Microbial contamination and proximate carcass of Cod (*Gadus morhua)* obtained from local markets of Imo State

Abstract

The microbial and proximate quality of Cod *Gadus morhua* obtained from cold room and open markets of three Local Government Areas of Imo state, Nigeria was carried using standard mehods. Microbial analysis revealed that the total viable count for the fish species sampled from cold room ranged from 5.3 x 10^4 – 9.5 x 10^4 cfu/g while that of the open market samples ranged from 8.0 x 10^4cfu/g to 2.8 x 10^5cfu/g. Total Fungal Count (TFC) had increasing microbial values in the open markets than in the cold rooms and ranged from 1.0 x 10^3cfu/g to 7.2 x 10^3cfu/g for cold room samples whereas a range of 1.0 x 10^5cfu/g to 3.4 x 10^5cfu/g was obtained for open markets. Generally, ten bacterial species and nine fungal species were isolated and identified during characterization from the cold room and open market samples, bacteria being *Micrococcus spp., Stphylococcus aureus, Bacillus cereus, Bacillus subtilis, Streptococcus spp., Escherichia coli, Klebsiella spp., Proteus spp., Pseudomonas aeruginosa, Salmonella spp.* while fungi include *Geotrichum spp., Candida spp., Rhizopus stolonifera, Mucor spp., Rhodotorula spp.*, and four species of *Aspergillus*. Result for proximate composition shows that crude protein cold room value was 17.24 ±0.52 but significantly increased in the open market samples (19.44±0.94) just as there was significant difference in crude fiber values of cold room (6.98±0.54) and open markets (ranged between 3.04±0.81 and 4.39±1.30). On the other hand, an insignificant increase in values of moisture content, NFE, ash content and ether extract but with values reducing from cold room (1.30±0.62 and 1.06±0.50) to open market (0.12±0.70 and 1.00±1.00) as their minimum value for the later. It is suggested that fish be appropriately handled in ice boxes during transport and storage before sale especially in the absence of refrigerators so as to reduce microbial contamination and maintain its original proximate value.

Key words: *Gadus morhua*, microbial contamination, proximate composition, cold-room, open-market, Imo state

Introduction

Fish, a commodity of high importance, is highly perishable and unless correctly treated after harvesting, can soon become unfit to eat and possibly dangerous to health through microbial growth, chemical change and breakdown of endogenous enzymes (FAO, 2014). Fish is one of the food commodities that quickly change form by spoilage if not appropriately exposed to a form of processing (Nwazuo *et al.,* 2016). Despite the great importance attributed to fish consumption, it is often overlooked when sustainable and safe food are discussed. Previous studies indicates that the importation of frozen fish plays a key role in bridging the gap between the demand for and supply of fish from domestic sources (Teslim, 2010). This demand for high quality, safe and healthy fish is now on a global increase (Huss, Ababouch and Gram, 2003 & Sen, 2005) yet, low income earning countries like Nigeria preferably export high market value products and import low market value products for domestic consumption as previously stated by Asche *et al.*, (2015).

Gadus morhua (cod) is benthopelagic lean fish, distributed in the North Atlantic and in the Arctic and abundant in cold and temperate shelf areas (FAO, 2018). Cod is one of the top imported fishes in Nigeria with high demand necessitating its importation in its various sizes and variously preserved forms especially, frozen form. Global capture production of cod in 2020 exceedes 1000kilo tonnes which is nothing to be compared to aquaculture production rated at around 662kilot tonnes of the same year (FAO 2022). External uncontrolled factors are likely to affect bacterial composition in the wild than in the controlled products. In addition, the removed function of the fish immune system at death allows for bacteria and

enzymes to penetrate the walls of the tissues leading to spoilage of the tissue. This action of bacteria is further enhanced by the exposure of fish to unfavourable conditions during storage and handling (Sallam, 2007).

Fish constitute a major delicacy during all occasions in the south eastern part of Nigeria especially the frozen form as reported by Agom, *et al.,* (2012) who noted that some fish like croaker and mackerel has its most supply during the festive season and off the market or scarce during non-festive seasons. With the fish high rate of consumption and the need to avert consequential effects of consuming non-safe fish of low nutritional value, this paper indirectly instigates the need for improved policies on import and preservation methods, buttress the need for diversification into local production and consumption of fresh live fish and inform the government on the need to put more effort into ensuring that fish sold within Imo state and Nigeria as a whole are safety risk free. This is because there is a time and temperature relationship which tells on the final quality of fish as microbes acclimatize better in lower temperatures of higher than 30^0c (Johnston *et al*.,1994 and Castro *et al*., 2006). This paper therefore exposes the microbial composition and carcass quality of *Gadus morhua* (cod) which is a commonly consumed frozen fish in Imo state.

Materials and methods

Study Area and Experimental Design

The study was carried out in Imo state located in South Eastern Nigeria, constituting of twenty seven local government areas and subdivided into three zones (Imo west- Orlu zone, Imo north- Okigwe zone and Imo East- Owerri zone). Most persons in this region are Christians with almost no phobia for fish. A total of eighty (80) samples were used for the experiment constituting eight samples each of the *Gadus morhua* (cod) collected from a cold room (a major distributor) and three local fish open markets of each of the three representing local government areas of the zones in Imo state- Orlu zone, Owerri zone and Okigwe zone. Representing Orlu zone were three local markets selected from Ohaji Egbema LGA, Owerri Zone was represented by local markets from Mbaitoli LGA while Okigwe zone was represented by local markets from Isiala Mbano LGA.

For experimental purposes, fish samples were codded based on place of collection (Table 1). This served to keep information discrete and remove subjective judgement of samples.

Table 1; Code allocation for the place of fish sample collection

Local Government Areas	**Codes**			
	Cold room	**Open markets**		
		I	**II**	**III**
Owerri Municipal	**AC**			
Ohaji		**IO_1**	**IO_2**	**IO_3**
Isiala Mbano		**AO_1**	**AO_2**	**AO_3**
Mbaitolu		**AnO_1**	**AnO_2**	**AnO_3**

Where AC --- Cold room

$IO_{1,2,3}$ – Open market I, II, III in Ohaji

$AO_{1,2,3}$ --- Open market I, II, III in Isiala Mbano

$AnO_{1,2,3}$ --- Open market I, II, III in Mbaitolu

Fish Identification and Transportation

The fishes were identified with the aid of standard fish identification keys by Reed *et al.,* (1967), Loveque *et al.,* (1991) and FAO (1990) Field identification Guide to the commercial marine resources of the Gulf of Guinea. The length, weight and temperature of the fish

samples were recorded and the fish carefully put in well labelled sterile polyethene bags, stocked inside iced boxes and quickly transported to the laboratory for processing and analysis. Temperature close to that of the cold rooms was maintained in the iced boxes using ice blocks.

Microbial Analysis

Microbes were isolated from the skin, tissue, gills and intestines of the sample fishes. Media used for inoculation included Nutrient agar (all-purpose bacteriological media) at 2.8g/100ml, Macconkey agar (for enumeration of coliforms) at 4.9g/100ml, Saboraud Dextrose agar (for enumeration of fungi) at 6.5g/100mls, Salmonella Shigella agar (for enumeration of Salmonella and Shigella) 6.4g/100mls, Manitol Salt agar (for Staphylococcus spp.) at 11.1g/100mls and Centrimide agar (for enumeration of Pseudomonas sp.) at 4.8g/100mls. Media were poured aseptically, samples serially diluted adapting 10-fold serial dilution and samples inoculated by spread plate method. Bacteriological plates were incubated at 37^0C for 24 hours while mycological plates incubated at 27^0C (room temperature) for 48 hours. To identify species of microbes, cultural characteristics such as shape, colour, size and consistency was carried out where isolates were gram stained and subjected to appropriate biochemical tests which included Oxidase, Motility, Indole test, Spore stain, Catalase, Citrate, Coagulase and Sugar utilization tests (Slaby *et al* 1981).

Proximate Composition of Carcass Quality

Samples of each test fish carcass was analysed chemically in accordance with the Official Analytical Chemists (AOAC, 2005) for such parameters as crude protein, moisture and dry matter, ash, crude fibre, crude fat (or lipid), carbohydrate, caloric value and Nitrogen free extract (NFE) to ensure that the fish meat meet the basic nutritional requirements of consumers. This analysis was carried out at the Food Science and Technology laboratory of the Federal University of Technology Owerri and subsequently at National Root Crops Research Institute Umudike, Abia state. The routine semi micro-kjeldahl procedure was used to determine crude protein, whereas moisture content was determined with a modified version of the AOAC 967-08 (AOAC 2005). The NFE was determined by difference. This was done by subtracting the sum of (% moisture + % crude protein + % ether extract + % crude fiber + % ash) from 100 i.e. 100 - (%M + % CP +% EE +% CF + %Ash).

Comparative Statistical Analysis

The experiment was designed as a completely randomized experiment (CRD). Consequently the resulting data compared with one way analysis of variance (ANOVA) as described by Steel and Torrie (1996) and Njoku et al., (2014). The observed significant difference in mean values was separated using the LSD multiple range test. The analysis employed the computer statistical package for Social Sciences (SPSS) version 20 window 7.

Results and discussion

Fish, in the form of *Gadus morhua*, a necessary commodity that bridges the gap of protein supply and hunger alleviation is readily available in its frozen form to meet almost all occasions in Imo state, showed varying levels of increasing microbial content and load as fish moved to the open markets from the cold rooms.

The result of the microbial and fungal loads/occurrence on the fish species from cold room and open markets together with the bacterial and fungal isolates are presented in the tables below;

Table 2.1; Length, weight and temperature data of experimental *Gadus morhua*

LGA	Place of collection	Mean length (cm)	Mean weight (kg)	Initial temp	Final temp
Owerri Municipal	Cold room	40.3	3.91	-22	-1

OHAJI	Open market	39.6	4.00	13	19
ISIALA MBANO	Open market	40.4	4.02	-6	-1
MBAITOLI	Open market	40.0	3.99	3	3.2

Table 2.2a; Mean microbial load of cold room frozen *Gadus morhua* samples collected from Owerri market

Site of collection	TVC (Cfu/g)	TCC (Cfu/g)	TSC (Cfu/g)	TPC (Cfu/g)	TSSC (Cfu/g)	TFC (Cfu/g)
Skin	6.7×10^4	3.7×10^4	1.3×10^4	4.0×10^2	-	7.2×10^3
Tissue	9.5×10^4	6.0×10^3	6.8×10^3	6.0×10^2	-	1.0×10^3
Gill	8.5×10^4	-	4.0×10^3	-	-	8.2×10^3
Intestine	5.3×10^4	2.0×10^4	1.1×10^3	-	4.0×10^2	2.2×10^3

Table 2.2b; Mean microbial load of open market frozen fish samples collected from Ohaji LGA markets

Site of collection	TVC (Cfu/g)	TCC (Cfu/g)	TSC (Cfu/g)	TPC (Cfu/g)	TSSC (Cfu/g)	TFC (Cfu/g)
Skin	1.5×10^5	8.6×10^4	6.2×10^5	3.1×10^3	5.6×10^4	3.4×10^5
Tissue	1.4×10^5	2.5×10^4	4.0×10^5	2.8×10^4	9.5×10^4	2.0×10^5
Gill	2.8×10^5	9.4×10^3	1.8×10^5	3.8×10^4	5.7×10^5	2.6×10^5
Intestine	1.2×10^5	-	2.8×10^6	-	-	1.8×10^5

Table 2.2c; Mean microbial load of open market frozen fish samples collected from Isiala Mbano LGA markets

Site of collection	TVC (Cfu/g)	TCC (Cfu/g)	TSC (Cfu/g)	TPC (Cfu/g)	TSSC (Cfu/g)	TFC (Cfu/g)
Skin	9.0×10^4	8.4×10^4	2.9×10^5	2.8×10^3	4.8×10^4	3.5×10^5
Tissue	1.0×10^5	1.5×10^4	2.0×10^5	1.7×10^4	6.0×10^4	1.6×10^5
Gill	1.8×10^5	1.4×10^4	1.3×10^5	2.5×10^4	4.4×10^5	1.8×10^5
Intestine	8.0×10^4	-	2.0×10^6	-	-	1.0×10^5

Table 2.2d; Mean microbial load of open market frozen fish samples collected from Mbaitoli LGA markets

Site of collection	TVC (Cfu/g)	TCC (Cfu/g)	TSC (Cfu/g)	TPC (Cfu/g)	TSSC (Cfu/g)	TFC (Cfu/g)
Skin	1.2×10^5	1.3×10^5	4.4×10^5	2.4×10^4	4.6×10^4	3.0×10^5
Tissue	1.2×10^5	2.0×10^4	3.0×10^5	2.0×10^4	8.5×10^4	1.8×10^5
Gill	2.0×10^5	1.9×10^4	2.0×10^5	2.7×10^4	4.9×10^5	1.0×10^5
Intestine	1.0×10^5	-	2.4×10^6	-	-	1.4×10^5

Where TVC- total viable count, TCC- total coliform count, TSC- total Staphylococcal count, TPC- total pseudomonas count, TSSC- total Salmonela/Shigella count, TFC- Total fungal count and Cfu/g- colony forming unit per gram

The total viable count for the fish species sampled from cold room (table 2a) ranged from $5.3 \times 10^4 - 9.5 \times 10^4$ cfu/g with the most overall viable count as obvious in the tissue and the least from the intestine. TVC of the open market samples however ranged from 8.0×10^4cfu/g to 2.8×10^5cfu/g with samples obtained from Ohaji LGA open markets showing the most viable count as samples from the gills revealed the most TVC. Cold room samples had Total

coliform count (TCC) that ranged from not being detected in the gills to 3.7 x 10^4cfu/g obtained from the skin. On the other hand, open market samples showed varying TCC ranges from being totally absent (in intestinal samples) to as high as 8.6 x 10^4cfu/g, 8.4 x 10^4cfu/g and 1.3 x 10^5cfu/g in samples of the skin from Ohaji, Mbano and Mbaitoli respectively. Total Staphylococcal count (TSC) likewise recorded increasing values from cold room to open markets with the highest TSC value obtained from the skin (1.3 x 10^4cfu/g) of the cold room and frim the intestine (2.8 x 10^6cfu/g) of the open market sample. Emikpe *et al.*, (2011) noted that the means of contamination and route of microbial transmission are likely to be through handling. Onsight contamination of fish during transportation, display and handling as reported by Nwazuo *et al*., (2016) and Adams and Moses (2000), explains the increase in microbes as the fish proceeds from cold rooms to the open markets. Of note is the gill isolation of the cold room samples which had isolations (2.0 x 10^4cfu/g) but absent in the open market samples. Same is recorded for the Total Salmonella/Shigella Count (TSSC) which were present (4.0 x 10^2cfu/g) in cold room samples but entirely absent in the open market samples. Total Fungal Count (TFC) showed increasing values from cold room with a range of 1.0 x 10^3cfu/g - 7.2 x 10^3cfu/g to open markets samples with a range of 2.0 x 10^5cfu/g – 3.5 x 10^4cfu/g the latter obtained from the skin.

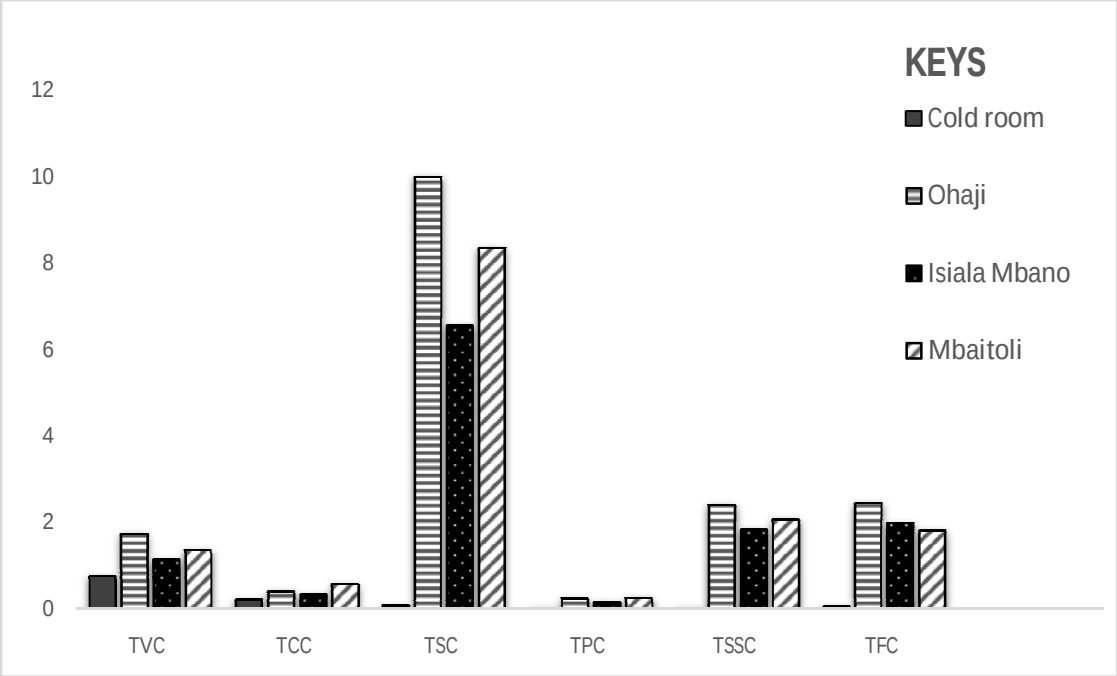

Fig 1; Bar chart showing compared microbial indices for cold room and open market *Gadus morhua* iced fish.

Comparison of mean microbial composition of cold room and open market frozen fish samples

Table 3; Comparative analysis of mean microbial load in cold room and open markets iced fish in Imo state

Sample	**Parameters** (Cfu/g)	**Cold room (x10^5)**	**Ohaji (x10^5)**	**Isiala Mbano (x10^5)**	**Mbaitoli (x10^5)**	**p-value**

Gadus morhua	TVC	0.75 ± 0.18	±	1.73 ± 0.72	1.13 ± 0.45	±	1.35 ± 0.44	± 0.089
	TCC	0.15 ± 0.16	±	0.30 ± 0.38	0.28 ± 0.37	±	0.42 ± 0.59	± 0.838
	TSC	0.06 ± 0.05	±	9.95±12.16	6.62 ± 8.94	±	8.57 ± 10.33	± 0.462
	TPC	0.00 ± 0.00	±	0.17 ± 0.18	0.11 ± 0.12	±	0.17 ± 0.12	± 0.226
	TSSC	0 00 ± 0.00	±	1.80 ± 2.62	1.37 ± 2.03	±	1.55 ± 2.25	± 0.601
	TFC	0.05 ± 0.03	±	2.45 ± 0.71[a]	1.97 ± 1.07[b]	±	1.80 ± 0.86[c]	± 0.005

Table 4; Comparative analysis of average occurrence of **bacteria in *Gadus morhua*** in cold room and open markets of Imo state.

Bacterial isolates	**Maximum occurrence**	***Cold room***	**Open market**			**p-value**
			Ohaji	**Isiala Mbano**	**Mbaitoli**	
Micrococcus spp.	16	16.00 ± 0.00	11.00 ± 2.65	10.00 ± 5.19	10.00 ± 2.00	0.532
Staphylococcus aureus	16	13.00 ± 0.00	14.67 ± 1.52	13.33 ± 0.57	13.33 ± 0.57	0.340
Bacillus cereus	16	8.00 ± 0.00	5.00 ± 1.00	3.33 ± 1.15	4.00 ± 2.00	0.130
Bacillus subtilis	16	7.00 ± 0.00	11.00 ± 1.00	10.33 ± 1.52	10.67 ± 3.55	0.452
Streptococcus spp.	16	13.00 ± 0.00[a]	7.33 ± 1.15[b]	6.00 ± 2.00[c]	6.00 ± 1.00[d]	0.024
Escherichia coli	16	6.00 ± 0.00	7.67 ± 1.52	6.67 ± 1.52	7.33 ± 2.08	0.087
Klebsiella spp.	16	3.00 ± 0.00	4.00 ± 1.00	3.33 ± 0.58	3.33 ± 0.57	0.586
Proteus spp.	16	3.00 ± 0.00	4.00 ± 1.00	3.67 ± 1.15	3.33 ± 1.52	0.705
Pseudomonas aeruginosa	16	7.00 ± 0.00	10.67 ± 2.51	10.67 ± 4.72	10.67 ± 4.50	0.861
Salmonella spp.	16	4.00 ± 0.00	15.67 ± 0.57	14.67 ± 1.15	15.33 ± 1.15	0.000

Table 5; Comparative analysis of average occurrence of **fungi in *Gadus morhua*** in cold room and open markets of Imo state.

Fungal isolates	**Maximum occurrence**	***Cold room***	**Open market**			**p-value**
			Ohaji	**Isiala Mbano**	**Mbaitoli**	
Geotrichum sp.	16	4.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	NA
Candida spp.	16	13.00±0.00[a]	0.33 ±	0.00 ± 0.00[c]	0.33 ±	0.000

			0.577[b]		0.57[d]	
Aspergillus fumigatus	16	0.00 ± 0.0	4.00 ± 1.73	3.33 ± 1.52	3.33 ± 2.08	0.366
Rhizopus stolonifer	16	0.00 ± 0.00[a]	8.33 ± 1.52[b]	6.67 ± 1.52[c]	8.00 ± 2.00[d]	0.025
Rhodotorula spp.	16	0.00 ± 0.00	4.00 ± 1.00	3.33 ± 1.52	3.33 ± 1.52	0.193
Aspergillus flavus	16	0.00 ± 0.00	8.00 ± 2.64	5.67 ± 1.52	6.67 ± 1.52	0.062
Mucor spp.	16	0.00 ± 0.00	4.00 ± 1.73	2.67 ± 1.15	2.67 ± 1.52	0.240
Aspergillus terreus	16	0.00 ± 0.00	12.00 ± 3.60	10.33 ±2.51	11.67 ± 3.21	0.068
Aspergillus niger	16	0.00 ± 0.00	4.00 ± 3.46	3.37 ± 2.08	4.00 ± 1.00	0.538

Results from the comparative analysis reveals that TFC values alone showed significance difference at p-value 0.005 across the cold room and open markets collection points. Comparatively, there is no significant difference in the bacterial occurrence of *Micrococcus spp., S.aureus, B. cereus, B. subtilis, E. coli, Klebsiella sp, Proteus spp., and P. aeruginosa* across cold room and open markets of the three local government areas with p-values of 0.532, 0.340, 0.130, 0.452, 0.087, 0.586, 0.705, and 0.861 respectively but significant difference in values of *Streptococcus spp*. and *Salmonella spp*. Just as was reported in Onyeanula *et al.,* (2021) and Orji *et al.,* (2014), in their studies on frozen fish marketed in Imo State and Abakaliki metropolis respectively, similar bacteria were isolated. Values for *Micrococcus spp., Bacillus cereus, and Streptococcus spp.* were higher in cold room samples (16.00, 8.00 and 13.00 respectively) than in open markets with 11.00, 5.00 and 7.33 (Ohaji), 10.00, 3.33 and 6.00 (Isiala Mbano) and 10.00, 4.00 and 6.00 (Mbaitoli). This may be attributed to the fact that their growth may be significantly reduced at higher temperatures and lower pH which is evident in fish that have left the cold rooms to warmer temperatures and susceptible to other microbial contamination which will likely increase the pH. Onyeanula *et al*., (2021), observed same with *Scomber scombrus* obtained in Imo State local market. Decrease in occurrence of *Bacillus cereus* and *Streptococcus sp*. from cold room to open markets however negates the observations of Onyeanula *et al*., (2021) and may be attributed to the physiochemical composition of *Gadus morhua*. Fungal occurrence showed a non-significant difference for *A. fumigatus, Rhodotorula spp., A. flavus, Mucor spp., A. terreus* and *A. niger* across the cold room and open market samples with p-value of 0.366, 0.193, 0.062, 0.240, 0.068 and 0.538 respectively (table 5). *Geotrichum sp.* occurred in only cold room samples but was absent in open markets just as *Candida sp.* and *R. stolonifera* presented statistical significance across cold room and open market samples. Similar observation of fungal isolations was made for *Scomber scombrus* as reported by Onyeanula *et al*., (2021). Of all the nine fungi isolated, *Geotrichum sp.* showed significant difference at $p \leq 0.05$. Adebayo-Tayo *et al*., (2012), Ibrahim *et al*., (2015) and Onyeanula *et a*l., (2021) reported similar isolations with *Candida sp*p. having the most average occurrence as observed in this study. Nishihara *et al., (*2008) also reported that despite disifection of fish samples surface, its incubation for up to 14 days at room temperature still presented *Candida sp*. among few other fungi isolated. Isolates of the other fungi from the present study had no occurrence in cold room samples but significantly increased values in open market samples. This further buttress the fact that improper storage, transport and display facilities predispose these food commodities to fungal growth (Gill and Barbosa, 2011; Adebayo-Tayo *et al*., 2012).

Proximate composition for frozen fish sold in Imo state markets

Table 6; Proximate analysis for frozen *Gadus morhua* from cold room and open market showing mean values

Fish specie	Parameters	Cold room (AC)	Ohaji O1	Ohaji O2	Ohaji O3	Isiala Mbano O1	Isiala Mbano O2	Isiala Mbano O3	Mbaitoli O1	Mbaitoli O2	Mbaitoli O3	p-value
Gadus morhua	C P	17.24±0.52	19.44±0.94	19.44±0.72	19.44± 7.05	19.34± 0.53	19.14±1.01	19.14±0.51	19.13±0.71	18.14±1.00	17.29±0.63	0.042*
	M	72.31±0.57	72.88±0.58	73.15±1.05	73.27± 0.70	74.00± 1.06	74.09±1.05	73.09±0.58	73.66±0.91	73.63±0.53	71.63±0.51	0.671
	A	1.30 ± 0.62	0.98 ± 0.63	0.12 ± 0.70	0.13 ± 0.99	0.84 ± 0.87	0.97 ± 0.83	0.87 ± 1.00	0.92 ± 0.72	0.91 ± 0.72	0.84 ± 0.58	0.611
	E E	1.06 ± 0.50	1.05 ± 0.93	1.05 ± 0.50	1.05 ± 1.05	1.05 ± 0.61	1.05 ± 1.08	1.06 ± 1.31	1.05 ± 0.65	1.00 ± 1.00	1.04 ± 1.74	0.993
	C F	6.98 ± 0.54	3.38 ± 0.86	4.37 ± 0.66	3.16 ± 0.50	3.80 ± 0.87	4.39 ± 1.30	4.39 ± 0.81	3.17 ± 0.81	3.06 ± 0.50	3.04 ± 0.81	0.001*
	N F E	1.08 ± 0.60	2.28 ± 0.94	1.88 ± 0.92	2.95 ± 1.78	0.98 ± 0.73	0.36 ± 0.50	1.45 ± 0.73	2.08 ± 0.52	2.00 ± 1.11	1.91 ± 0.54	0.612

Where CP= crude protein, M= moisture, A= ash, EE=ether extract, CF= crude fiber, NFE= nitrogen free extract
p-values with ‘’*’’ shows significant difference p<0.05

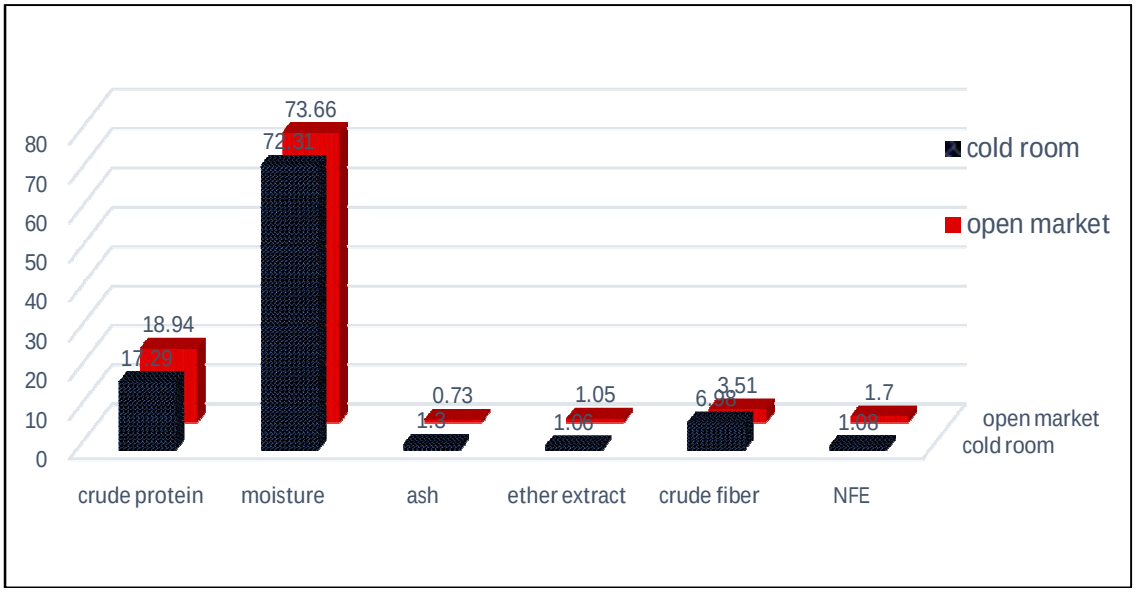

Fig 2: Bar chart comparing mean values for proximate evaluation of fishes sampled from cold room

Result shows that crude protein cold room value was 17.24 ±0.52 but significantly increased in the open market samples (19.44±0.94) but with a unique value of 17.29±0.63 in one open market of Mbaitoli. The increase in values of moisture content from the cold room (72.31±0.57) to the open market (74.09±1.05) was insignificant just as was recorded for NFE to be 1.08±0.60 for cold room and 2.95±1.78 as maximum value for open market. On the other hand, an insignificant difference was recorded for ash content and ether extract but with values reducing from cold room (1.30±0.62 and 1.06±0.50) to open market (0.12±0.70 and 1.00±1.00) as their minimum value respectively. Crude fiber showed significant difference in values of cold room (6.98±0.54) and open markets (ranged between 3.04±0.81 and 4.39±1.30), thus a significant difference ($p<0.05$) was observed in crude protein and crude fiber values of *Gadus morhua* which is possibly related to an increase in the number of bacteria and fungi. Proximate composition values obtained from this study agrees with those undertaken by Tawfik (2009) and Nurnadia *et al*., (2011) with their nutritional properties acceptable especially for those obtained from the cold-rooms. Crude protein mean values indicates an increase in values in fish obtained from the open market to fish obtained from the cold room. The protein content of Atlantic mackerel in Olaolu *et al*., (2011) supports this finding. Post rigor mortis is also associated in increased water retention capacity of proteins, thus may be responsible for the increased protein content in the open market.

Conclusion

There is a marked recorded difference in microbial and carcass quality of fish in the cold rooms and those in the open markets available to vast majority of consumers, the microbial load being evident and carcass quality being reduced in the open market samples than in the cold room samples. Most of these quality difference has been linked to the handling method used within the state and negligence of the use of best practices. Because frozen fish is exposed to large variations of temperature fluctuations, during storage and transport, short-term storage of the raw material, gentle processing, quick freezing, short-term storage as a semiprocessed product, and short-term cold storage at temperatures lower than 30°C, will result in the best product.

Summary

The study looked at the microbial composition and carcass quality of *Gadus morhua* (a commonly sold and consumed fish) obtained from local markets of Imo state. An effective way of long term preservation of fish is by freezing (Nielsen and Flemming, 2012). The fluctuation of temperature is one of the most significant factors in maintaining quality through the chain of distribution. Just as it is important to quickly cool fish immediately it is caught to inhibit the onset of biochemical and microbiological change, it is equally important to maintain a relatively steady temperature as it is transported and made available to the final consumers. Results revealed that the difference in microbial and carcass quality of fresh and thawed fish may be negligible if fish was handled with care during and after purchase from the cold rooms, kept frozen as quickly as possible and stored at a stable temperature of about 30°C even at the point of display for sale. This however is almost impossible with the handling habits found in our markets. Handlers and traders act as they deem fit depending on the limited resources available to them and market place involved. Small scale traders stay at cold room sites to share a carton of fish- and in so doing, start the exposure of the fish to microbial contamination accounting for the high levels of microbes in open market samples.

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