Microbiological and Proximate Assessments of Cold-smoked *Gadus morhua* in Traditional Fish Smoking Centers in Ota Metropolis.

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ABSTRACT

This study evaluated the microbiological and proximate assessments of cold- smoked Atlantic cod, *Gadus morhua*. Fresh fish samples were purchased from cold room depots and were taken to five traditional fish smoking centers in Ota metropolis for cold smoking. The Atlantic cod were cold-smoked for a period of 1 hour and taken to the laboratory in baskets and stored on the shelf at room temperature (± 27^0C) for 4 weeks. Thereafter, the smoked fish samples were analyzed for Total plate count, *Staphylococcus* count, Coliform count, mold count, moisture content, crude protein, ash content, lipid content and salt content.

The microbiological analyses were carried out every three days while proximate analyses were weekly. From the analyses, microbiological parameters, moisture and ash contents of the smoked fish on storage increased while the percentage protein, lipid and salt contents of the fish sample decreased; from the second sampling day. TPC increased from 4.17 $\log_{10}$ cfu/g to 5.78 $\log_{10}$ cfu/g, Coliform from 5.03$\log_{10}$ cfu/g to 6.46 $\log_{10}$ cfu/g and Moisture contents was between 11.15% and 25.80. The lipid content ranged between 12.56% and 15.64% while the protein contents ranged between 9.48% and 41.54%.

(Keywords: *Gadus morhua,* smoking centers, Ota, cold smoking, microbiological, proximate assessments)

INTRODUCTION

Fish has been accounting for 40% of the protein intake in Nigeria for some time, reaching 6.5 to 7.5 kg per capital consumption (Olatunde, 1989). Nutritionally, fish proteins are highly digestible containing essential amino-acids. Fish is a valuable resource of high quality protein and in the case of oily fish; the fat is of considerable nutritional importance. The fat of fish is an excellent source of vitamins A and D (Norman and Joseph, 1996). The annual consumption of fish by the Nigerian population is projected to hit 5 million metric tonnes mark at the end of the century, however, only 350,000 metric tonnes is currently being produced (Olatunde, 1989).

Meats and fish are the most common smoked foods (McGee, 2004). In this modern world, there are several smoking methods such as the cold, hot, liquid and electrostatic. However, the two major methods of fish smoking are cold and hot smoking. In cold smoking, the proteins of raw fish turn edible as a result of their enzymatic ripening, while in hot smoking, this is accomplished due to their thermal denaturation. In both methods, the operations are similar; however, different parameters of time and temperature are used. The temperature in the kilns does not exceed 30^oC during cold-smoking, while in hot-smoking; it is not lower than 60^oC. Consequently, the products of these two smoking procedures differ in their sensory properties and in their shelf life. In both methods, various techniques of dressing, salting, smoke development and deposition, heating, cooling and packaging are used (Nikitin, 1965).

Cold smoking is being used as a flavor enhancer for items such as cod, beef, pork chops, salmon, scallops and steak. (Hui, 2001). Cold smoking process includes three stages: salting, drying and smoking itself that should be conducted at temperatures lower than 30ºC (Sigurgisladottir *et al.*, 2000). Unfortunately, cold-smoked Atlantic

cod may deteriorate very rapidly due to many factors. These include oxidative reactions, bacteria or mold, inappropriate processing/ preservation, fragmentation and insect infestation (Tobor, 1990). Also, smoked fish products generally have been reported to be a source of microbial hazards including *Listeria monocytogenes*, *Salmonella specie*, and *Clostridium butulinum*. In addition, *L. monocytogenes*, as been identified in several food borne outbreaks (Fleming *et al.*, 1985) and has been detected in a wide range of sea products (Dillion *et al.*, 1994). Similarly, the presence of indigenous pathogenic bacteria (e.g., *Clostridium botulinum*, *Listeria monocytogenes*, *Aeromonas hydrophila,* and *Vibrio* sp.) in fish has been reported. It is being suggested that the spoilage is probably caused by lactic acid bacteria, certain psychrotrophic *Enterobacteriaceae* and/or *Photobacterium phosphoreum*. Smoked fish, especially those with low water activity (A_w) show inhibited growth of bacteria. However, molds can grow on its surface (Ray,1996).

The traditionally processed cold-smoked fish products that dominate Nigerian markets are known not to be shelf-stable. Cold-smoked fish retains relatively high percentage of moisture, making it susceptible to microbial growth or contamination. This is largely due to the cold smoking method; whose duration is shorter compared to hot-smoked fish products. Meanwhile, one major way of contaminating these products is the poor handling technique often adopted by the retailers. However, no investigation had been made on the microbiological and nutritional safety of the widely consumed cold-smoked Atlantic cod, *Gadus morhua;* especially in Ota metropolis and its environs. This justifies the need for this investigative research work. Hence, the broad objectives are to assess the smoking procedures and post-mortem qualities of cold-smoked *Gadus morhua* from the selected traditional fish smoking centers.

MATERIALS AND METHOD

Fifty (50) pieces of frozen Atlantic cod, *Gadus morhua* (140–150g each) were used in the research work. Cartons (20kg each) were purchased from reputable cold fish storage across Ota in Ogun State, Nigeria. The pieces of fish in different batches were cleaned, salted and folded into round shape and taken to five randomly selected smoking centers; coded as: Winners (A), Iyana Iyesi (B), Oju-Ore I (C), Oju-Ore II (D) and Oju-Ore III (E). Samples of *Gadus morhua* were cold smoked for an hour, monitored (using thermometer) at temperature less than 30^0C.

Each piece of fish was held in place with a stick and the fishes were arranged on smoking racks; then, the racks were placed on drum–type smoking kilns (Plate 1). After cold-smoking, the smoked fish samples in each centre were cooled and stored in clean metal baskets (Plate 2).

The baskets were taken to the Microbiology laboratory of Bells University where microbiological and proximate analyses were carried out. The metal baskets were kept on the shelf in the laboratory at room temperature (± 27^0C) for 4 weeks. The microbiological analyses were carried out every three days while the proximate analyses were done weekly.

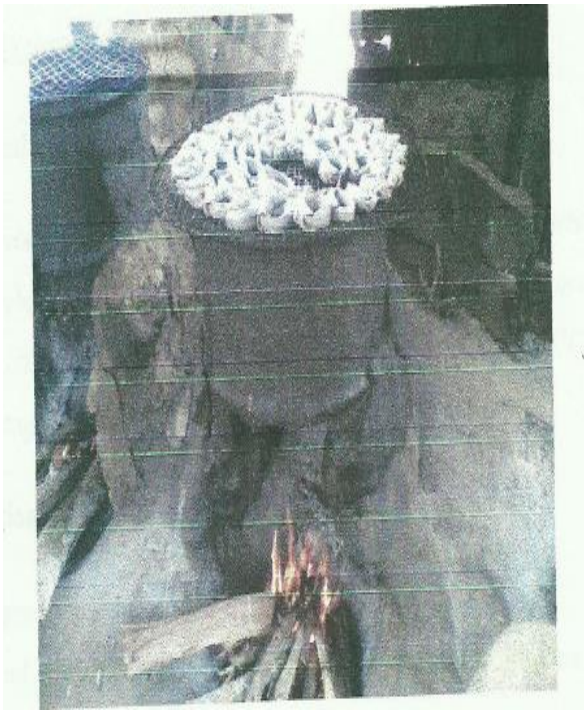

Plate 1: The Cold-smoking of *Gadus morhua* at 30^0C on the drum- type smoking kiln with a single smoking rack.

Plate 2: Cold-smoked *Gadus morhua* stored in the metal smoking basket.

Proximate Analyses

The proximate analyses of the fish samples were carried out on the freshly smoked fish (Day 0) and weekly for 4 weeks. The moisture, protein, ash, and lipid contents were determined using A.O.A.C (1990) methods.

Salt Content

Determination of the salt content of salted smoked fish samples was carried out using the modified Volhard method (Eyo, 2001).

Microbiological Analysis

The method of microbiological analysis as described by Lyne, 1976, was adopted for the samples of cold-smoked *Gadus morhua.* Microbiological parameters assessed were: Total Plate Count (TPC), *Staphylococcus aureus* count, Coliform count and Mold count.

Statistical Design and Analysis

Completely randomized design (CRD) was adopted in carrying out the experiment. One-way analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) was used on the raw values obtained. Statistical Package for Social Science (SPSS) 16.0 software was used in data analysis.

RESULT AND DISCUSSIONS

The values of the microbial loads of the *Gadus morhua* samples from the different smoking centers were significantly different ($P < 0.05$). Out of the five batches of smoked fish, Sample A recorded the highest microbial load. However, food including fish has been reported to have the possibility of being contaminated during processing and handling. Small numbers of these pathogenic organisms in fishery products is not a serious problem but food poisoning can occur if the product is handled carelessly during processing resulting in multiplication of the organisms (Lyne, 1976).

Microbiological Counts of the Cold-smoked *Gadus morhua*

Total Plate Count: The changing trend in the total plate count of the fish samples subjected to different smoking centers is presented in Table 1. TPC, a measure of the microbial load, varied among the five study samples. The loads were neither too high nor extremely low. Sample A recorded the least count of $4.17\log_{10}$ cfu/g during the initial analysis but gradually increased to $6.46\log_{10}$ cfu/g at day 6, $6.03\log_{10}$ cfu/g at day 12 and finally to 5.78 $\log_{10}$ cfu/g at day 24. Sample B recorded a very consistent increase in the TPC from day 0 with a value of 4.27 $\log_{10}$ cfu/g to day 24 with a value of 5.78 $\log_{10}$ cfu/g. Sample C still at a minimal level of 4.37 $\log_{10}$ cfu/g on day 3 but increased to 5.74 $\log_{10}$ cfu/g at day 24 of storage. Sample D recorded the lowest though inconsistent TPC values of the analysis, ranging from 4.25 $\log_{10}$ cfu/g at day 0 to 5.95 $\log_{10}$ cfu/g at day 6 and finally to 5.77 $\log_{10}$ cfu/g at day 24. Although Sample E increased inconsistently, it had a count of 4.25 $\log_{10}$ cfu/g at day 0, 4.45 $\log_{10}$ cfu/g at day 3 and 5.77 $\log_{10}$ cfu/g at day 24. Analysis of variance of the cold-smoked *Gadus morhua* samples showed a significant difference ($p<0.05$) between the samples.

***Staphylococcus* Count:** Also, variations were also observed in the count of Staphylococcus specie (Table 2). The first two sampling days

recorded very minimal count for all the samples; varying from 5.04 $\log_{10}$ cfu/g for sample A at day 0 to 7.15 $\log_{10}$ cfu/g at day 6. Sample B showed slight inconsistency from day 3 with a value of 6.48 $\log_{10}$ cfu/g to 7.35 $\log_{10}$ cfu/g at day 9. Sample C had its minimal count at day 0 with a value of 5.76 $\log_{10}$ cfu/g and highest count of 7.77 $\log_{10}$ cfu/g at the last sampling day. Sample D also recorded moderate number of cell count of 5.35 $\log_{10}$ cfu/g at day 0 and 7.19 $\log_{10}$ cfu/g at day 24. The increase in the staphylococci count agrees with Lyne (1976) report that Staphylococci can grow best in foods including fish, in which the competing organisms are present in low numbers.

Coliform Count: It was observed from Table 3 that the coliform count from the five analyzed samples was inconsistent throughout the 4-week storage period. Sample A recorded an increase in Coliform count from 5.0 $\log_{10}$ cfu/g of at day 1 to 6.08 $\log_{10}$ cfu/g at day 3. The count increased slightly at day 6 with a value of 6.44 $\log_{10}$ cfu/g and 6.46 $\log_{10}$ cfu/g at day 24. Sample B recorded a Coliform count of 5.08 $\log_{10}$ cfu/g at day 0 , 6.04 $\log_{10}$ cfu/g at day 3 and 6.45 $\log_{10}$ cfu/g at day 24. Sample C recorded its least value on day 0 with a value of 5.97 $\log_{10}$ cfu/g and increased to 6.35 $\log_{10}$ cfu/g at day 3 after which the count became inconsistent up to the final day of analyses. Sample D increased slightly from day 0, day 2 recorded a Coliform count of 5.97 $\log_{10}$ cfu/g, 6.03 $\log_{10}$ cfu/g at day 18 and 6.46 $\log_{10}$ cfu/g was recorded at day 24. Like other samples, Sample E recorded its least count of 5.48 $\log_{10}$ cfu/g at day 0 and 6.46 $\log_{10}$ cfu/g at day 24. The differences in the coliform count of the smoking centers were significant. Sample D had the least coliform count though it was inconsistent throughout the sampling days. Coliforms are indicators of contamination when they occur in small numbers. Their occurrence in large numbers indicates mishandling such as temperature abuse in product handling (Mossel, 1967).

Mold Count: The mold count was observed to be low during the first 2 days of analyses (Table 4). Sample A mold count was inconsistent, with 4.47 $\log_{10}$ cfu/g at day 0 to 5.44 $\log_{10}$ cfu/g at day 24. Sample B recorded a low value of 4.60 $\log_{10}$ cfu/g at day 0 and increased consistently to the last day of analyses. Sample C recorded its lowest mold count of 4.65$\log_{10}$ cfu/g at day 0 and highest count of 6.48 $\log_{10}$ cfu/g at day 15. Mold count for Sample D was inconsistent; it increased from 4.83 $\log_{10}$ cfu/g at day 0 to 5.46 $\log_{10}$ cfu/g at day 12 up to 5.60 $\log_{10}$ cfu/g at day 18. Sample E recorded a slightly increase in mold count from day 0 with a value of 4.46 $\log_{10}$ cfu/g up to the final analysis (day 24) with a value of 5.30 $\log_{10}$ cfu/g. Molds have reported to germinate and grow particularly rapidly on fish stored under damp, poorly ventilated conditions in climates with high ambient relative humidity and temperature (Doe and Olley, 1990). Molds on the smoked fish samples grew likewise weekly.

Proximate and Salt Analyses of the Cold-smoked Atlantic Cod

From the proximate analyses, it can generally be deduced that the moisture and ash contents of the cold-smoked *Gadus morhua* increased while its protein, lipid and salt contents decreased.

Moisture Content: From the study, it was observed that the moisture content of the fish samples increased from the second sampling week to the fourth sampling week (Figure 1). Sample A recorded its least moisture content of 12.90% at week 0, but gradually increased to 14.10% at week 1, 15.15% at week 2, 17.52% at week 3 and finally 22.25% at week 4. Sample B was analyzed to be 13.53% at week 0. This increased to 15.80% at week 1, 16.60% at week 2, 18.15% at week 3 and finally 25.80% at week 4. Sample C also recorded the least moisture content with a value a value of 11.30% at week 0, 12.40% at week 1, 13.60% at week 2, 17.42 at week 3 and finally increased to 22.95% at week 4. Sample D recorded a moisture content of 11.45% at week 0. This increased to11.70% at week 1, 11.95% at week 2, 18.90% at week 3 and finally to 24.90% at week 4. Like others, sample E had its least moisture content with a value of 11.15% at week 0, 12.95% at week 1, 15.35% at week 2, 17.80% at week 3, and finally, 23.75% at week 4.

Table 1: Total Plate Count of the *Gadus morhua* Cold-Smoked at Five Smoking Centers.

TRTS	DAY 0	DAY 3	DAY 6	DAY 9	DAY 12	DAY 15	DAY 18	DAY 21	DAY 24
A	4.17±0.03^{pqr}	4.36±0.02^{mno}	6.46±0.02^{qr}	5.87±0.04^{hij}	6.03±0.03^{kl}	6.10±0.01^{lm}	6.33±0.01^{pq}	5.96±0.04^{jk}	5.78±0.02^{fgh}
B	4.27±0.03^{nop}	4.46±0.02^{qr}	6.47±0.02r	5.96±0.01^{jk}	5.96±0.03^{jk}	5.95±0.01^{ijk}	6.28±0.02^{op}	5.96±0.02	5.66±0.02^{ef}
C	4.30±0.01^{op}	4.37±0.02^{pqr}	6.28±0.02^{op}	6.46±0.02^{qr}	5.20±0.14^{c}	6.48±0.01^{r}	5.76±0.02^{efgh}	6.15±0.02^{lmn}	5.52±0.02^{d}
D	4.25±0.21^{nop}	4.43±0.03^{qr}	6.26±0.03^{nop}	5.65±0.03^{ef}	4.86±0.01^{a}	5.74±0.02^{efg}	5.83±0.02^{ghi}	5.07±0.03^{b}	5.74±0.03^{efgh}
E	4.25±0.02^{nop}	4.45±0.04^{qr}	5.95±0.03^{ijk}	6.46±0.03^{qr}	4.88±0.02^{a}	5.64±0.03^{e}	5.68±0.02^{ef}	6.25±0.21^{nop}	5.77±0.04^{efgh}

Note: All samples with the same superscripts are not significantly different (p<0.05)
***(Mean ± Standard deviation)**
KEYS: TRTS= TREATMENTS, A= WINNERS, B= IYANA IYESI, C= OJU-ORE I, D= OJU-ORE II, E= OJU-ORE III

Table 2: Staphylococcus Count of *Gadus morhua* Cold-Smoked at Five Smoking Centers.

TRTS	DAY 0	DAY 3	DAY 6	DAY 9	DAY 12	DAY 15	DAY 18	DAY 21	DAY 24
A	5.04±0.21^{cd}	5.83±0.21^{ab}	7.15±0.02^{klm}	7.16±0.03^{klm}	7.16±0.02^{klm}	7.15±0.03^{klm}	7.16±0.03^{klm}	7.14±0.04^{klm}	7.16±0.01^{klm}
B	5.08±0.21^{cd}	6.48±0.02^{ghi}	7.17±0.04^{klm}	7.35±0.21^{m}	7.16±0.03^{klm}	7.19±0.01^{lm}	7.17±0.02^{klm}	7.17±0.14^{klm}	7.16±0.04^{klm}
C	5.76±0.03^{a}	6.97±0.03^{k}	7.16±0.01^{klm}	7.04±0.02^{kl}	7.17±0.01^{klm}	7.15±0.02^{klm}	7.04±0.04^{kl}	7.04±0.03^{kl}	7.77±0.28^{j}
D	5.04±0.03^{cd}	6.04±0.02^{cd}	7.16±0.03^{klm}	7.16±0.03^{klm}	6.26±0.03^{ef}	5.95±0.03^{bc}	5.96±0.01^{bc}	6.44±0.21^{fgh}	6.64±0.28^{ij}
E	5.35±0.01^{efg}	6.18±0.01^{de}	7.14±0.01^{klm}	7.16±0.02^{klm}	7.16±0.03^{klm}	6.60±0.28^{hij}	6.50±0.42^{ghi}	7.14±0.01^{klm}	7.19±0.02^{lm}

Note: All samples with the same superscripts are not significantly different (p<0.05)
***(Mean ± Standard deviation)**
KEYS: TRTS= TREATMENTS, A= WINNERS, B= IYANA IYESI, C= OJU-ORE I, D= OJU-ORE II, E= OJU-ORE III

Table 3: Coliform Count of *Gadus morhua* Cold-Smoked at Five Smoking Centers.

TRTS	DAY 0	DAY 3	DAY 6	DAY 9	DAY 12	DAY 15	DAY 18	DAY 21	DAY 24
A	5.03±0.02^{ghi}	6.08±0.02^{hi}	6.44±0.03^{lm}	5.95±0.03^{fgh}	6.03±0.03^{ghi}	5.54±0.03^{c}	5.94±0.03^{efg}	5.97±0.02^{gh}	6.46±0.02^{lm}
B	5.08±0.02^{hi}	6.04±0.02^{ghi}	6.05±0.03^{ghi}	5.55±0.21^{c}	6.03±0.03^{d}	5.03±0.03^{a}	5.84±0.01^{def}	5.96±0.01^{gh}	6.45±0.03^{lm}
C	5.97±0.01^{gh}	6.35±0.03^{kl}	6.25±0.02^{jk}	5.77±0.04^{d}	6.07±0.03^{hi}	5.97±0.02^{gh}	5.83±0.03^{de}	6.46±0.02^{lm}	6.30±0.14^{k}
D	5.14±0.01^{ij}	5.97±0.02^{gh}	6.30±0.14^{k}	5.63±0.02^{c}	5.74±0.02^{d}	5.80±0.14^{d}	6.03±0.03^{ghi}	6.48±0.01^{m}	6.46±0.02^{lm}
E	5.48±0.01^{m}	6.14±0.02^{ij}	6.03±0.02^{ghi}	6.46±0.03^{lm}	6.03±0.03^{ghi}	6.24±0.01^{b}	6.46±0.02^{lm}	6.33±0.02^{k}	6.46±0.01^{lm}

Note: All samples with the same superscripts are not significantly different (p<0.05)
***(Mean ± Standard deviation)**
KEYS: TRTS= TREATMENTS, A= WINNERS, B= IYANA IYESI, C= OJU-ORE I, D= OJU-ORE II, E= OJU-ORE III

Table 4: Mold Count of *Gadus morhua* Cold-Smoked at Five Smoking Centers.

TRTS	DAY 0	DAY 3	DAY 6	DAY 9	DAY 12	DAY 15	DAY 18	DAY 21	DAY 24
A	4.47±0.01^{s}	5.52±0.01^{hij}	6.33±0.03^{m}	5.18±0.01^{e}	4.77±0.02^{cd}	5.53±0.02^{hij}	5.30±0.14^{efg}	5.44±0.03^{ghi}	5.44±0.03^{ghi}
B	4.60±0.14^{ab}	5.55±0.21^{ij}	6.33±0.02^{m}	6.03±0.02^{l}	5.45±0.04^{ghi}	6.17±0.03^{l}	5.14±0.01^{e}	5.47±0.01^{ghi}	5.47±0.01^{ghi}
C	4.65±0.07^{bc}	6.08±0.01^{l}	5.68±0.02^{j}	6.03±0.01^{l}	5.54±0.03^{hij}	6.48±0.01^{l}	5.60±0.28^{ij}	5.53±0.03^{hij}	5.53±0.03^{hij}
D	4.83±0.03^{d}	5.61±0.01^{ij}	5.55±0.03^{ij}	5.47±0.03^{ghi}	5.46±0.03^{ghi}	5.35±0.01^{fg}	5.60±0.01^{ij}	5.22±0.01^{ef}	5.22±0.01^{ef}
E	4.46±0.02^{m}	5.47±0.02^{m}	5.87±0.01^{k}	5.37±0.01^{fgh}	5.55±0.04^{ij}	5.67±0.03^{j}	5.83±0.02^{k}	5.30±0.14^{efg}	5.30±0.14^{efg}

Note: All samples with the same superscripts are not significantly different (p<0.05)
***(Mean ± Standard deviation)**
KEYS: TRTS= TREATMENTS, A= WINNERS, B= IYANA IYESI, C= OJU-ORE I, D= OJU-ORE II, E= OJU-ORE III

The moisture content of the five samples increased during the storage period. The highest analyzed moisture content was 25.80% recorded in Sample C while Sample E recorded the least percentage moisture content of 11.15%. The cold-smoked fish samples have considerable percentage of moisture, since they were cold-smoked for 1 hour (60 minutes) and this is therefore expected to affect the shelf stability of the five samples. Meanwhile, Jallow (1995) who stated that increase in moisture content could be attributed to the difference in moisture of the smoked fish relative to the surroundings. Also a standard moisture content of 12% was reported by FAO/APHCA (1989) as the level beyond which fish products begin to grow mold after a few days. Results from previous studies have shown that smoke-dry process which took about 10- 18 hours and sometimes 3- 4 days yield fish of 10 -15% moisture content; fish with moisture of about 0% when stored properly could have a shelf life of 3-9 months (Jallow, 1995).

Meanwhile, the *Gadus morhua* was cold smoked in line with the standard procedures with reference to FDA (2001).

Crude protein: The protein contents of the smoked fish samples decreased from week 0 to week 4 (Figure 2). Sample A recorded its highest value of 36.69% at week 0, but it decreased to 26.88% at week 1, 26.25% at week 2, 24.12% at week 3 and finally decreased to 20.56% at week 4. Sample B was analyzed to be 33.36% at week 0; this decreased to 24.54% at week 1, 20.19% at week 2, 18.30% at week 3 and finally 17.79% at week 4. Sample C also recorded the highest protein content with a value of 40.95% at week 0, 31.43% at week 1, 23.14% at week2, 17.61% at week 3 and finally reduced to 13.01% at week 4. Sample D recorded a protein content of 41.54% at week 0; this decreased to 31.56% at week 1, 29.45% at week 2, 19.03% at week 3 and finally to 10.31% at week 4. Sample E had its highest protein content at week 0 with a value of 36.54%, it decreased to 22.42% at week 1, 15.24% at week 2, 10.94% at week 3 and finally to 9.48% at week 4. Therefore, the percentage crude protein reduced over the period of storage. This showed a degradation of the crude protein in the fish species gradually to more volatile products such as Total Volatile Bases (TVB), Hydrogen sulphide and Ammonia (Eyo, 2001). According to Stroud (1988), smoking process has been found to affect the nutritional value of fish, mainly by reducing the biological availability of proteins. Similarly, Emokpae (1980), observed changes in protein and lipid content during storage may have been due to leaching out of some extractable soluble protein fraction and hydrolysis of some of the lipid fractions.

Lipid content: Sample A recorded its highest value of 15.64% at week 0, but gradually decreased to 15.52% at week 1, 15.37% at week2, 15.10% at week 3 and finally increased to 14.33% at week 4 (Figure 3). Sample B was analyzed to be 15.44% at week 0; this decreased to 15.31% at week 1, 15.28% at week 2, 15.16% at week 3 and finally 15.08% at week 4. Sample C also recorded the highest lipid content with a value of 13.64% at week 0, 13.40% at week 1, 13.39% at week 2, 13.19% at week 3 and finally reduced to 13.04% at week 4. Sample D recorded a lipid content of 13.12% at week 0 and this decreased to13.05% at week 1, 12.95% at week 2, 12.72% at week 3 and finally to 12.56% at week 4. Sample E had its highest lipid content at week 0 with a value of 14.82%, decreased to 14.63% at week 1, 14.40% at week 2, 14.23% at week 3 and finally to 14.09% at week 4. However, fish oil has been found to be more liable to spoilage than other oils due to their greater number of unsaturated fatty acids as shown by the lower specification number and higher iodine value (Eyo, 2001). The greater the decree of unsaturation, the greater would be the tendency for fat oxidation (rancidity). Meanwhile, Balogun (1992) stated that there might be high risks of rancidity during prolonged storage conditions due to fatty nature of the fish. Also, reduction in the lipid content could be attributed to oxidation of poly- unsaturated fatty acids (PUFA) contained in the fish tissue to products such as peroxides, aldehydes, ketones and free fatty acids. The rate of fat deterioration was gradual.

Ash Content: From the study, it was observed that the Ash content of the *Gadus morhua* samples increased from the second sampling week to the fourth sampling week (Figure 4). It was noteworthy that Sample A had the highest values of ash content while Sample B had at the least ash content. Sample A recorded its least value of 8.78% at week 0, but it gradually increased to 14.68% at week 1, 17.82% at week 2, 19.30% at week 3 and finally got to 20.23% at week 4. The ash content of Sample B was analyzed to be 9.36% at week 0; this increased to 10.54% at week 1, 10.59% at week 2, 11.02% at week 3 and finally 11.16% at week 4. Sample C also recorded the least ash content with a value a value of 10.58% at week 0, 12.20% at week 1, 13.34% at week 2, 14.36% at week 3 and finally increased to 15.04% at week 4. Sample D recorded Ash content of 8.9% at week 0; this increased to 9.95% at week 1, 10.18% at week 2, 12.30% at week 3 and finally to 14.42% at week 4. Samples E had its least ash content at week 0 with a value of 7.15%, it increased to 7.63% at week 1, 8 .45% at week 2, 10.91% at week3 and finally to 19.05% at week 4. From this study, there was an increase in the ash contents of the smoked fish sample. This agreed with Daramola *et. al.,* (2007), who reported an increase in ash content of the smoked *Clarias gariepinus* on storage.

Salt content: Sample A recorded the highest value of 1.84g at week 0, decreased to 1.04g at

week 1, 0.7g at week 2 and 0.35g at week 4 (Figure 5). Sample B was analyzed to be 1.83g at week 0; this decreased to 1.53g at week 1, 0.95g at week 2, 0.8g at week 3 and 0.4g at week4. Sample C also recorded its highest salt content at week 0 with a value of 1.61g, decreased to 1.51g at week 1, 1.20g at week 2, 0.95g at week 3 and finally to 0.30g at week 4. Sample D recorded a salt content of 1.42g at week 0, decreased to 1.15g at week 1, 1.04 at week 2, 1.0g at week 3 and 0.85g at week 4. Sample E contained the highest salt content. Like others, sample E had its highest salt content with a value of 2.0g at week 0, 1.87g at week 1, 1.38g at week 2, 1.0g at week 3 and finally to 0.89g at week 4. Brining and prolonged smoking has been found useful in increasing the storage life of cold smoked fish by retarding the development of mold growth without increasing the development of lipid oxidation (Sadiku, 1991).

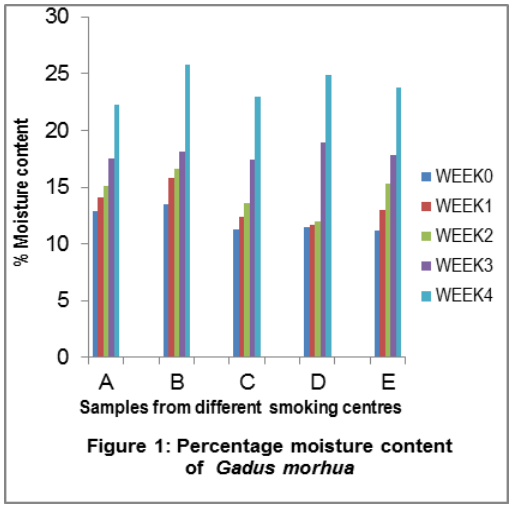

Figure 1: Percentage moisture content of *Gadus morhua*

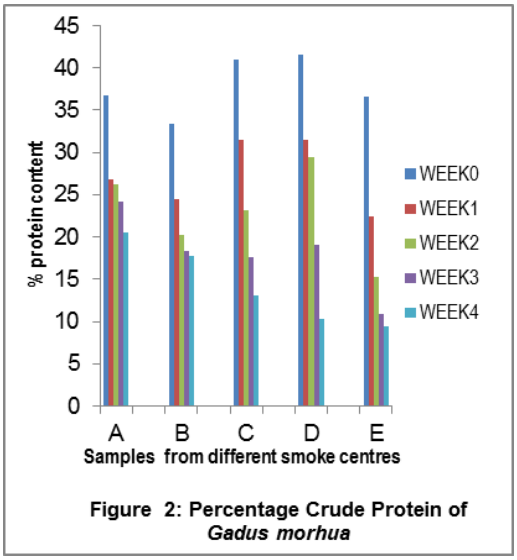

Figure 2: Percentage Crude Protein of *Gadus morhua*

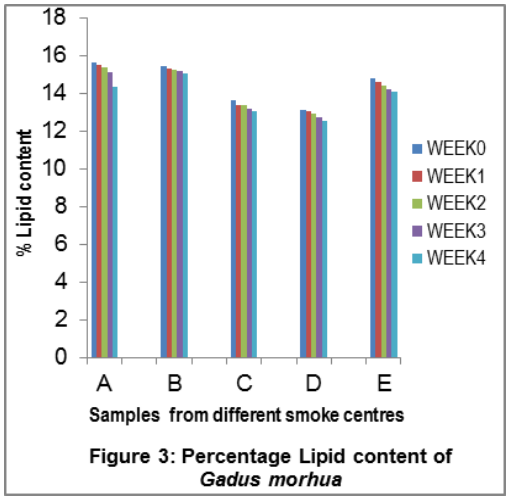

Figure 3: Percentage Lipid content of *Gadus morhua*

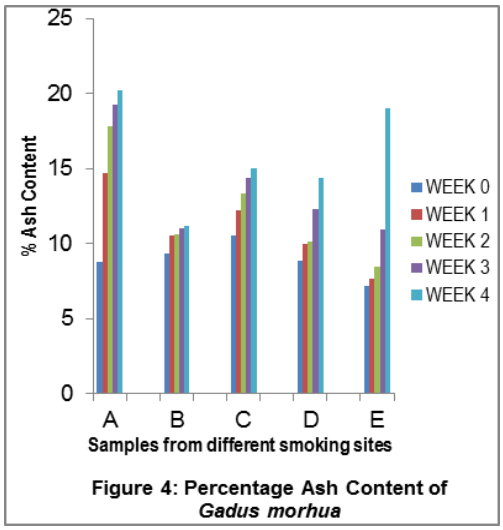

Figure 4: Percentage Ash Content of *Gadus morhua*

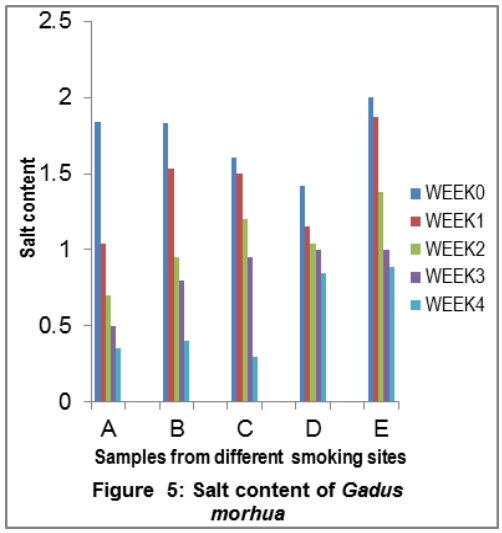

Figure 5: Salt content of *Gadus morhua*

CONCLUSION

The increase in the microbial loads, moisture and ash contents as well as the decrease in lipid, protein and salt contents of the cold smoked *Gadus morhua* samples are factors which indicates the proliferation of spoilage organisms in the fish during storage. This automatically reduced the shelf life of the fish. Conversely, since cold–smoked *Gadus morhua* is widely acceptable by a good Nigerian populace and commonly available in Nigerian markets and does not have a long shelf life (less than 30 days) when stored under ambient temperature, it is better if they are supported with refrigeration storage since most micro-organisms are relatively inactive at such low temperatures.

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