THE EFFECT OF HOT SMOKING ON MICROBIAL AND PHYSICOCHEMICAL QUALITY OF ATLANTIC HERRING IN LIBERIA

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ABSTRACT

Fish is an important source of animal protein in the diet of the Liberian population. The methods of harvesting, handling, preservation, processing, and packaging have become a major problem for human health. Smoking as a method for preservation has remained the most widely used method for the preservation of fisheries products. The main objective of the research paper is to provide an improved method of fish smoking comparing modern or conventional methods of fish smoking. To achieve this, Atlantic herring was smoked, both ungutted and gutted, then measured for physiochemical, proximate, and microbial analysis. The final products were packed in a sterilized box and store at 20C° room temperature and 0-4 for up to 23days. Samples stored at low temperature were stable. Samples stored at 0-4°C never exceeded maximum limits for TVC and TVB-N allowed in fish products during 20days. Ungutted samples had more FFA indicating more enzymatic activity. Based on the results it is not possible to determine the extended shelf life of the gutted product compare to ungutted. These results show that the fish stored at 20°C spoils within two days, as the TVB-N reaches unacceptable limits.

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ABBREVIATIONS

aw – Water Activity
EC – European Commission
FAO – Food and Agricultural Organization of the United Nations
FEP – Fluorinated Ethylene Propylene
GMP – Good Manufacturing Practice
IA – Iron Agar
ICES – International Council for the Exploration of the Sea
ISK – Iceland Krona
ISO – International Organization for Standardization
LOG – Logarithm
MRI - Marine Research Institute
NaFAA-National fisheries and Aquaculture Authority
TCA – Trichloroacetic Acid
TL – Total Length
TVB-N – Total Volatile Basic Nitrogen
TVC – Total Viable Count

1 INTRODUCTION

Fish is an important source of animal protein in the diet of the Liberian population. The methods of harvesting, handling, preservation, processing, and packaging have become a major problem for human health. Smoking as a method for preservation has remained the most widely used method for the preservation of fisheries products. This method is common in most developing countries with Liberia being no exception. This traditional method of preservation has been done for centuries by fishmongers and traders. Fish processing through hot smoking is an age long practice in most parts of the world (FAO, 2010). Fish smoking practices in Liberia have yet to gain importance on a large industrial scale due to the lack of appropriate technology to assist the fish smoking business. Locally available methods such as mud bricks, firewood and cut drums, can adversely affect the quality of the fish which make the quality control and improved hygienic condition difficult to withstand the market demand diminish the market value due to damage and non-attractive appearance of the product (FAO, 2010).

The National Fisheries and Aquaculture Authority (NaFAA) of Liberia reported in its 2018 annual report that 43% of fish captured in the artisanal sector are preserved by smoking while 2% is preserved by freezing and 55% is sold fresh or preserved by other methods like salting and fermenting (NaFAA, 2018). Preserving artisanal catch by freezing in Liberia is a serious challenge and is mostly in the coastal communities since there is limited electricity. Artisanal fishermen usually give the remainder of their catch after trade to traders or directly to consumers or to their wives for processing.

In Liberia, smoking ovens are usually constructed by joining two opened 50-gallon steel oil drums and cutting a stokehole at the base. Akinwumi *et.al* (2015) reported the average diameter of the metal oven as 115 cm, with a height of 90 cm and a stokehole of approximately 40 x 40 cm. Iron rods are fitted about 60 cm above the base of the drum to serve as a support for the layers of fish (Bianchi *et.al*, 1999). The processing equipment is light and portable but vulnerable to rust and deterioration. Smoking of fish using this method gives off considerable heat during the smoking process to the discomfort of the processor because it is made of metal steel (Figure 1). The fish usually spend 24 hours on the cut drum oven and heat is estimated at 45°C and the temperature dropped to 10°C.

Figure 1: Hot smoking of Atlantic herring in Robertsport Fanti Town, Liberia in 2016 (NaFAA,2018)

Fish is an important source of animal protein in the diet of the Liberian population, but the post-harvest practices in the coastal and rural communities remains a major challenge (NaFAA, 2018). The poor quality and safety of the smoked fish products in Liberia is due to poor handling, preservation, processing, and storage facilities and pose serious health risks. The problems of post-harvest losses through smoking are a direct result of the way the fish are handled, preserved, and processed at the end of production. Traditional smoking methods cause heavy smoke and high fire, causing the fish to burn. The product brittle is easily broken. Un-gutted smoked herring are part of the traditional diet of Liberians. Besides, the holding time, as well as the environmental conditions, are contributing to the poor quality of the fish, when bacteria act on the harvested product.

Fish is an important animal food for human consumption. Nowadays fishermen usually hold their catches for a long time because they want to catch more. They do not carry ice onboard for preserving the fish temperature, which results in the deterioration of quality over time.

It is against this background that this research is conducted to know the effect of hot smoking on microbial and physicochemical quality of herring. Research showed this method will not add value to the fish, and the fish will not last a longer time of preservation after smoking it ungutted. Traditional fish smoking methods are harmful for human consumption (Akinwumi, *et.al*, 2015).

It is essential to investigate the microbial content to ensure that the end products are safe for human consumption. This research paper will suggest recommendations to improve the smoking method in Liberia especially in the artisanal sector.

1.1 Objective

The main objective of the research paper is to provide an improved method of fish smoking comparing modern or conventional methods of fish smoking.

The specific objectives of this work are:

- To conduct microbiological tests to know the difference in microbial communities between un-gutted and gutted smoked herring.
- To determine the best strategies for improving the microbial quality of smoked small pelagic species.
- To provide technical knowledge at a local and national level for achieving high value and longer shelf life of fish products when the fish is processed by smoking method; and
- To know the effects of storage temperatures on smoked fish products.

2 LITERATURE REVIEW

2.1 Fish processing and hygienic risks

The main role of processing is preservation. Processing not only extends the shelf life but also can add value to the product. It is imperative that only fresh, prepared fish be used for smoking to obtain good quality end product. Smoking will not make poor quality or spoiled fish acceptable. The suitability of fish for yielding high quality of smoked fish depends on the characteristics of the fish. The biological state and effects of catching and handling and after catch. The most important factors are the composition of fish, including the content of fat and enzyme activity, as well the vulnerability to bacterial spoilage to smoking. The microbial flora

associated with fish could be from the environment in which the fish are harvested and not specific to a particular species. In Liberia, handling is not done under hygienic condition. The fish that is smoked, are displayed on dirty floor/ mats, trays and open containers or untidy table in the market for sale. Fish are easily contaminated with microorganisms in nature, through handling during processing and post processing.

2.2 Hot smoking

Hot smoking is a traditional method of processing fish in Liberia. This method of preservation is wildly practiced in Africa for consumption and commercial propose. The fish is smoked at temperature that are high at 70ºC to 80ºC which causes the fish to be cooked and can be consumed without further cooking (Coata, 2018). When high temperature is applied during smoking, the fish takes short time.

2.3 Atlantic Herring

Herring schools in coastal waters from inshore to the edge of the shelf prefer clear saline water with a minimum temperature below 24°C. The juveniles tend to stay in nursery areas, while adult stocks are typically found offshore (Bianchi *et.al*, 1999). It is a highly migratory species and often rise to surface at night. It feeds mainly on zooplankton, especially copepods; the juveniles feed on phytoplankton (Bianchi *et.al*, 1999). This species breeds throughout the year and have two main spawning periods. Herring species is marketed fresh, canned, smoked or fried (Whitehead, 1985). In Liberia, herring is marketed when the fish is smoked.

Herring species are found along the West African coast, and the Gibraltar southward to Saldanha Bay in South Africa (Whitehead, 1985); also, in the Mediterranean Sea and the Black Sea. Herring can also be found in the western Atlantic Ocean from Cape Cod in the USA to Argentina (Whitehead, 1985), including the Bahamas, this species can also be found in the Antilles, Gulf of Mexico and the Caribbean coast (Smith, 1997)

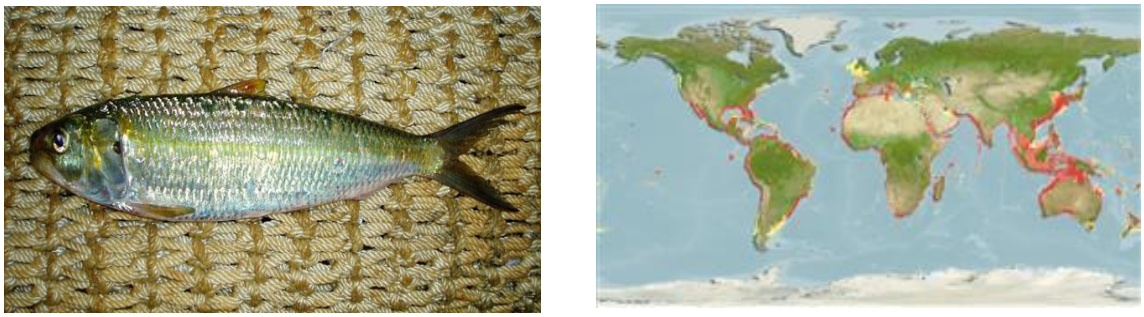

Figure 2. Pictorial View of Atlantic Herring and Distribution Map in the Atlantic
Source: (FishBase.org)

2.4 Post-harvest losses

Fish is easily spoiled without any preservative or processing measures. Due to its chemical composition, fish is a perishable food material and its flavour and texture change rapidly during storage after death.

Fish harvesting, handling, processing, and distribution provide a livelihood for millions of people, as well as provide foreign exchange to many African countries (FAO, 2010). In many rural fishing communities, the infrastructure for post-harvest processing and preservation of

fish are inadequate. The fishing industry, despite its importance, suffers from enormous post-harvest losses which are estimated at 35–40% of landed weight, and it is estimated that post-harvest losses remain about 25% of the total world catch annually (Adeyeye *et.al*, 2016). In Africa, some 5% of the population, about 35 million people, depend solely on the fisheries sector, mostly artisanal fisheries, for their livelihood. Various traditional methods are employed to preserve and process fish for consumption and storage (Adeyeye *et.al*, 2016). These include smoking, drying, salting, frying, and fermenting and various combinations of these.

In many countries in Africa, smoking is the most widely practiced preservation method. Adeyeye *et.al* (2016) reported that virtually all species of fish caught can be smoked, and estimated that 70–80% of artisanal and freshwater catch is consumed in smoked form. Therefore, the quality and safety of all smoked fish as food should be of major concern to ensure consumer protection in the provision of nutritional and good smoke fish products.

3 MATERIALS AND METHOD

3.1 Raw Material

About 20 kg of frozen headed and gutted Atlantic herring were used in this study. The samples were purchased from SVN, an Icelandic fish processing company, and kept in a frozen storage at -24°C. The fish samples were thawed at low temperature 0 to 4C° for 24 hours.

3.2 Experimental Design

3.2.1 Pretrial

Before the main experiment, a pretrial was carried out to set up the best brining and smoking procedure for the main experiment. Ten frozen headed herring samples were used in the pretrial, frozen and stored at -24°C. The samples were thawed at low temperature 0-4°C for 24 hours. The herring product was divided into two groups, based on the brine used (salt concentration), the brining time was mainly to determine the best time for the brine concentration .The two groups of herring were kept in the brine solution at different times; one for 45 mins and the other 60 mins in the brine solution. After the pre-trial, it was determined that the best time for the brining was 60 mins. The gutted fish was descaled and washed. The belly cavity was cleaned as well as any traces of blood and belly lining and was placed in brine solution. The two groups were brined in an 8% sodium chloride solution. Thawed frozen fish of good quality were used for making hot smoked products in gutted and ungutted Atlantic herring.

Figure 3. Pre-trial testing of Atlantic herring; different brining time, un-gutted without scale, gutted, after they have been taken from brine solutions.

The herring samples were tested in the smoke oven after removal from the brine at the set timing to determine the best smoking time. The smoking oven was set at different timing and temperatures during smoking. At the first stage, the temperature was set at 30°C and the time was 30 minutes to prevent subsequent breakage, after which the temperature was raised to 50°C for 30 minutes to allow partial cooking. The temperature was later raised to 80°C and the time was increased to 60 minutes to complete the final smoking. The specimens were then chilled and transferred to the laboratory to be tested for salt content. The importance of the pre- trial was to set up the best brining time and smoking procedure for the main experiment for acceptable product in the market.

3.3 Main Experiment

The frozen herring that were used in this study were purchased from SVN an Icelandic fish processing company and kept in a frozen storage at -24C°. the fish sample were thawed at low temperature 0-4 for 24 hours.

The experimental design of the main trial is shown in (Figure 4). The results obtained in the pretrial, however determine the main trial and experimental designed. Frozen herring arrived at the laboratory and were thawed at 0-4C°overnight and was divided into two groups, washed the herring removed the gut from the fish ,washed the fish and placed it in the brine for sixty minutes, after brining the herring, it was divided into two groups. The fish was placed in the box and was taken to the smoking site. The smoking fuel was used based on the results from the pretrial. Temperature loggers were placed on the smoking racks as well as inside to monitor the temperature profile during smoking. The final products were packed in a sterilized box and store at 20C° room temperature and 0-4 for up to 23 days.

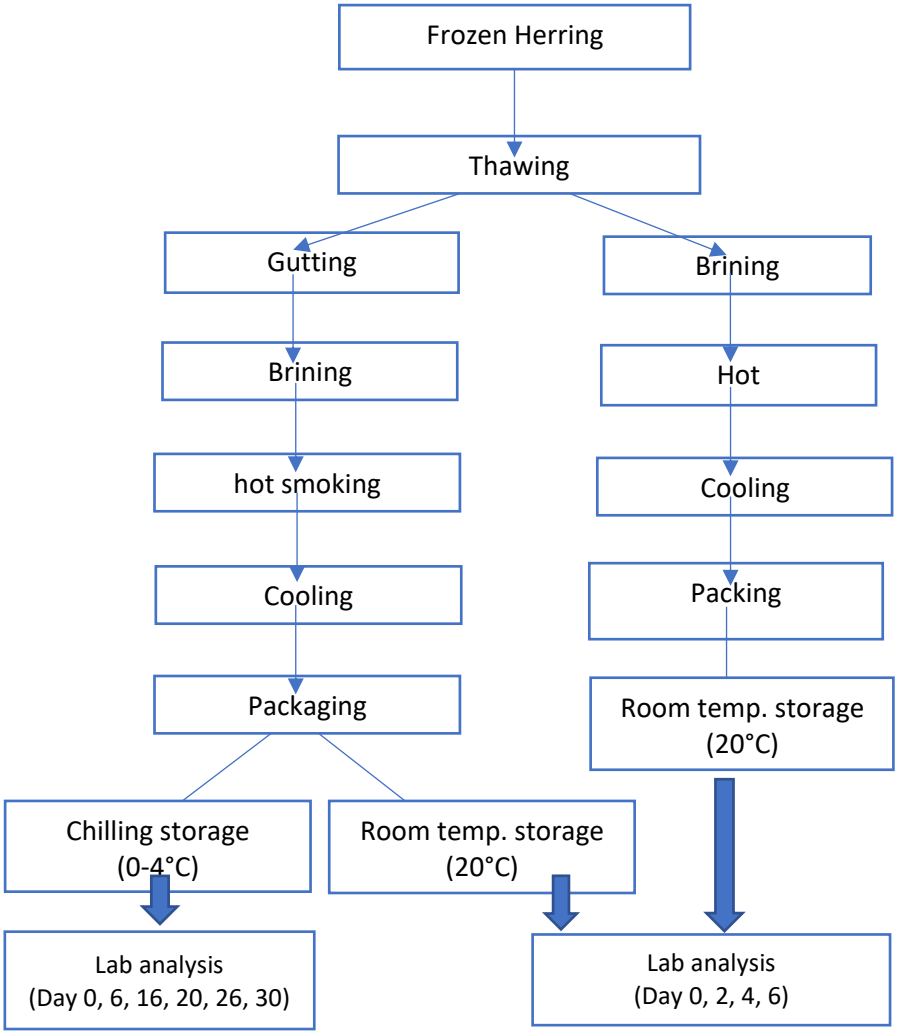

Figure 4. Flow chart of the smoking process of gutted and un-gutted Atlantic herring.

Physiochemical and microbial analysis were carried out on the sampled species in water content, free fatty acid (FFA), total volatile basic nitrogen (TVB-N), and total plate count (TPC) were measured in the raw material and after smoking. Free fatty acid (FFA) total plate count (TPC), water activity (aw) and total volatile basic nitrogen (TVBN) were done form (0-23) days and (0-6) days at room temperature (20C°) for both groups, and cold temperature (0-4) for gutted herring. All analysis was performed in duplicate.

3.4 Physicochemical analysis

During the pre-trial stage of the experiment, physicochemical analysis was carried out on both raw materials, water activity (aw) and salt content were measured.

3.4.1 Water activity

An aqualab water activity meter was used to measure water activity (aw) of the fresh and smoked fish. About 2 g of sample were put into the instrument and aw was measured automatically after starting the program, each sample were measure in duplicate.

3.4.2 Total Volatile Basic nitrogen (TVB-N)

The total volatile basic nitrogen (TVB-N) was determined according to the method described by Malley & Poumeyrol (1986). TVB-N was measure by steam distillation (stuer TVN distillatory, STRUERS, Copenhagen) and titration, after extraction 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. TVB-N content was expressed as mg/100g of fish sample. TVB-N was than calculated as,

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

3.4.3 Temperature

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

3.5 Proximate Analysis

3.5.1 Moisture content (Mc)

The moisture content was determined by weight loss of a sample during drying at 105 over night The results were expressed as percentage of wet weight. The sample glass was made from plex glass and were 19mm in inner diameter, 62mm in height, and 25mm in outer diameter. The samples were centrifuged at 1500 mp for five minutes in special samples glasses. Samples were prepared by chopping them in braum mixer for 10-20 seconds until homogenous. The sample glass was weighed empty and then 2g of sample were weighed into the glass. After centrifugation, the sample glass was weighed again without the loose bounded water.

$$\text{Moisture content (\%)} = \frac{\text{M2 -M3 X 100}}{\text{M2 -M1}}$$

3.5.2 Salt content

Salt content of products was determined according to (Costa, 2016). 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

$$\text{Percentage salt concentration} = \frac{salt\ content}{salt\ content + water\ content} \times 100$$

Where.

a =Volume of sulphuric acid (mL)

b= normality of sulphuric acid (%)

14=is the molecular weight of nitrogen.

3.6 Microbial Analysis

To determine and quantify the microbial activity on the analysis a microbiological method was assessed: Total Viable Counts (TVC) analysis was done on frozen, gutted in different storage.

3.7 Data analysis

Microsoft, Excel (Microsoft office 2016, c© corporation, Redmond, Wash USA) was used for calculating means and standard deviation. Value as presented as means and standard deviation (SD) for all multiple measurements in duplicate and to generate graphs.

4 RESULTS

4.1 Physicochemical analysis

4.1.1 Water Activity (a_w)

Water activity (a_w), 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 0.99 (Figure 5).

For samples stored at 20 °C, the (aw) was not stable in final product for both groups tested for the period between 0 and 4 days. Ungutted samples decreased and increased in day 6 in terms of temperature. The gutted samples also decreased in (aw) from day 0 to day 1, increased on day 4 and decreased slightly on day 6. For samples stored at 0-4^{0}C, the (aw) was not stable. It increased from day 6 to day 11, decreased on day 14 and increased on day 20. Generally, for the samples stored at the two different temperatures, (aw)decreased in time for samples stored at 20^{0}C and increased for samples stored at 0-4^{0}C.

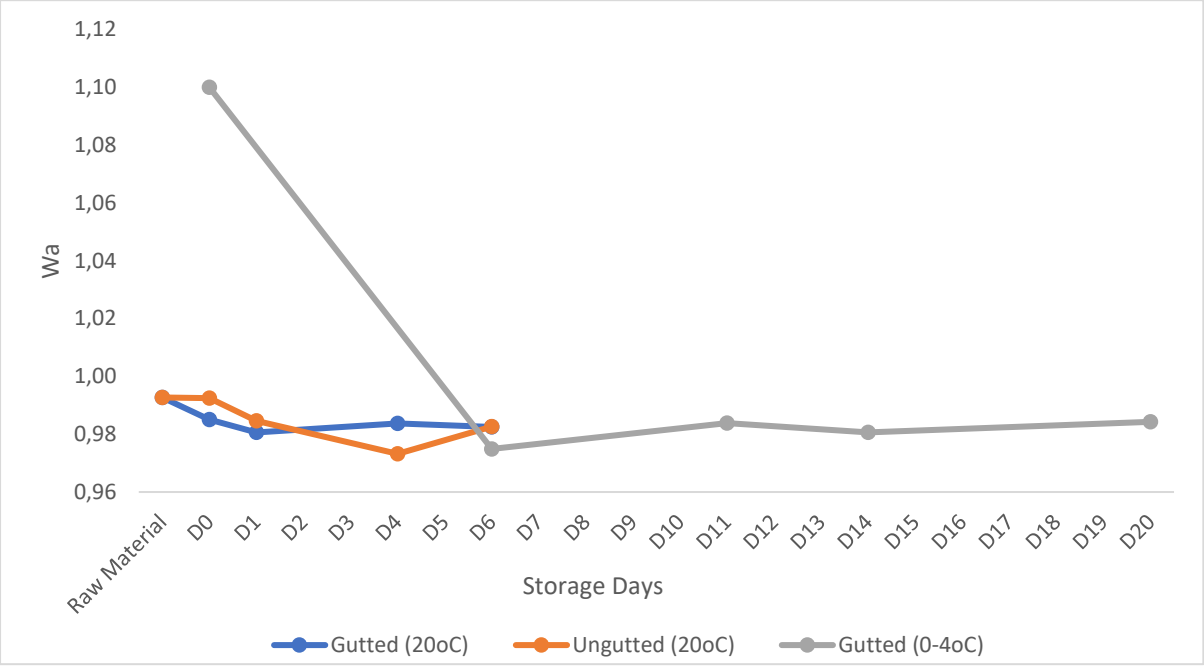

Figure 5. Water Activity in Gutted and Ungutted smoked Atlantic Herring stored at 200C and 0-40C.

4.1.2 TVB-N content

The TVB-N results (Figure 6) showed that increase in temperature increases the concentration of the TVB-N over time. The Gutted and Ungutted samples stored at 20°C both increased significantly from day 0 to day 6. However, the TVB-N concentration of Ungutted sample

(117.4mg N/100 g) at this temperature was higher than for Gutted samples (90.2 mg N/100 g) at the same temperature at the day 6. The day 0 values for the gutted and the ungutted samples were 14.2 mg N/100 g and 15.7 mg N/100 g, respectively. The TVB-N concentration for samples stored at 0-4 °C were, however, relatively stable ranging between 18.0 mg N/100 g at day 6 and 18.3 mg N/100 g at day 20.

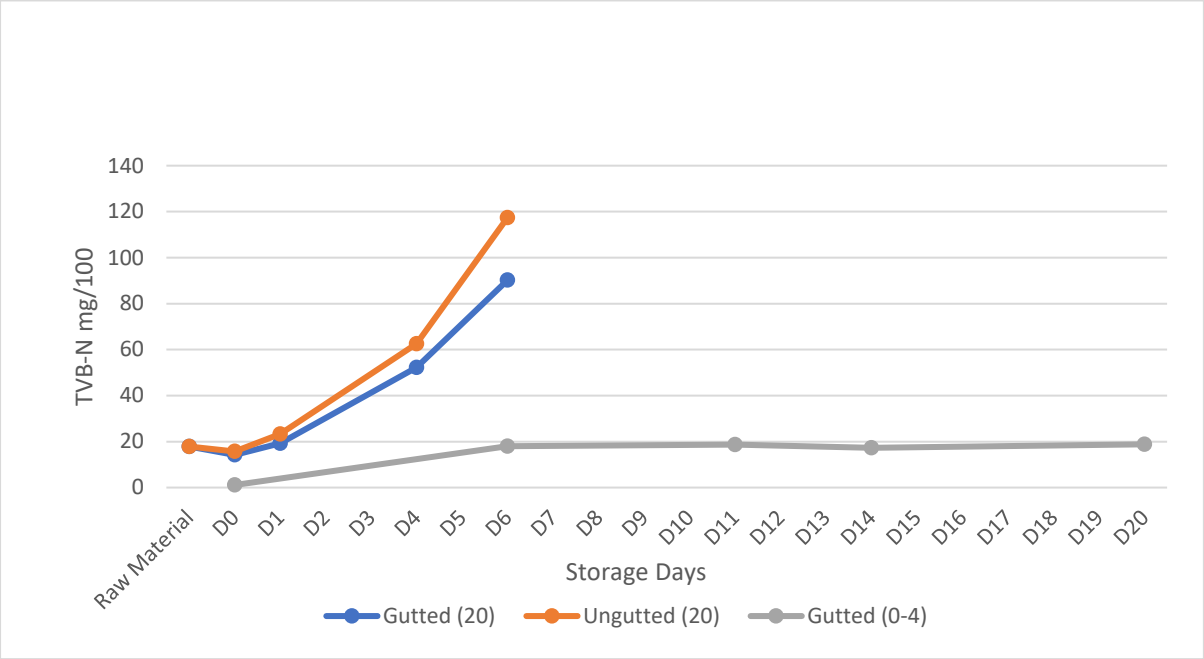

Figure 6. TVB-N in gutted and ungutted smoked Atlantic herring stored at 20 C° and 0-4C°

4.2 Proximate Analysis

4.2.1 Moisture content (Mc)

The moisture content for the treatments followed a different pattern during the storage period, as shown in Figure 7. In the beginning of the storage time, the Mc was similar between gutted samples at different temperatures (20 ˚C and 0-4 ˚C) but different for ungutted samples stored at 20 °C.

The Mc for the Gutted sample stored at 20 ˚C decreases with the storage time from 67.56% at day 0 to 61.97% at day 6. Similarly, the Mc for gutted sample stored at 0-4^{0}C, though relatively unstable, decreased from 67.53% at day 0 to 61.10% at day 20. The Ungutted samples, however, increased in Mc from 59.01% at day 0 to 65.35% at day 6.

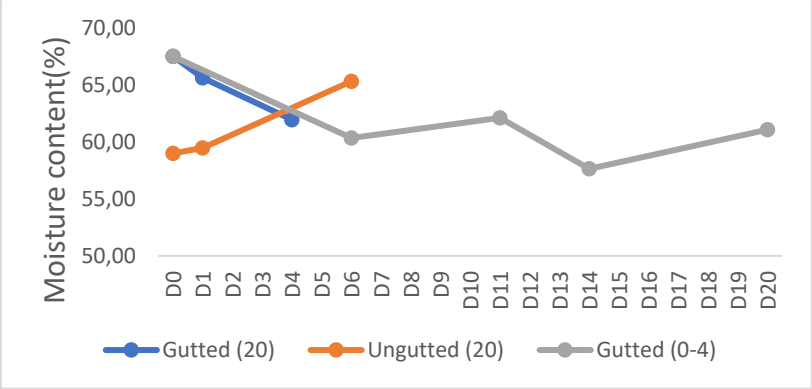

Figure 7. Moisture content in gutted and ungutted smoked Atlantic herring stored at 20°C and 0-4°C

4.2.2 Salt content

The changes in salt content of smoked Atlantic herring storage temperature and time for both smoked groups are presented in Figure 8. The smoked gutted and ungutted herring stored at 20 °C increased over time except for smoked gutted herring stored at 20°C; the smoked gutted and ungutted herring stored at 20°C initially increased in salt concentration and decreased after the first day of smoking. The ungutted herring stored at 20°C experience an increased in salt concentration from the initial 0.4% and stabilized from the fourth day of smoking to 1.2%. The gutted herring stored at 0-4 °C, however had slight increase in salt concentration.

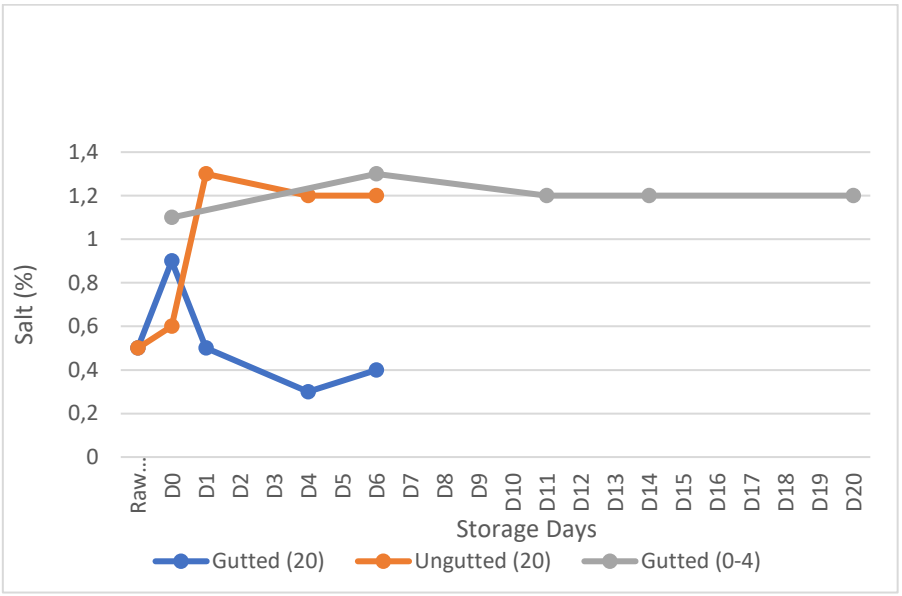

Figure 8. Salt content in gutted and ungutted smoked Atlantic herring stored at 20° C and 0-4°C

4.2.3 Lipid content

The lipid content of all the samples decreased with time, as illustrated in Figure 9. For the gutted and ungutted samples stored at 20°C, both samples decreased gradually from 0.08 and 0.07 at day 0 to 0.08 and 0.07 at day 6, respectively. The lipid content of samples stored at 0-4^{0}C also declined with time from 0.08 at day 6 to 0.058 at day 20.

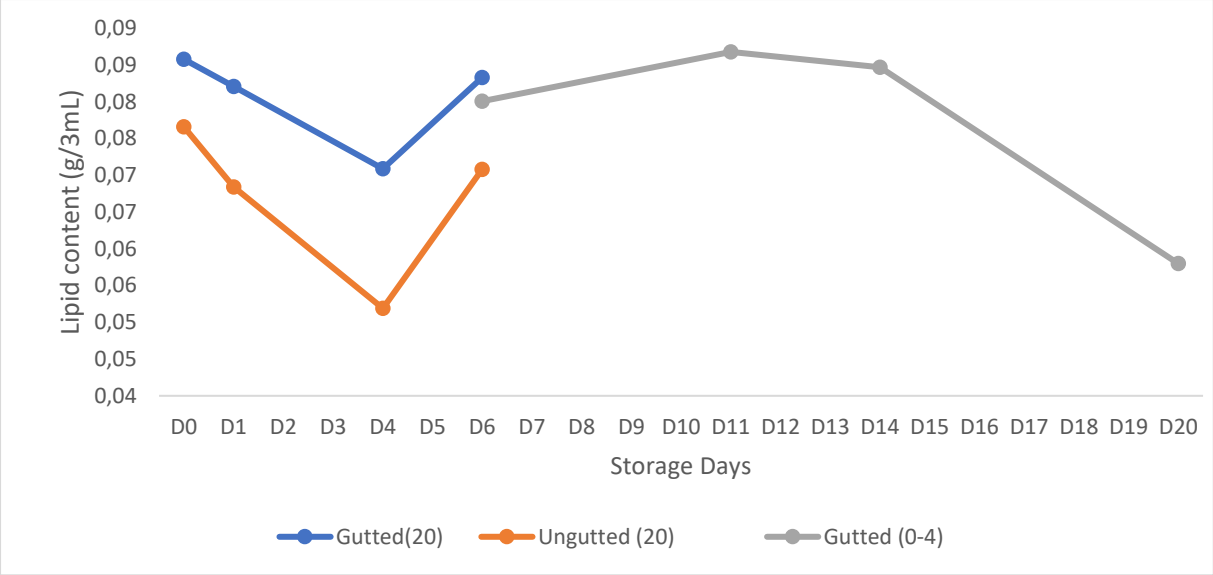

Figure 9. The Lipid content in gutted and ungutted smoked Atlantic herring stored at 20° C and 0-4C°

4.2.4 Free fatty acid content

The free fatty acid (FFA) content of the gutted and ungutted samples at different temperatures behaved differently with time, as shown in Figure 10. For the gutted samples stored at different temperatures (20^0C and 0-4^0C), the FFA content were relatively stable from day 0 to 6 and day 6 to 20, respectively. On the other hand, the FFA content of the ungutted samples increased significantly from 2.95 at day 1 to 24.69 at day 6.

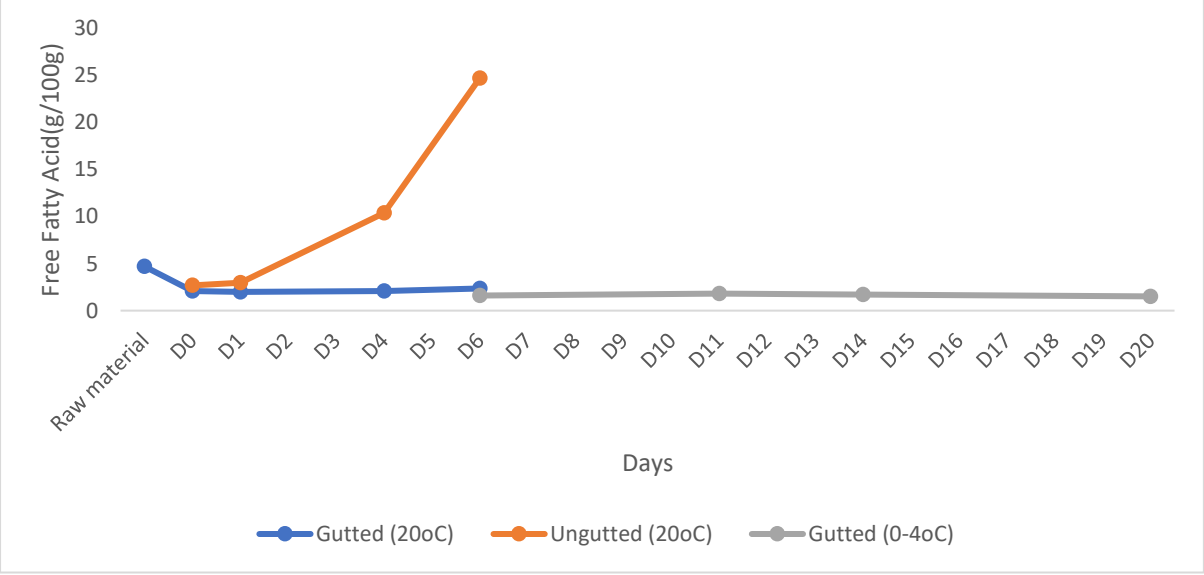

Figure 10. FFA in gutted and ungutted smoked Atlantic herring stored at 20 C° and 0-4°C

4.3 Microbial analysis

For both groups and storage temperature tested, the total Plate count bacterial (TVC) increased with time for ungutted smoked samples and decrease for gutted SAMPLE STORED at 0-4°C (Figure11).

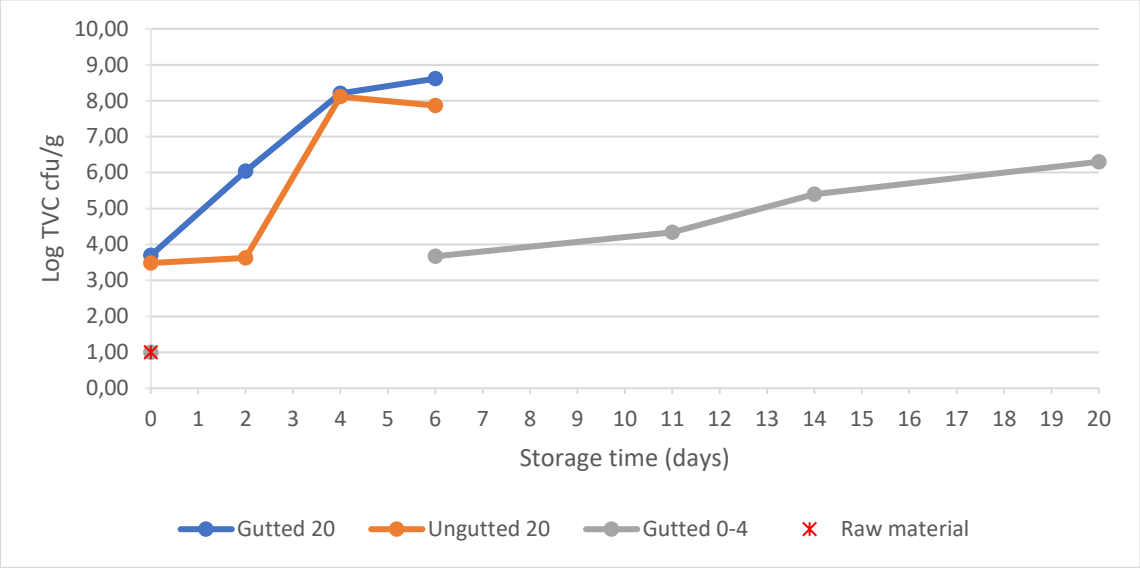

Figure 11. The FFA in gutted and ungutted smoked Atlantic herring stored at 20 C° and 0-4°C

During smoking (TVC) increased. There is not much difference between gutted and ungutted stored at 20°C. since they spoil so fast. After six days the TVC has not increase much in gutted samples at 0-4°C, The limits for TVC 10 is unacceptable but five is good.

DISCUSSIONS

4.4 Water activity (a_w)

Water activity (aw), 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 0.9927. Generally, for the samples stored at the two different temperatures, aw decreased in time for samples stored at 20^0C and increased for samples stored at 0-4^0C. High temperatures increased evaporation which causes water activity to decrease. Therefore, water activity increases with low temperature and decreases with high temperature as observed in the samples at different storage temperatures. This agrees with the results of Costa (2016) who observed that water activity decreased with increasing temperature. However, the water activity for all samples were still above 0.9 and so the samples are susceptible to microbial growth and mould contamination. To avoid microbial growth, dried fish products water activity should be maintained below the critical value of 0.60 (Perera & Rahman,1997). However, although yeast and moulds organisms are more tolerant at a reduced aw and can grow at value above 0.62, the pathogenic bacteria cannot grow aw below 0.85-.86 (Rahman & Labuza 2007).

4.5 TVB-N content

The total volatile basic nitrogen (TVB-N) is one of the most widely used measurement of seafood quality. TVB-N value is an important parameter to determine the freshness of fish products. TVB-N value is affected by species, catching region and season, age and sex of fish

(Gokoglue *etal*., 1998). According to Huss (1995), it is a general term which includes the trimethylamine, dimethylamine, ammonia and other volatile basic nitrogenous compounds associated with sea food spoilage.

The total volatile basic nitrogen or total 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-Garriod, 1997) and other nitrogen compounds that become volatile when made alkaline (Pedrosa-Menabrito & Regenstein, 1990). The results of analysis are given in nitrogen equivalent, Ammonia-N, DMA-N, TMA-N and TVB-N.

TVB-N is commonly used as an indicator of spoilage. Its increased is related to the activity of spoilage bacteria and endogenous enzyme s(Fernandez-Segovia *et,al.,* .2012; Ozyurt, Kuley, Ozkutuk & Ozogul, 2009). The increase in TVB-N content of Gutted and Ungutted samples stored at 20^0C from day 0 to day 6 showed declining quality of the fish. This agrees with the study of Rizo *et.al.* (2015) who observed that the smoke-flavoured sample gradually increased in TVB-N throughout the storage period. The TVB-N concentration for samples stored at 0-4^0C were however, relatively stable ranging between 18.0mg at day 6 and 18.3mg at day 20. The treatment to which fish is subjected is known to affect its TVB-N content and the Chilean fishing authority, as cited by Rizo *et.al.* (2015), proposed acceptability limit for smoked fish to be between 30 and 40 mg N/100g.

4.6 Moisture content (Mc)

The moisture content for the treatments followed different pattern during the storage period. In the beginning of the storage time the Mc was similar between gutted samples at different temperatures (20^0C and 0-4^0C) but different for ungutted samples at 20 °C temperature.

The Mc for the Gutted sample stored at 20^0C decreases with the storage time from 67.56% at day 0 to 61.97% at day 6. Similarly, the Mc for gutted sample stored at 0-4^0C, though relatively unstable, decreased from 67.53% at day 0 to 61.10% at day 20. The Ungutted samples, however, increased in Mc from 59.01% at day 0 to 65.35% at day 6. The increase in Mc of Ungutted samples may have be as a result of the viscera content which already has an amount of moisture. Daramola & Adeparusi (2007) noted that fish stored at room temperature with moisture content above 12% has more tendency to grow moulds after a few days of storage. The moisture content of the samples stored at 20^0C could therefore make the fish more liable for mould to attach. This process may be slower for those stored at 0-4^0C owing to effect of storage temperature.

4.7 Salt content

The smoked gutted stored at 20C° decreased while ungutted increased from day 0. The gutted herring stored at (0-4 C°), however only had slight increase in salt concentration. Costa *et al* (2016) also observed slightly increased in salt content in samples stored at 0°C. However, the variability observes in samples stored 20°C salt content of samples but has been reported in other studies as well. Reduction in water content over storage time has also been said to increased salt content (Costa, 2016).

4.8 Lipid content

The lipid content of all the samples decreased with time. For the gutted and ungutted samples stored at 20^0C room temperature, both samples decreased gradually from 0.086 and 0.077 at day 0 to 0.083 and 0.071 at day 6 respectively. The slight drop in lipid content at day 4 may however be due to environmental conditions. The lipid content of samples stored at 0-4^0C also declined with time from 0.080 at day 6 to 0.058 at day 20. Reduction in lipid content could be

attributed to oxidation of poly-unsaturated fatty acids (PUFA) present in fish tissues. The rate of fat deterioration was slow. Fish oil has been said to be more susceptible to spoilage than other oils due to their greater number of unsaturated fatty acids thus increase in degree of unsaturation would increase the tendency of rancidity (Daramola & Adeparusi, 2007). This process was however faster in the ungutted fish which may indicate a faster rate of deterioration. Cyprian *et al*. (2015) has shown that proper storage and packaging of fish products could stabilize lipid content of fish.

4.9 Free Fatty Acid content

Free fatty acid is a tertiary product of rancidity which increases with storage time. The free fatty acid (FFA) content of the gutted and ungutted samples at different temperatures behaved differently with time. For the gutted samples stored at different temperatures (20^0C and 0-4^0C), the FFA content were relatively stable from day 0 to 6 and day 6 to 20 respectively. The FFA level of gutted sample stored at 20^0C, though stable within from day 1-6, was a little higher than the level of fish stored at 0-4^0C. On the other hand, the FFA content of the ungutted samples increased significantly from 2.95 at day 1 to 24.69 at day 6. The gut content of the ungutted sample may have hasten the rancidity of the fish during the storage period. The study of (Daramola & Adeparusi, 2007) demonstrated that fish stored at room temperature increased in FFA with time.

4.10 Total Volatile Count

Total volatile count and remaining shelf life is used for microbiological evaluation of fresh, frozen and smoked fish (ICMSF, 1986). Recommended TVC limits of 5x10cuf/g for marginally acceptable samples. However, these TVC limits seem indeed inappropriate for several types of seafood. For example, cod fillets with TVC of 10 cfu/g can be excellent sensory quality and have remaining shelf life of 1-2 weeks at 0°C.

5 CONCLUSIONS AND RECOMMENDATIONS

Samples stored at low temperature were stable. Samples stored at 0-4°C never exceeded maximum limits for TVC and TVB-N allowed in fish products during 20days.

Ungutted samples had more FFA indicating more enzymatic activity. Based on the results it is not possible to determine the extended shelf life of the gutted product compare to ungutted.

These results show that the fish stored at 20°C spoils within two days, as the TVB-N reaches unacceptable limits.

The viscera are full of enzymes and bacteria which is known to have bad effects on quality, food safety and their shelf life. It is recommended to gut all fish if possible.

Based on the results of the study, the following recommendations are made.

- Fish should be gutted and preserved at low temperature, to increase the shelf life and in turn add value to the products
- It is important to continue the work in Liberia and measure quality parameters to ensure safety

- The competent Authority of National Fisheries and Aquaculture in Liberia needs to educate fishmongers and fishermen on the importance of gutting and cooling at low temperature fish.
- Adequate handlining is important and ensure that fresh fish is used.

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