from the north and the cold Benguela current in the south creates a strong upwelling with a highly productive ecosystem for marine resources. Angola also has several high value freshwater fish species, currently estimated 255 species exploited. *Tilapia sp*. is among the most important and abundant fresh water fish found in Angola. Other species include the catfish (*Clarias gariepinus*), fresh water prawns, Giant river prawn (*Macrobrachuin rosenbergii*) (FAO, 2007) and Rascasso-rosado (*Scorpaena elongate)*, Folger's scorpionfish *(Neomerinthe folgori*) (Tweddle & Anderson, 2008).

Angola loses about 30 thousand tons of continental fish annually due to lack of processing and capture centres, according to the representative of the United Nations Food and Agriculture Organization (FAO) in Angola (Mamoudou, 2015).

The most common fish processing methods applied in Angola are salting drying and drying hot drying smoked, identical to many other African countries. Various smoking kilns are used all over the world. Older ovens have low purchasing cost but high operating costs due to fuel consumption and the difficulty of controlling the system compared to more modern smoking kilns (Arvanitoyannis, 2012).

The smoking of fish in Angola is performed in several rural areas, but the excess of smoke in the product, the lack of control throughout processing and the amount of wood used for smoking is high. This has led to the indiscriminate destruction of sensitive ecosystems forested like mangroves has several other negative environmental impacts associated with this practice.

Government institutions are responsible for regulating the introduction at new fish smoking methods which one friendly to the environment protect health a safety of processors and ensure safety of the fired products. Angola has not produced industrial smoked fish since 1975 and developing this activity is necessary to diversify Angola's economy.

1.1 Overall objectives

The main goal of this project is to examine a new smoking technology, which could benefit the rural areas of Angola. The aim is to develop a final product with better commercial value, and better food safety.

1.1.1 Specific objectives

- To compare the changes in smoked Redfish between two smoking methods; new cabin kiln and modern Bradley smoker.
- To determine how quality and storage stability of smoked products are influenced by different smoking techniques, smoking fuel and storage conditions, measuring and comparing chemical (TVB-N, Free fat acid, TBARS, PAH), microbiological, and physical parameters.

2 LITERATURE REVIEW

2.1 Fish smoking

Processing of seafood mainly inhibits and/or inactivates bacteria and enzymes which results in shelf-life extension and also assures food safety. While the main role of processing is preservation, processing not only extends shelf life but also creates a new range of products (Blackwell, 2014).

It is imperative that only fresh, properly prepared fish be used for smoking. Smoking will not mask or otherwise make a poor quality or spoiled fish acceptable (Martin, 1990). The suitability of fish for yielding high-quality smoked products depends on the species characteristics, but each species also depends on the impact of the nutrition, biological state, and the effect of catching and handling after catch. The most important factors are the composition of the meat (the content of fat and enzyme activity, as well as the vulnerability to bacterial spoilage prior to smoking) (Doe, 1998).

In some species like herring, mackerel and freshwater trout, all of each have high lipid contents, rancidity has been detected during spoilage (Connel, 1995). 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 (Rustad, 2010; Sohn & 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 other effects (Rustad, 2010), this the reason because lipid degradation analysis combined with sensory analysis gives information that can be used in evaluating the quality and storage life of smoked fish.
Heat processing remains one of the major methods for extending the shelf life of seafood and provides a high level of safety and convenience. Smoking is the process of flavouring, cooking, or preserving food by exposing it to smoke from burning or smouldering material, most often wood or other fuels. However, agricultural biomass such as bagasse (plant material derived from sugar cane), corn cobs, millet or rice stalks and coconut husks or shells can also be used as fuel (Ndiaye, 2014).

Smoked foods generally cause health concerns, especially with respect to the possible presence of Polycyclic Aromatic Hydrocarbons, (PAH), (Arantxa Rizo *et al*., 2016). PAHs are a large class of organic material containing two or more fused aromatic rings formed by incomplete combustion of wood and other organic materials. Generally, smoked foods contain large amounts of these compounds (Chen, 1997; Moret, 1999; Phillips, 1999; Sinko, 2002). PAHs are a class of high lipophilic compounds that comprise a class of chemical compounds known to be potent carcinogens. PAHs are present in the environment; in water, air, soil and traces of these substances have been found in various food products. Food can become contaminated during thermal treatments that occur in processes of food preparation and manufacturing (drying and smoking) and cooking (roasting, baking, and frying)

(Ishizaki, 2010), incomplete burning of coal, oil, gas, wood, garbage, or other organic substances (Agency for Toxic Substances and Disease Registry, 1995).

Due to their carcinogenic activity, PAHs have been included on the European Union (EU) and the United States Environmental Protection Agency (USEPA) priority pollutant lists. Human exposure to PAHs occurs in three ways: inhalation, dermal contact and consumption of contaminated foods. Diet is the major source of human exposure to PAHs as it accounts for 88 to 98% of such contamination (Farhadian, 2011).

The choice of smoking method and fuel are important aspects to consider to avoid potential food contamination. For example, food contamination by PAHs differs depending on whether wood, stalks or hay are used. Oilseed contamination with PAHs is higher when coconut husks are used, instead of coconut shells, which are less rich in lignin (Ndiaye, 2014). Through the years' various ways of pyrolyzing wood to produce smoke-flavour compounds have been developed. From a commercial standpoint this evolved from the first primitive ways which probably just involved hanging meat on the ceiling of a dwelling and permitting smoke resulting from a fire that was used solely as a source of warmth to pass through the product (Maga, 2000).

In some countries advanced smoker – generation technology has been adapted in response to the potential health concerns associated with certain rather primitive smoke – generation systems (Maga, 2000).

As stated previously, smoking is a traditional preservation technology, used primarily for its sensory advantages (taste and colour), in minimally processed products with lower salt content to satisfy consumer taste (Gomes-Guillen *et al.*, 2009). The smoking process leads to weight loss due to both dehydration of the fish muscle and leaching of lipids from the fish muscle. The weight loss depends on the raw material, the final product characteristics and the smoking method (Blackwell, 2014).

2.1.1 Hot smoke

Hot smoking is a traditional smoking method using both heat and smoke. In Africa, hot-smoking is a common way to preserve and market fish. The fish is smoked at temperatures that are high enough and for a sufficient period of time to obtain heat coagulation of the protein and elimination of bacteria. Generally, the temperature should reach at least 70–80 °C (Blackwell, 2014; Ahmed, 2011). During hot smoking, the fish is completely cooked and can be consumed without further cooking (Blackwell, 2014). Due to the high temperature, hot smoking takes only a short time, depending on the initial temperature of the product (Jr. George, 2010). The smoking process can take the form of wet hot smoking or dry hot smoking. Both processes are carried out at temperatures high enough to cook the fish (Alakali *et al.*, 2013).

Hot smoking involves the application of wood smoke to impart a smoky or smoked flavour and to partially dry a fish product and to extend the shelf life of the product under some conditions. Components in the fuel (wood/charcoal) via pyrolysis are broken down in the

process of burning to form smoke, which imparts on the fish a unique aroma and improves taste and colour of the fish (Adeyemi, 2011).

Although the smoke-drying process may extend the shelf-life of fish by reducing the moisture content which hinders microbial spoilage, the final product is often sold on open markets where the fish are displayed uncovered on top of tables in the market place. This exposes the products to contamination by unsanitary handling (by both sellers and buyers), dust and insects such as flies and beetles (Ikutegbe, 2014). An image of a fish market common in Angola is pictured in Figure 1.

Figure 1: Estalagem informal market, Luanda.

2.1.2 Open fire smoking

African populations have developed traditional fish processing techniques that make use of available natural means, namely sun and wood (Ahmed, 2011). Smoking-drying is carried out using various wood varieties. Fish are smoked for 2-3 hours at 70-80 °C, followed by mild smoking (30-35°C) for 24-48 hours. (Ahmed, 2011). Dry hot smoking takes about 10–18 hours, sometimes days yielding fish with 10–15% moisture content, or even below 10%. Fish smoked by this process have an estimated shelf life of 6–9 months, packaged in air and stored room temperature.

The hot smoking in fish includes diverse steps, the most important steps include drying the surface and muscle, heating/cooking, smoking, drying, and cooling. Then, cooling down to less than (3.3 °C) as quickly as possible and keeping products at that temperature to reduce the growth of food poisoning bacteria until consumption (Kenneth & Hilderbrand, 1992). Hot smoking has been applied to different fish species including Horse mackerel, sardine and freshwater tilapia and Catfish.

2.1.3 Cold smoking

This involves smoking fish at temperatures where the products do not show any signs of heat coagulation of the proteins. In cold smoking, the temperature should be maintained below 30 °C. Cold smoking is used to impart aroma and flavour in the fish muscle (Doe, 1998). The Relative Humidity (RH) should be kept at 75–85%. During cold smoking, the fish will not be cooked; therefore, it has to be cooked before consumption (Boziaris, 2014).

3 MATERIAL AND METHODS

3.1 Golden Redfish (*Sebastes norvegicus*)

Golden Redfish (*Sebastes norvegicus*) (Figure 2) also known as (*Sebastes marinus*) (ICES, 2012), is a species that as gain respect as a good food fish. Is one of the most common and commercially important fish in Icelandic waters today (Ministry of Fisheries of Iceland, 2016).

Figure 2: Golden Redfish (*Sebastes norvegicus*) and fillets.

3.2 Cabin Kiln

The smoking cabin is a smoking kiln constructed by MATIS, used in some projects in Africa (Figure 3). The smoking cabin is made of wood with a metal drum beneath the chamber where burning wood is the source of heat and smoke. A metal cylinder connects the drum and the smoking chamber to allow the heat flow into the compartment. A metal plate is placed above the cylinder to diffuse the hot air and provide a more even circulation in the smoking chamber. The fish is smoked on removable wooden frames with metal mesh. The effectiveness of the cabin kiln may be impacted by weather conditions, permit efficient use of the burned wood.

Figure 3: Matis cabin kiln smoker (Source: Mgana 2014).

3.3 Bradley smoker

Bradley smoker is an alternative electric smoker which is easier to control and more versatile than traditional smokers, with the automatic smoke generator, electronic control and fully insulated cabinet (Figure 4).

Figure 4. Bradley smoker.

3.4 Pre-trial

Two pre-trials were performed before the main experiment in order to determine appropriate brining procedure (concentration and time). Pre-trials also compared two different smoking facilities and two different smoking fuels, and defining appropriate processing procedures during smoking, such as duration.

Fresh redfish fillets were thawed at 2-4°C overnight and were immersed in 8% and 12% salt solution (ratio of 1:2 fish to brine) for up to 90 minutes at 0-2 °C. Samples were collected after 30, 60 and 90 minutes for determination of salt content. After brining, the fillets were placed on racks to drain overnight at 0-2 °C. The samples were smoked according to the

experiment design outlined in Figure 5, resulting in four experimental groups. Temperature and time were monitored throughout the smoking period. The physical properties (colour, water activity, pH, NIR and NMR) of the smoked samples were evaluated.

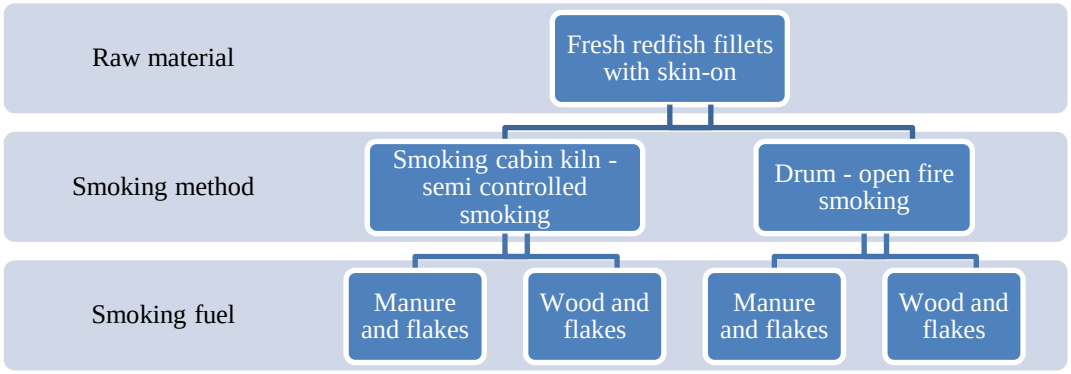

Figure 5: Flow chart of the smoking pre-trial.

3.5 Main trial

The experimental design of the main trial is shown on Figure 6. The results obtained in the pre-trial however determined the final experimental design of the main trial. Frozen fillets of redfish arrived at laboratory and were thawed at 2-4°C overnight and directly applied to brining. After brining, the fillets were drained and dried at room temperature for approximately 10 hours. The fish were subjected to two different smoking methods facilitated in a smoking cabin kiln and Bradley. The smoking fuel used were based on the results obtained in the pre-trial. Temperature loggers were placed both on the smoking racks as well as inside the muscle to monitor the temperature profile during smoking. After smoking, the final product was packed in open plastic bags (air packaging) and stored at 20 °C and 0-4 °C for up to 20 days.

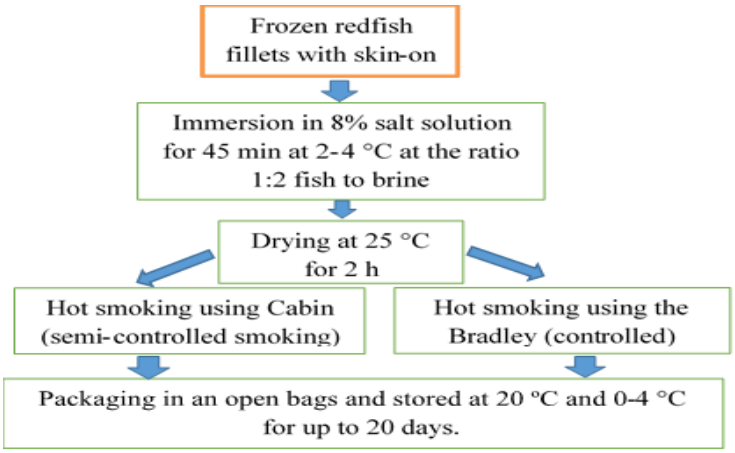

Figure 6: Flow charter of the main trial

3.6 Sampling

Physicochemical and microbial analysis were performed as shown in Table 1. Water content, Free fatty acid (FFA), TVB-N, Total plate count (TPC) were measured in raw material before brining and again once the fish had cooled down after smoking. Measures of colour, pH, peroxide value (PV), free fatty acid (FFA), thiobarbituric acid reactive substances (TBARS), total plate counts (TPC), water activity (W_a), and total volatile basic nitrogen (TVB-N) were done on days (5 and 10) and (5, 10, 15 and 20) of storage at room temperature (15-20 °C) and cold temperature (0 – 4 °C) respectively for Bradley and cabin kiln smoked fillets. All analyses were performed in duplicates (n=2).

Table 1: Sampling plan

Raw material	Treatment	Storage temperature	Sampling days (2 replicates per sample)						Total samples
			0	**5**	**10**	**15**	**20**	**-**	
Frozen redfish fillets	Raw material	-	X	-	-	-	-	-	2
	Kiln smoking	20 °C	-	X	X	-	-	-	10
		0-4 °C	-	X	X	X	X	-	6
	Bradley smoker	20 °C	-	X	X	-	-	-	10

Raw material

The redfish fillets used in this study were caught in January 2017. Fillets were processed post catch by HB Grandi fish processing company in Reykjavik, Iceland, and 3 Styrofoam boxes with an average weight of 15 kg of deskinned fillets were used.

3.7 Methods of analysis

3.7.1 The proximate composition

The water content was calculated as the loss in weight during drying at 105 °C for 4 hours (ISO, 2005). 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 (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 100g wet muscle. The TL extract was further used to evaluate the amount of free fatty acids evaluated according to ISO 6496:1999.

3.7.2 Colour

The intensity of the flesh colour was measured with a Minolta Chroma Meter CR-300 (Minolta, Osaka, Japan) using the CIE Lab system. The instrument records the L (lightness), a (redness) and b (yellowness) values on CIELAB colour scale. The L value, lightness, was recorded on the scale of 0 to 100 from black to white; a value was recorded as (+) red or (-) green, and b value as (+) yellow or (-) blue. The colour was measured above the lateral line at five positions, from the head to the tail of each fillet.

3.7.3 Free fatty acids

Free fatty acids (FFA) were determined according to method from (Lowry and Tinsley, 1976) with a modification made by Bernardez *et al*., (2005). About 3 mL of the lower phase resulting from lipid extraction (Bligh & Dyer, 1959) was added in a screw cap culture tube. Any solvent present was removed at 55°C using nitrogen jet. After cooling down, 3 mL of cyclohexane was added by 1 mL of Cupric Acetate – pyridine reagent and vortex for 40 seconds. After centrifugation at 2000 rpm for 10 min at 4 ^{o}C, the upper layer was read at 710 nm in spectrophotometer. The FFA concentration in the sample was calculated as µmol Oleic Acid based on a standard curve spanning a 2-14 µmol range.

3.7.4 Thiobarbituric Acid Reactive Substances (TBARS)

A modified method of Lemon (1975) was used for measuring thiobarbituric acid reactive substance (TBARS). A sample (5.0 g) was homogenized with 10.0 mL of trichloroacetic acid (TCA) extraction solution (7.5% TCA, 0.1% propyl gallate and 0.1% EDTA mixture prepared in ultrapure water) using a homogenizer at maximum speed for 10 seconds (Ultra-Turrax T-25 basic, IKA, Germany). The homogenized samples were then centrifuged at 5100 rpm for 20 min (TJ-25 Centrifuge, Beckmann Coulter, USA). Supernatant (0.1 mL) was collected and mixed with the 0.9 mL thiobarbituric acid (0.02 M) and heated in a water bath at 95°C for 40 min. The samples were cooled down on ice and immediately loaded into 96-wells microplates (NUNC A/S Thermo Fisher Scientific, Roskilde, Denmark) for reading at 530 nm (Tecan Sunrise, Austria). A standard curve was prepared using tetraethoxypropane. The results were expressed as µmol of malomaldehyde diethylacetal per kg of wet muscle.

3.7.5 Water activity

An Aqua Lab water activity meter was used to measure water activity (W_a) of the fresh and smoked fish. About 2 g of samples were put into the instrument and W_a were measured automatically after starting the program. Each sample were measured in duplicate.

3.7.6 Water content (WC)

Water content (WC) is the ability of a muscle to retain fluid under specific conditions. WC was determined by a method that is built on a method by Børresen (Eide 1982). The sample glasses were made from plexi-glass and their dimensions were: height 62 mm, inner diameter

19 mm and outer diameter 25 mm. The rotor used was SS-34 for Sorvall centrifuge, type RC-5B (Dupoint, USA). The samples were centrifuged at 1500 rpm for five minutes in special sample glasses. Samples were prepared by chopping them in a Braun Mixer (Type 4262, Germany) for 10-15 seconds (until homogenous).

The sample glass was weighed empty and then 2 grams of the sample were weighted into the glass. After centrifugation, the sample glass was weighed again with the sample in it minus the loose bounded water.

The Water Holding Capacity (WHC) of the sample was then calculated using the following formula:

$$WHC = \frac{W_1 - \Delta r}{W_1} \times 100(\%)$$

Where:
W_1 is the water content of the sample before centrifugation (%).
Δr is the weight lost by centrifugation (%).

3.7.7 Total Volatile Basic Nitrogen (TVBN)

The total volatile base nitrogen (TVB-N) was determined according to the method described by Malle & 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 then collected in boric acid solution and titrated with sulphuric acid solution. TVB-N content was expressed as mgN/100 g of fish sample. TVB-N was then calculated as;

$$\frac{14\frac{mg}{mol}xaxbx300}{25\ mL}\left[\frac{mgN}{100}\right]$$

Where;
a = volume of sulphuric acid (mL)
b = normality of sulphuric acid (%)
14 = is the molecular weight of nitrogen.

3.7.8 Temperature

The temperature during smoking and storage was recorded at five-minute intervals, by data loggers placed inside in the fillet, on each rack of the smoker and oven, in the cooling room and in room temperature storage. Additionally, the temperature in the centre of fish was measured during smoking by a thermometer.

3.7.9 Salt content

Salt content of products was determined according to (AOAC 17th ed. 2000 no 976.18). Soluble chloride was extracted from the samples with water. Upon addition of nitric acid, the solution was titrated with silver nitrate and the end point was determined potentiometrically.

3.7.10 Acidity (pH)

The acidity of both muscle was determined with a combination glass electrode, pH meter at room temperature. The pH of the muscle was measured by inserting the electrode directly into the fillet mince, according to the method of Kramer and Peters (1981). The pH meter was previously calibrated with buffer solutions of pH 7.00 ± 0.01 and 4.00 ± 0.01 at 20 °C, after was measured using a calomel electrode (SE 104) pH meter (Knick-Portamess 913 (X) pH meter, Germany, Berlin). The sample was done in duplicate.

3.7.11 Polycyclic Aromatic Hydrocarbons (PAH) Analysis

Polycyclic Aromatic Hydrocarbons was measured in the Eurofins WEJ contaminant laboratory. After smoking, samples of Redfish fillets from the Bradley smoker and the cabin kiln smoker were vacuum packaging keep in frozen storage (-80°C) and sent to the laboratory for analysis.

3.7.12 Data analysis

The results from the experiment were analysed using Microsoft Excel 2016 to calculate means and standard deviations for all multiple measurements in duplicate, and to generate graphs. Single factor ANOVA and two sample t-test were also carried out. The significance level was set at 95 % ($p < 0.05$).

4 RESULTS

During the smoke process, some changes in chemical content of the fish muscle occurred, mainly in salt and water content, and consequently, in the weight of the fish. The results of pre-trials on optimizing the best salting brine and steps in main trial are presented in Appendix, Figures (21 to 23) and Tables (5 and 6).

This chapter presents the major changes in weight, salt percent, pH, water activity, water content and the results of chemical and microbiological analysis of main trial of the final product of the smoked redfish fillets during storage time.

4.1 Composition of Redfish fillets

The composition of the raw material fillets was measured after thawing. The total volatile basic nitrogen (TVB-N) was determined to be 8.8±0.2 mg N/100g, the Water content (WC) 80.6±0.4 (%), total plate count 5.0±0.1 log (cfu/g), acidity 6.43±0.1, salt content 0.4, water activity 1.00 and TBARS

4.2 Yield changes

Generally, the total yield changed in both study groups. It increased after brining and decreased after smoking. The increase in yield at the brine salting step in cabin kiln method was 5.51% and 5.91% for Bradley method. The dehydration after smoking yield had different outcomes for two methods tested. Weight decreased to 5.93 kg for fillets produced in cabin kiln and 7.28 kg for fillets produced using Bradley smoke method. The final product yield was 76.32% and 61.48% for Bradley smoked and cabin kiln smoked fillets respectively. Statistical analysis showed a difference between all phases in weight of the fillets (raw material, after brine, after smoke and drying in oven) ($p<0.03$) (Figure 7).

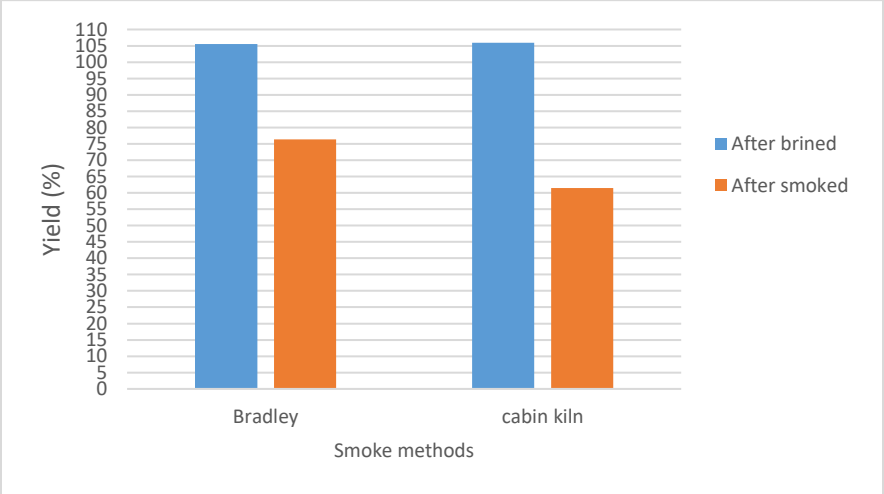

Figure 7: Yield changes in Golden Redfish fillets smoking process.

4.3 Changes in temperature profile during smoke process and drying fillets

The temperature profiles are shown in Figures (8 and 9). The temperature was not as well distributed in the cabin kiln smoke as inside Bradley smoker. The highest value recorded in the fish muscle in the cabin kiln smoker were 120 °C and Bradley smoker 69.5 °C.

The temperature was higher on the top and decreased at the bottom in cabin kiln smoker. For the Bradley smoker, the temperature was higher on the bottom and decreased at the top.

The temperature was 113.9±20.1 °C on rack and 69.3±17.1 inside muscle fillet at the top and 93.1±19.2 °C on rack, and 52.3±4.99 °C inside muscle on rack at the bottom for cabin kiln smoker. For the Bradley smoker the temperature was 75.5±6.2 on rack, 50.5±7.2 inside muscle fillet on the bottom, 69.5±6.7 on rack, and 49.5 inside muscle fillet on top.

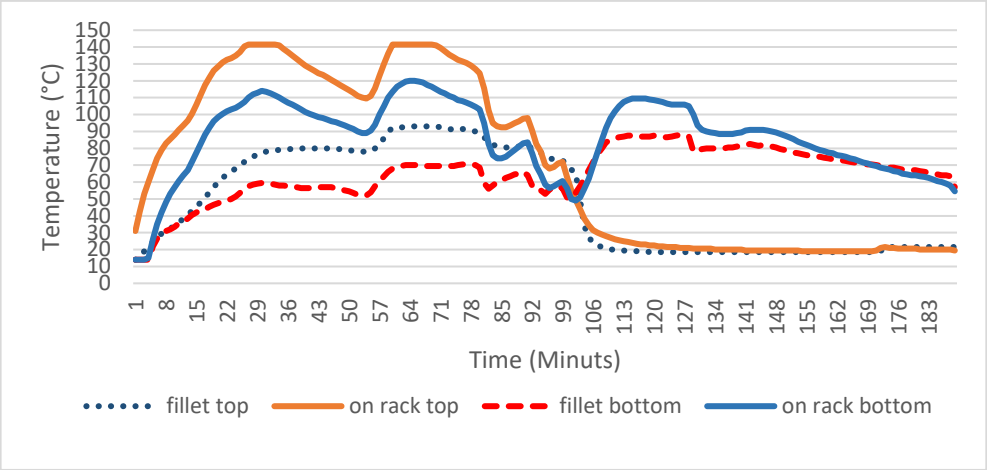

Figure 8: Temperature changes in muscle fillets and inside cabin kiln smoker during smoking redfish.

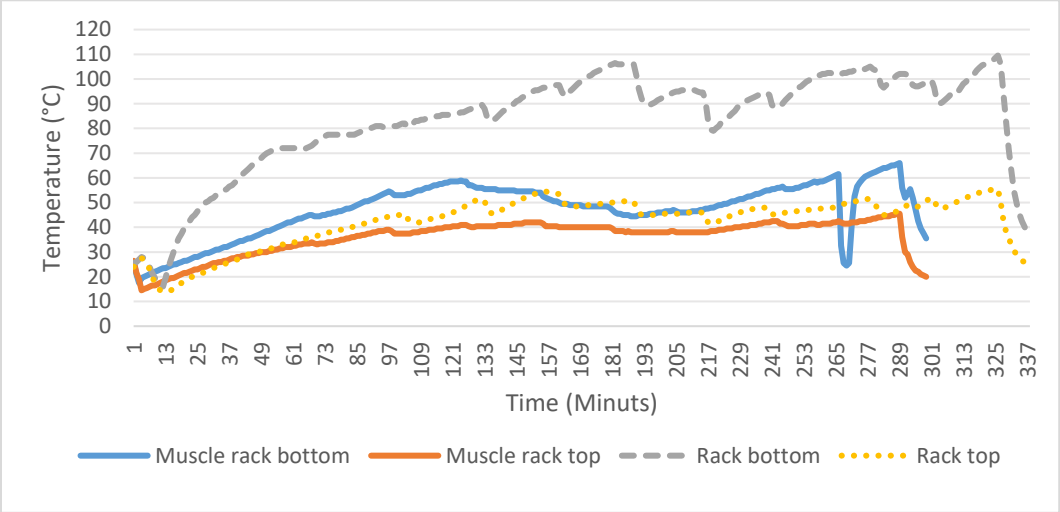

Figure 9: Changes in temperature in muscle fillet and distribution inside Bradley smoker during smoking redfish.

The result showed that the drying temperature increased with time, with a mean temperature of 38.5±6.6 °C, and a maximum of 44°C during the 2 hours of oven drying (Figure 10).

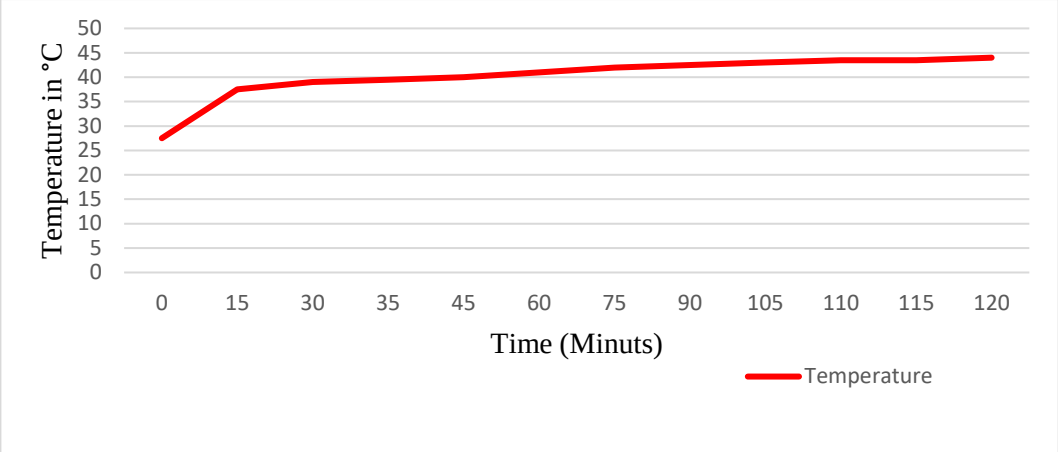

Figure 10: Temperature inside redfish fillet during oven drying.

4.4 Water activity

Water activity (W_a), measures how efficiently the water present in a food material can take part in a chemical or physical reaction. The water activity of the raw material fillets was 1.000 (Figure 11).

For 0 °C storage samples, W_a was not stable in final product for both methods tested. For the period between 5 and 10 days Bradley samples decreased and increased in day 20. For 20 °C storage samples, W_a decreased in time and both smoke methods had similar evolution.

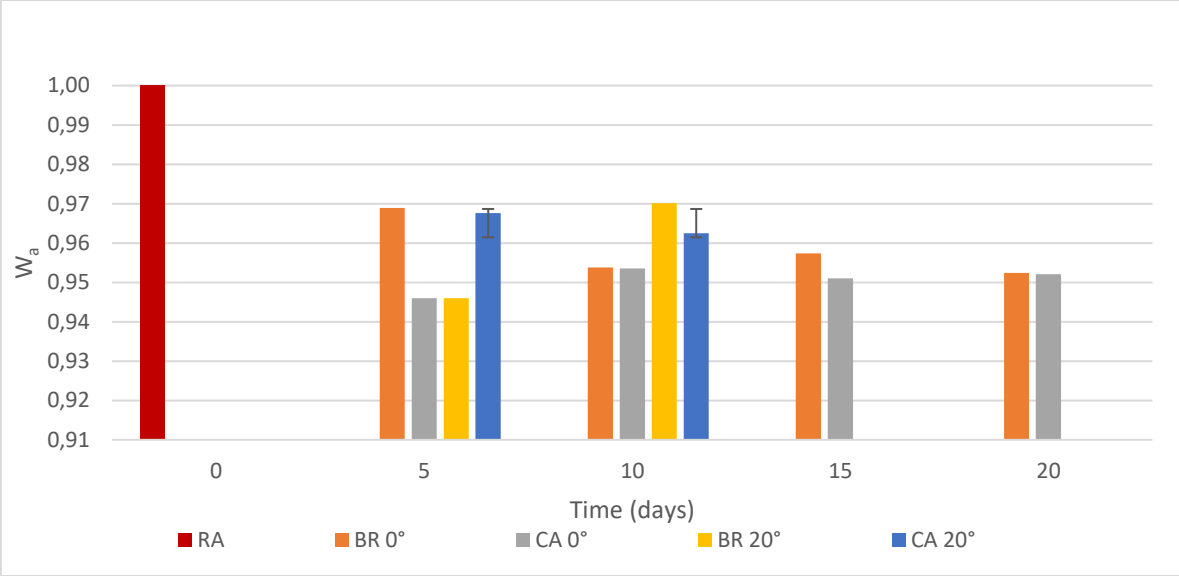

Figure 11: Changes in water activity (w_a) after smoking and evolution during storage, RA- Raw material; BR- Bradley; CA- cabin kiln; 0° and 20°- storage temperature.

4.5 Water content (WC)

The water content of the hot smoke redfish fillets for both treatments decreased during the storage period. In the beginning of the storage time the WC was similar between storage samples at 0-4 °C temperature also but different for storage samples at 20 °C temperature.

Initial WC of the raw material was 80.6%. After smoking that decreased down to 66.5±4.2 % and storage time further reduced WC, resulting in similar values in both smoke methods and storage temperature. For samples stored at 0-4° C the WC was 62.8±0.2 and 61.2 for Bradley smoker and cabin kiln smoker respectively (Figure 12).

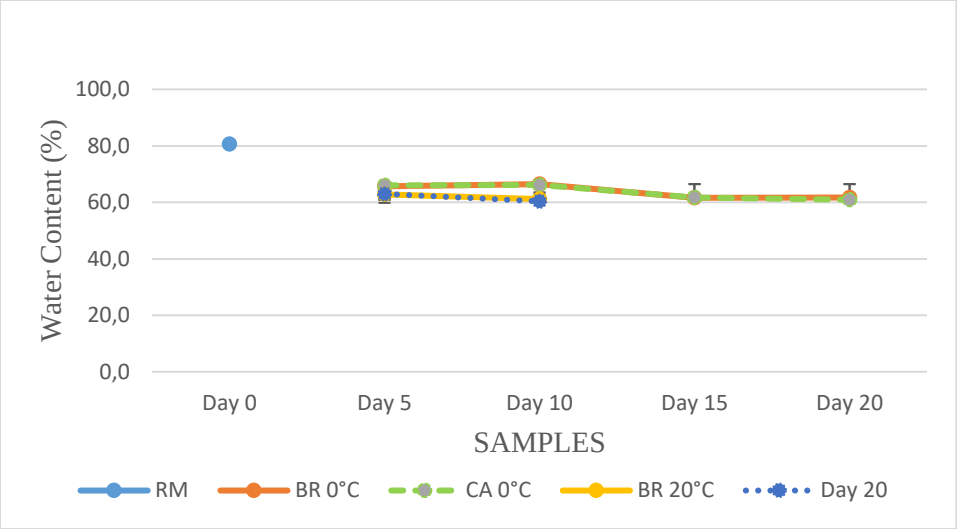

Figure 12: Changes in Water Content (WC) of smoked fillets for different smoking methods and different storage conditions.

4.6 Evolution in salt content over storage time

The changes in salt content in the smoked redfish fillets increased over time in all groups except for Bradley smoked storage samples at room temperature. In all groups, salt content percent is two times higher between content measured in the pre-trial (Figure 13). For samples stored at 20 °C, for both tested methods the results were above 3.5% with exception for Bradley smoke method in day 10. The statistical results showed no difference between all groups ($p>0.05$).

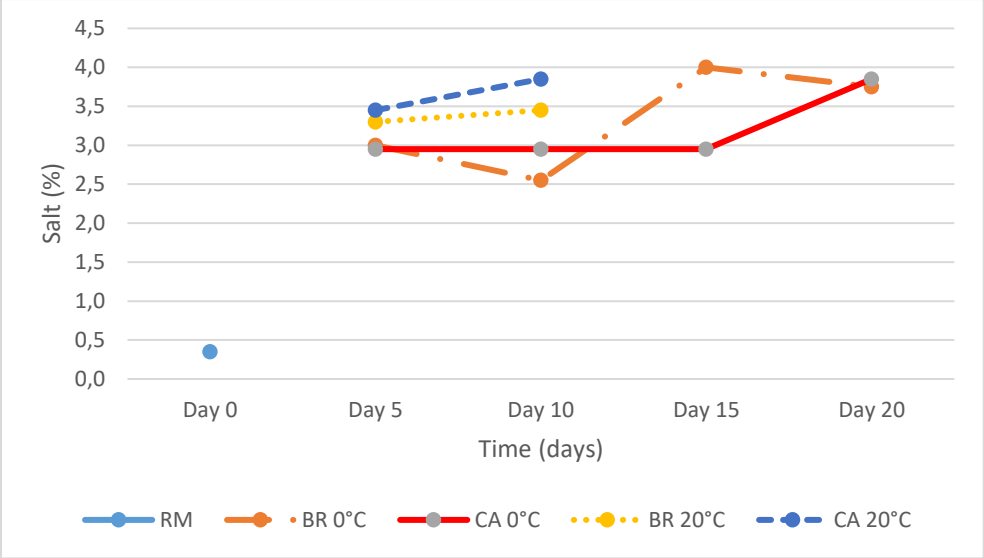

Figure 13: Effect the smoke method in salt content (%) and storage conditions.

4.7 Changes in TVB-N over storage time

The TVB-N of the samples after smoking and during storage were determined and presented in Figure 14. In comparison with the raw material, the TVB-N of smoke fillets in all group was increased significantly. It tripled during chilled storage samples and increased tenfold in room temperature samples. There were very small variances between all groups (0.045±0.01 mg N/100g) and storage days, but measurements on day 10 for the Bradley smoker samples storage at 20° C were highest (104.7 mg N/100g).

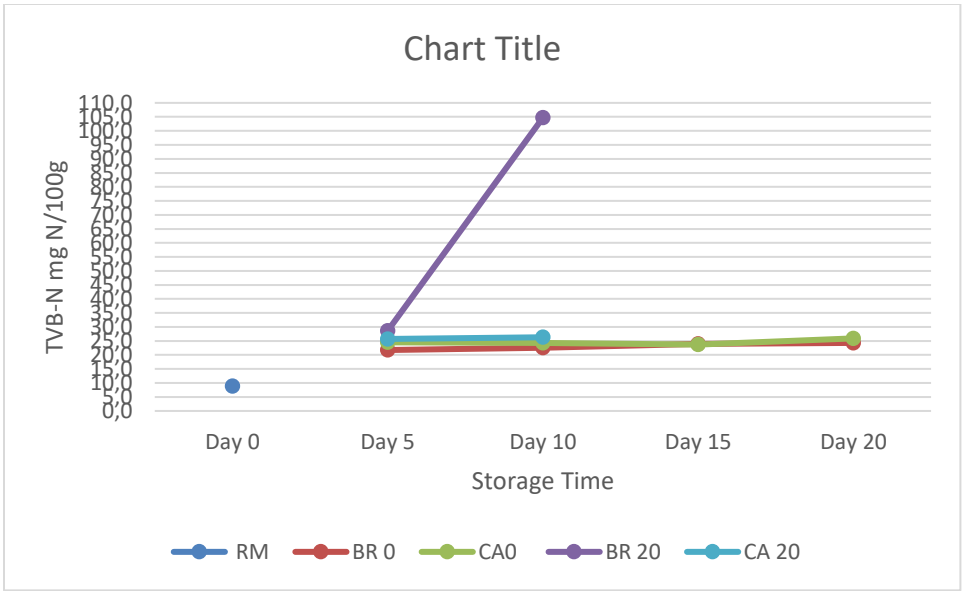

Figure 14: Changes in TVB-N for smoke methods (Bradley and cabin kiln), effect in storage temperature (0° C and 20°C) and shelf life.

4.8 Microbial Load

For both fish smoking methods and storage temperatures tested, the Total Plate Count bacteria (TPC) increased with time for Bradley smoked samples and decreased for cabin kiln smoked samples (Figure 15). The TPC range for the microbial load of the smoked fish products at 20 days was from $5.5x10^4$±0.1 cfu/g for raw material to $9.0x10^9$±0 cfu/g for Bradley smoked samples at room temperature storage. Samples stored at room temperature and smoked by the Bradley resulted in the most bacterial load. Statistical analysis showed there was difference between TPC obtained on raw material and all groups of smoked Redfish fillets mean over the storage period ($p<0.05$), but there was no difference between TPC obtained in all groups.

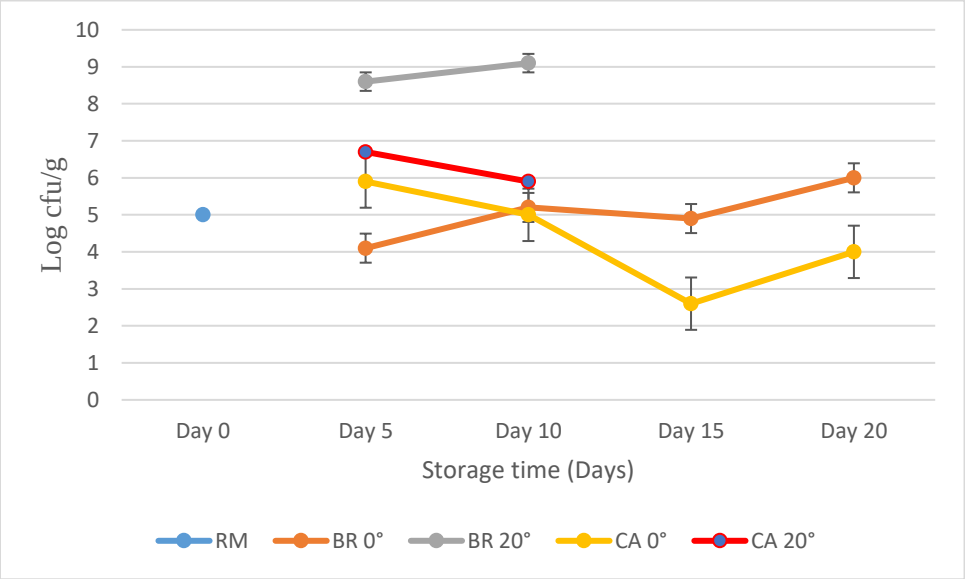

Figure 15: The total plate count (Log cfu/g) of smoke Redfish fillets (Bradley and Cabin kiln) during chilled storage.

4.9 Acidity (pH)

The pH of all smoke fillets changed over time. Day 5 to day 10 for samples stored at 20°C for both smoke methods showed no statistical difference among the fillets ($P>0.05$) (Figure 16), which indicates that smoking method and the storage temperature used had no effect on the pH levels of fillets during chilling storage. After smoking, pH increased over time storage temperature, the increase is very notable in all samples with the exception of the Bradley smoke fillets storage at room temperature.

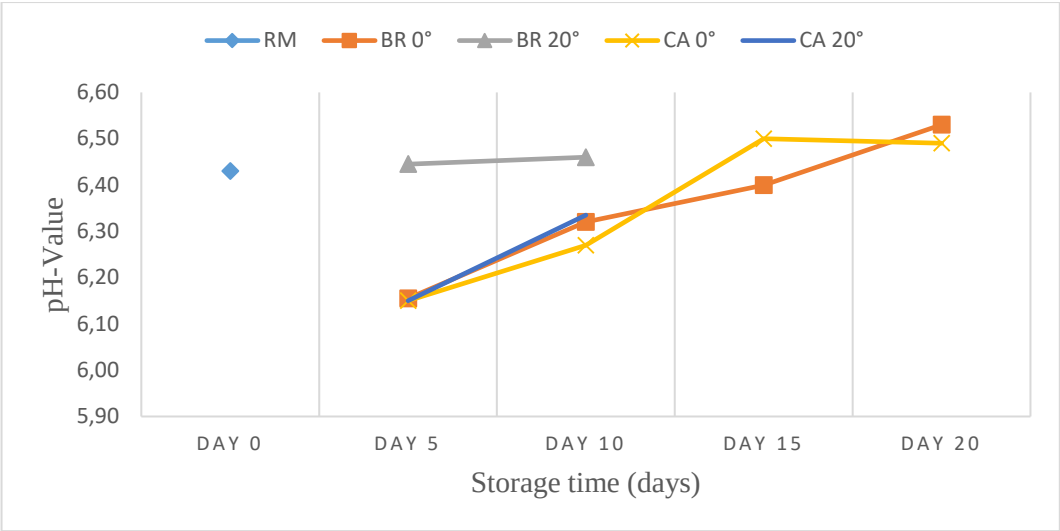

Figure 16: Acidity changes in storage time smoke Redfish.

4.10 Changes in colour

L* describing lightness (L* = 0 for black, L* = 100 for white), a* describing intensity in red (a* > 0), b* describing intensity in yellow (b* > 0).

The initial mean L* value (lightness) of raw material (redfish) fillets was 51.5±2.7 and decreased in time to 46.5±2.9 (Figure 17). No significant difference was observed between all groups in time and storage temperature (p>0.05). Significant difference in lightness was observed between the raw material and fillets produced in Bradley smoker (storage 0-4°C and room temperature) and cabin kiln smoker samples storage 0-4°C, (p=0.01 and p=0.008) respectively.

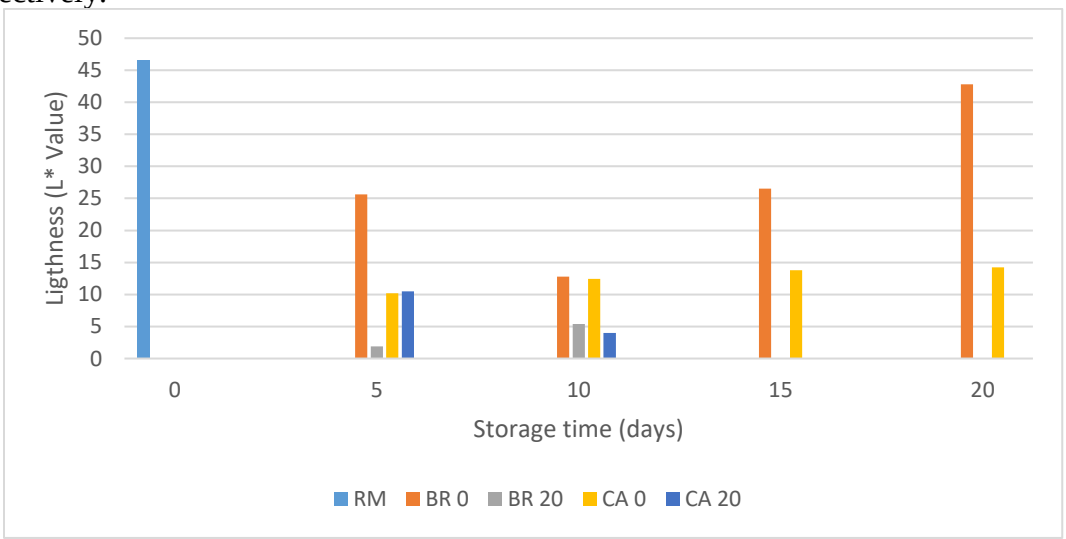

Figure 17: Lightness (L* value) colour changes over storage time.

Also, significant difference was observed in colour changes (lightness) between storage samples 0°C for Bradley smoker and cabin kiln smoker and differences were observed between temperature (p=0.0002).

The redness changes were alternating in storage temperature (Figure 18). The initial value for a* value for raw material redfish fillets was 4.48±2.0 and increased to 5.72±2.32, 5.29±2.27 and 6.85±3.33 for Bradley 0° C, cabin kiln 0° C and cabin kiln 20° C samples respectively. For Bradley 20° C samples the value decreased to 3.82±1.93. After smoking, no significant difference in redness was observed between the groups and raw material. The statistical analyses showed no difference in all smoked groups (p>0.05), and during prolonged storage.

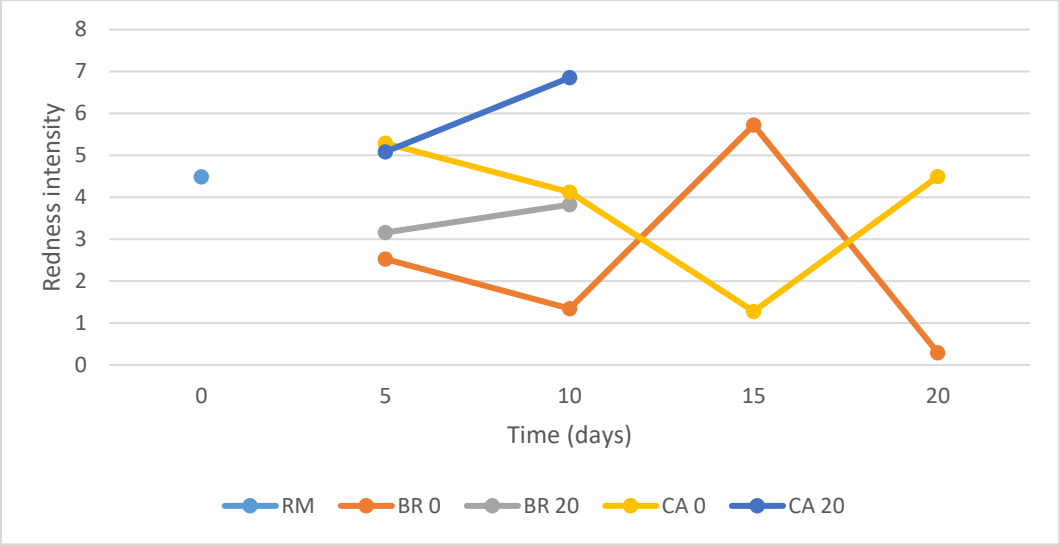

Figure 18: Effect over storage time and smoke methods in redness changes (a* value).

The b value (yellowness) describes the changes in intensity of blue (negative) and yellow (positive) colour of the redfish fillets before smoking and after smoking in storage time. The yellowness of the smoked redfish was not significantly different compared with the smoked method and all groups after storage time (p=0.194) but was significantly different in different storage time (p=0.002) (Figure 19).

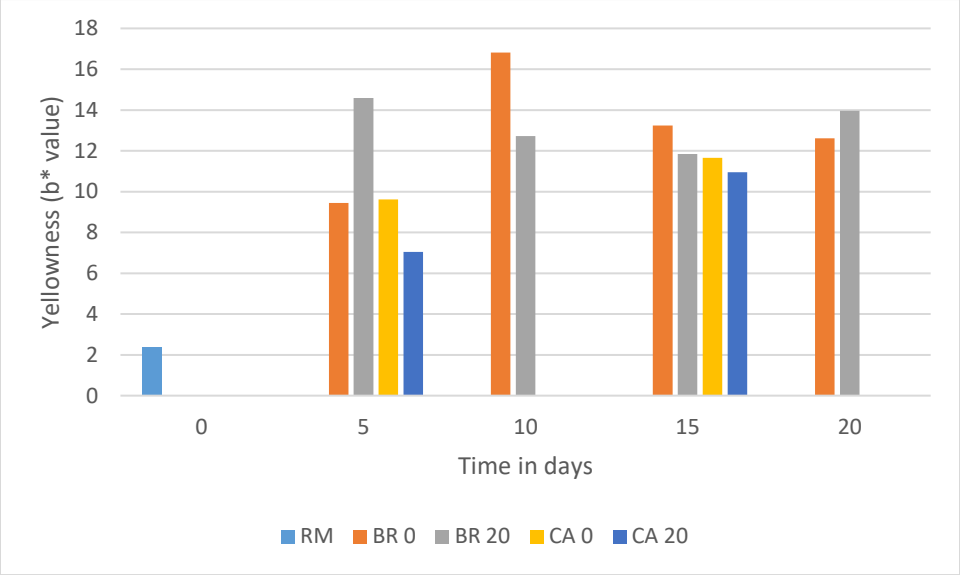

Figure 19: Yellowness Changes, b* value in smoked redfish fillets in storage time.

4.11 Changes in Free Fat Acids (FFA)

The effect of smoke method, storage temperature and storage time on smoked redfish fillets are presented in Table 2. The raw material samples of redfish had 3.98±0.9 g/100g lipid of free fatty acids (FFA) before they were smoked for storage samples at room temperature (20 °C). For cabin kiln it decreased (4.89±0.0 to 3.93±0.09), while the cabin kiln storage samples at cold room temperature (0 °C) and Bradley room temperature samples FFA value increased over storage time. There was no significant difference in FFA content between the two smoking methods and four groups during storage time $p>0.05$.

Table 2: Changes in free fatty acid in different storage conditions in smoked redfish fillets (g/100g Lipid).

	SAMPLES				
	R M	BRADLEY		CABIN KILN	
STORAGE DAYS		0° C	20° C	0° C	20° C
0	3.98±0.9	-	-	-	-
5	-	7.83±0.18	3.80±0.00	3.40±1.03	4.89±0.00
10	-	5.61±1.97	4.36±0.31	3.92±0.09	3.93±0.09
15	-	5.33±0.38	-	5.93±0.25	-
20	-	6.21±0.29	-	6.35±0.35	-

4.12 Changes in TBARS

The oxidative stability of the smoked redfish fillet samples smoked with wood and flakes was evaluated based on the concentration measurements of the substances reactive to thiobarbituric acid – TBARS, and the results (mean ± SD) are shown in Figure 20. The TBARS of raw material was 0.085 µmol/kg. After smoking TBARS decreased to 0.05 µmol/kg (for cabin kiln storage samples 0°C and day 10 for samples 20°C) and increased for other samples to 0.9 µmol/kg (for Bradley samples storage 0°C). The results indicated that the TBARS was not significantly different between smoking methods or storage temperature samples ($p>0.05$).

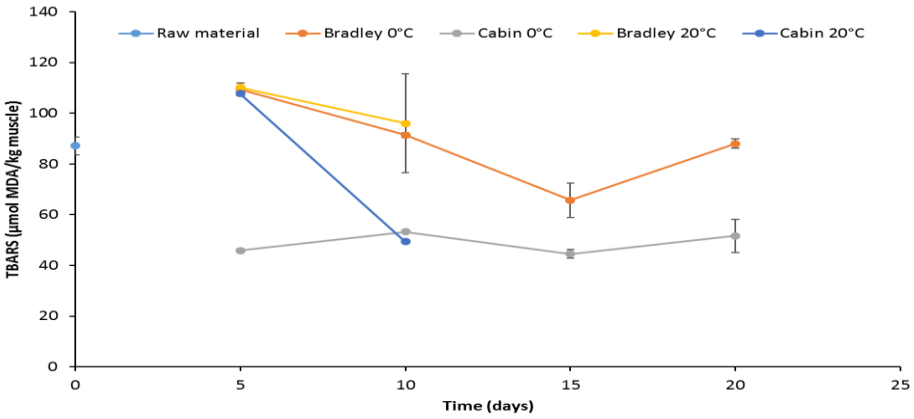

Figure 20: Effect of smoke method in redfish fillets over storage time.

4.13 PAHs measurement

Levels of PAHs in smoked redfish from the project are shown in Table 3. Cyclopenta (c,d) pyrene also known as CPP, Benzo (a) anthracene also known as BaA and Chrysene also known as CHR with 26.25±0.07, 24.15±0.07 and 24.00±0.28 respectively, were the most influent elements for samples smoked in cabin kiln. Moreover, the sum of the four main PAHs, Benzo (a) anthranthene, Chrysene, Benzo (b) fluoranthene and Benzo (a) pyrene in the smoked redfish fillets from Bradley was <2 µg/kg but inapplicable, for samples smoked in cabin kiln the sum of all positive PAHs was 117.55±0.35.

Table 3: Levels of Polycyclic Aromatic Hydrocarbons in smoked redfish fillets.

PAH compound	Abbreviation	Level of PAHs in Bradley smoker (µg/kg)	Level of PAHs in cabin kiln smoker (µg/kg)
Benzo (a) anthracene	BaA	<0.5	24.15 ±0.07
Chrysene	CHR	<0.5	24.00±0.28
benzo (b) fluoranthene	BbF	<0.5	7.3
benzo (k) fluoranthene	BkF	<0.5	3.5±0.14
benzo (j) fluoranthene	BjF	<0.5	4.8
benzo (a) pyrene	BaP	<0.5	7.75 ± 0.07
Indeno (1,2,3-cd) pyrene	IcP	<1	3.3
Dibenzo (a, h) pyrene	DhP	<0.5	2.85±0.07
Benzo (ghi) pirylene	BgP	<1	±0.9
Dibenzo (a, l) pyrene	DlP	<1	<1
Dibenzo (a, i) pyrene	DiP	<0.5	<1
Dibenzo (a, h) pyrene	DhA	<1	<0.5
Dibenzo (a, e) pyrene	DeP	<1	<1
Cyclopenta (c,d) pyrene	CPP	<1	26.25±0.07
5-Methylchrysene	5MC	<1	13.6±0.28
Benzo- (c) - fluorene	BcL	<1	4.15±0.07

5 DISCUSSION

5.1 Chemical composition of final product after smoking

There are several factors which influence hot smoking. These include; fish factors, method used and fuel. But fish factors like fat and water content in the muscles is very important. The WC after smoking for samples stored at 0 °C for both smoke methods decreased to 63.0 and 60.4 for Bradley smoked and cabin kiln smoked samples respectively. For samples stored at room temperature (20 °C) the results were 61.8 and 60.9°C respectively, showing small changes during the storage time for the Bradley samples and cabin kiln smoker samples. The results were not significantly different between groups and storage days, showing that the smoking method used had no effect on the parameter. The storage conditions RH (Relativity Humidity) affected the smoked redfish fillets and that effect is explained by (Boziaris, 2014) as increasing temperature and increasing processing time resulting in a loss of WC. Also, the changes in myofibrillar proteins which affect the quality of fish muscle have been related to proteolytic activity in the muscle of fish (Benjakul, 1997). These changes were consistent with (Yanar, 2006) in hot smoke tilapia and (Schubring, 2006) explain that changes can be caused by gradual denaturation of muscle proteins with increasing refrigerated storage time influenced by thermal treatment at low temperature during smoking and by additives, particularly salt.

The water activity starting at 1.000 (100%) in raw material, after smoking decreased to 96.8% for Bradley smoked fillets and 95.3% for cabin kiln smoked fillets. The values obtained for

this parameter were similar to those reported by other authors (Mgana, 2014; Karásková *et al.*, 2011), for this change in water activity value probably is the humidity in room storage and this is agreement with 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). The statistic results showed no significance difference between methods smoked used and storage days ($p>0.05$).

The salt content in the raw fillets was 0.35±0.07 and after smoking for samples that value increased for both methods, Bradley and cabin kiln smoker. The results showed significant difference between storage samples at 0 °C for both methods and raw material ($p<0.03$) with exception for storage samples at 20 °C ($p>0.05$). This variability has been also observed in other studies carried out with smoked fish products (Karásková *et al.*, 2011; Fuentes *et al.*, 2010). The increase in salt content in all redfish smoke fillets samples resulted from the salt diffusion into the fish muscle and the removal of water (drying) during the smoking process, and the less value of WHC over storage time. It could be because in pre-trial used fresh fillets the skin was on and in the main trial used frozen fillets the skin was off.

The total volatile basic nitrogen (TVB-N) is one of the most widely used measurements of seafood quality. TVB-N value is an important parameter for determining the freshness of fish products. TVB-N value is affected by species, catching region and season, age and sex of fish (Gökoğlu *et al*., 1998). According to Huss (1995), it is a general term which includes the trimethylamine, dimethylamine, ammonia and other volatile basic nitrogenous compounds associated with seafood spoilage.

The total volatile basic nitrogen or total volatile bases noted TVB-N or TVB or TVN consists mainly of a mixture of ammonia, DMA and TMA plus amines from the decarboxylation of amino acids (Garcia-Garrido, 1997) and other nitrogen compounds that become volatile when made alkaline (Pedrosa-Menabrito and Regenstein, 1990). The results of analysis are given in nitrogen equivalent, Ammonia-N, DMA-N, TMA-N and TVB-N.

The present study showed higher value for TVB-N value after smoking for all methods and over storage time and showed that the raw material samples 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 N/100 g for smoke fish., (Commission Regulation (EC) No 1022/2008, 2008). At the beginning, the TVB-N values of raw fillets redfish was 8.9 mg N/100 g and after smoking, it increased for all sample groups and all study method groups were higher than samples in cabin kiln smoker storage 20 °C (104 mg N/100 g flesh fish). The results showed no significant difference between raw material and all groups ($p>0.05$) with exception of Bradley smoked fillets stored at 20 °C ($p=0.01$) and that behaviour is similar over storage time between all smoked groups (Bradley smoked fillets storage 0 °C, cabin kiln smoked fillets storage 0 °C and cabin kiln smoked fillets storage 20 °C) and Bradley smoked fillets storage 20 °C in day 10, ($p<0.05$). Progressive increase in TVB-N at room temperature stored samples for Bradley smoked fillets signifies continuous deterioration of the smoked fish. While at cold room temperature the values kept on increasing but not at high rate.

The TVB-N of all the samples increased during the storage time but the values were not high and were acceptable according to (Commission Regulation (EC) No 1022/2008, 2008) except for 0°C storage samples after day 15 for Bradley smoked, cabin kiln smoked and all samples storage room temperature, TVB-N value increased more than 25 mg N/100 g. The results of this study are like the findings of other research (Ikutegbe, 2014; Alicicek & Atar, 2010; Kumolu-Johnson, 2010; Plahar *et al.*, 1999; Hood, 1983) where smoking processes influenced the TVB-N level of smoked rainbow trout where the TVB-N increased after smoking and through storage. This fact could be explained by the higher microbiological load observed in smoked redfish 9 log(cfu/g), Debevere and Boskou (1996) explain that this can be attributed to the fact that TMA values vary with species, season, storage conditions, bacteria and intrinsic enzyme activity. (Huss, 1995) total volatile basic amines (TVB) is one of the most widely used measurements of seafood quality. It is a general term which includes the measurement of trimethylamine (produced by spoilage bacteria), dimethylamine (produced by autolytic enzymes during frozen storage), ammonia (produced by the deamination of amino-acids and nucleotide catabolites) and other volatile basic nitrogenous compounds associated with seafood spoilage. Huss (1995) explain the little ammonia is also formed in the first weeks of iced storage due to autolysis. In some fish that do not contain TMAO or where spoilage is due to a non TMAO reducing flora, a slow rise in TVB is seen during storage, probably resulting from the deamination of amino acids.

5.2 Quality of smoked fillets using Bradley and Cabin kiln smoker

The environment affects the growth of microorganisms, and they can alter the environment. Also, microorganisms can inhibit or stimulate the growth of each other (Banwart, 1981). One objective of the study was the investigation of shelf life of hot smoked redfish. The microbiological results in this study showed mean total plate counts (TPC) samples of smoked redfish during over storage time and are given in Figure 17. After smoking and over storage time TPC increased significantly ($p<0.05$) between raw material and all study groups. TPC rose sharply when the temperature storage increased to 20 °C (room temperature). Furthermore, the TPC of redfish smoked samples was significantly ($p<0.05$) higher than that compared to storage days throughout the processing and storage time. Also, spoilage of the smoked fillets storage at 20 °C was not retarded by their exposure to storage conditions in the temperature room. All experimental groups were affected by microbial growth, enzymatic activity and lipid oxidation at different storage days although spoilage occurred more rapidly in smoked samples stored at 23 °C. Microbial rates were also affected by availability changes in both temperature and cold storage rooms

The results are associated with the higher results in WC, water activity and air packaging in all smoked fillets. (Flick, 1990) explains packaging can play a key role in the inhibition of bacteria controlling the environment to which the product is exposed. Vacuum packaging removes most of the available oxygen needed by spoilage bacteria. The storage life of smoked fish is affected by the initial microbial load of the fish, micro flora, packaging material, production method, size and composition of initial numbers of freezing and thawing cycles and quality of raw material, storage temperature and packing methods (Dondero, 2004).

Change in colour of hot smoked fish is a problem in the fishing industry concerning the presentation of product to final consumer. Significant changes were observed in the colour of the smoked redfish fillets during storage time (Figure 19, 20, 21, 22 and 23). There was no significant difference in colour parameters between raw material and the four smoked redfish groups ($p>0.05$) even as between smoked fillets groups.

Increase in lightness (L* value) of the muscle was observed in all groups with ageing. Also, that change increased between Bradley fillets smoked and cabin kiln smoked storage at 0 °C. The results showed the difference for raw material samples and all Bradley smoked fillets, also cabin kiln smoked fillets ($p<0.05$). The results probably associated the temperature inside the smoker used in this project (Sikorski and Kolakowski, 2000) this is mainly due to the protein denaturation rate in the muscle of the cod, which is higher than for other temperatures used, along with high enzyme activity in the muscle.

The changes in redness intensity (a* value), were quite unstable over storage time, and showed no statistical difference between all groups in this study $p>0.05$ and similar results were seen for smoked fillets samples storage in different and similar temperature. For samples stored at room temperature there was little increase over storage time, while for samples in cold storage, after smoked redness value was 2.25±2.39 for Bradley smoked fillets and 5.29±1.94 for cabin kiln smoked fillets, decreasing on day 10 to 1.34±1.39 and 4.12±1.52 for Bradley and cabin kiln respectively. This trend repeats for day 15 and day 20.

Yellowness changes (b* value) in this project was decreasing for Bradley smoked fillets cold storage samples and for cabin kiln smoked fillets at room temperature. (Doe, 1998) explains that the carotenoids contribute to the striking yellow, orange, and red colour of several important fish and shellfish products and changes in carotenoids during processing and storage of fish. Yellowness were quite unstable and had the same behaviour as a* value for fillets stored in cold room for cabin kiln and increased for Bradley room temperature samples. The statistical results showed no significant difference between smoking methods used ($p>0.05$) and significant difference in storage days ($p<0.05$). The increase in yellow colour was presumed to be due to the oxidation of pigment in the fish muscle by oxygen and enzyme oxidation (Khayat & Schwall, 1983; Hamre, 2003).

According to Karlsdottir *et al*., (2014) TBARS values measure secondary products of lipid oxidation (normally from peroxidation process) and are always used in detecting rancidity of tissues. The lipid oxidation product TBARS were generally more stable in smoked samples stored in the cold storage room (0 °C) compared to when stored at room temperature (20 °C). The TBARS decreased little over storage time. These finding were like previous results by Siskos, 2007, and results were in contrast with (Huong, 2013). For Bradley smoked fillets this was explained by the fact that low temperature (above 60) in muscle fillets during smoking process does not deactivate the enzymatic activity.

PAHs are a group of fused ring aromatic compounds that are formed during the incomplete combustion of organic material (Mcgrath, 2010). Levels of PAHs of smoked samples from the smoking Bradley was inapplicable limits. For cabin kiln the total sum of the positive main PAHs Benzo (a) anthranthene, Chrysene, Benzo (b) fluorene and Cyclopenta (c,d) pyrene

was 63.4 µg/kg and sum of all the positive PAHs was 117.8 µg/kg, and the EU legislation limits are 12.0 from 2014 (Commission Regulation, 2011). The results showing differences in PAHs concentration between samples (Yurchenko, 2005) explain, probablythe effect is due to differences in smoking method.

6 CONCLUSION

Results obtained in present study indicated that smoked products using the cabin developed by MATIS gives better smoked quality than Bradley smoker, is very cheap, but yields inapplicable levels of PAHs.

Appropriate drying temperature for redfish smoked fillets must be higher than 50 °C, we believe around 65 °C.

Microbial control can be ensured to minimize contamination before, during and after fish smoking and combination air packaging and room temperature storage is not recommended for longest shelf life products. The shelf life for smoked redfish in cold room temperature storage (0 °C) is 15 days whereas room temperature storage is below 10 days.

Storage conditions are important parameters for the shelf life of smoked fish products. After smoking fillets and over storage time the WC and salt concentration were inversely proportional.

Fresh redfish fillets yielded very good smoked raw material product; however frozen fillets are not so good for smoking because they are very difficult to manipulate and break easily.

7 RECOMMENDATIONS

This experiment could be repeated in rural areas in Angola using the cabin developed by MATIS and better results can be produced by extending smoking time.

An experimental project can be designed and proposed to the competent authority to study the introduction of these smoking methods in several areas in Angola and use the results to adapt to the real situation.

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APPENDICES

Pre-trial results

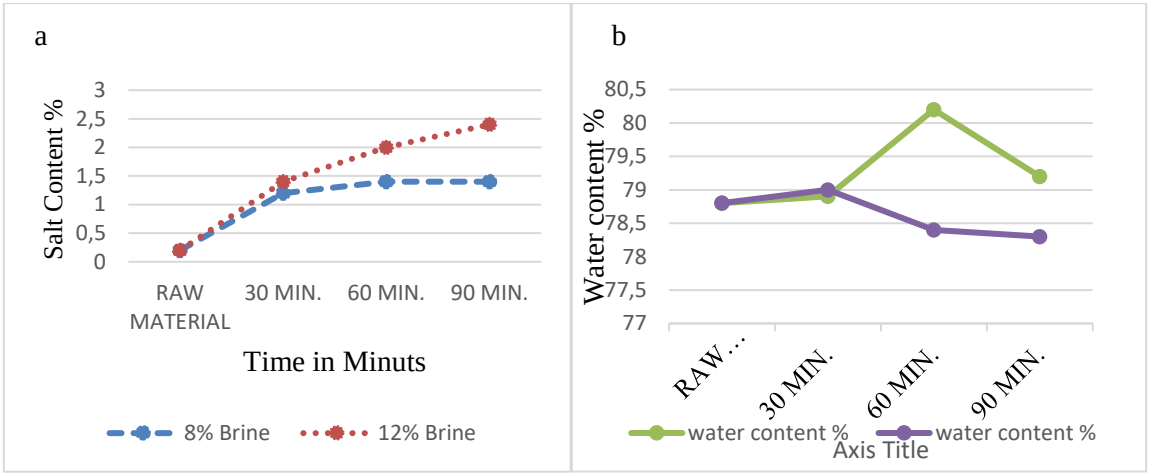

Figure 21: Evolution salt content (a) and water content (b) in redfish muscle using different brine concentrations and different time.

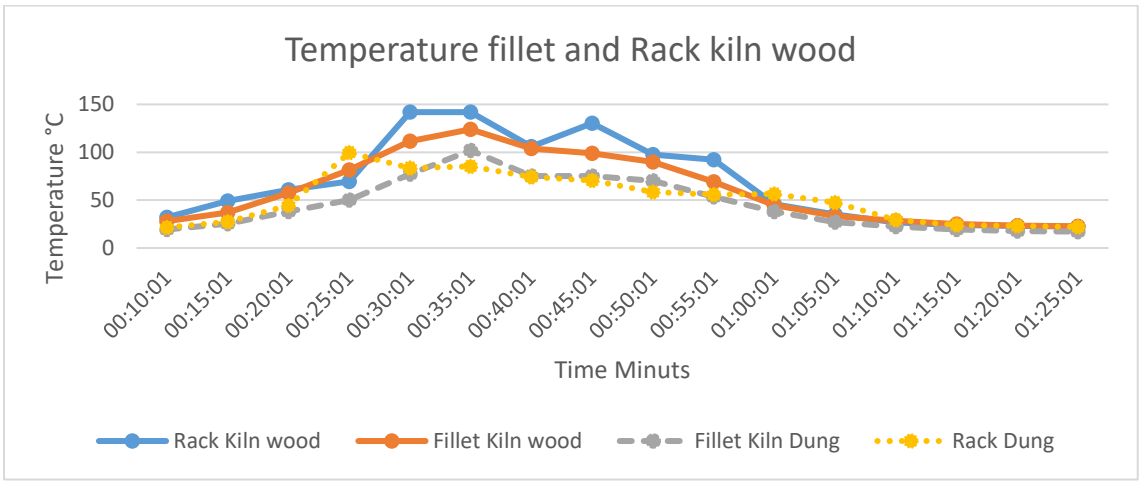

Figure 22: Temperature changes in muscle fillets in different smoke fish method, pre-trial.

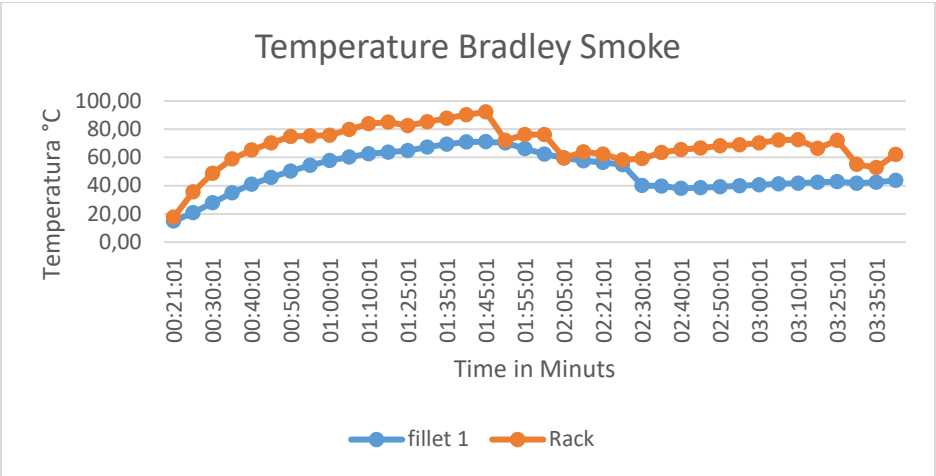

Figure 23: Evolution of temperature in Bradley smoker in pre-trial.

Table 4: Water activity and pH results at the pre-trial.

Smoke Method	Water activity value	pH
Open Fire Wood	0.9646 ± 0.005	6.7 ± 0.20
Open Fire Dung	0.9676 ± 0 .006	6.56 ± 0.20
Kiln Wood	0.9552 ± 0.012	6.69 ± 0.60
Kiln Dung	0.981 ± 0.011	6.41 ± 0.21
Bradley	0.9943 ± 0.010	6.43 ± 0.03

Table 5: Colour changes using different smoke methods and fuel.

Smoke method	L*	a*	b*
open wood	50.36±2.69	4.43 ± 1.81	14.99 ± 2.30
open dung	45.66±3.17	1.63 ± 1.25	13.01 ± 3.15
cabin kiln wood	34.68±2.45	0.65 ± 1.00	10.85 ± 3.76
cabin kiln dung	39.38±1.87	5.10 ± 1.70	24.83 ± 3.70
Bradley	40.30±1.67	0.26 ± 1.30	15.28 ± 0.94

Pictures of smoke Redfish processing

Figure 24: Redfish fillets smoked in Kiln method.

Figure 25: Fillets in drying Oven.