PROXIMATE AND MINERAL COMPOSITIONS OF SOME FROZEN MARINE FISH SPECIES SOLD IN SELECTED LOCAL GOVERNMENT AREAS OF KANO STATE, NIGERIA

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Abstract
This study was carried out with the aim of evaluating the proximate and mineral compositions of some frozen marine fish species; Atlantic herring (Clupea harengus, Linnaeus, 1758), Atlantic mackerel (Scomber scombrus, Linnaeus, 1758) and Atlantic horse mackerel (Trachurus trachurus, Linnaeus, 1758) sold in selected local government areas of Kano State, Nigeria. A total of 81 samples comprising of 27 C. harengus, 27 S. scombrus and 27 T. trachurus were sampled/purchased from the three sampling areas (Bichi, Dambatta and Gwarzo. The sampling was done on weekly basis for a period of three weeks in March, 2022. Each week 3 samples of each fish species were collected from one major cold room/fish seller of each selected local government area/sampling station. The samples were analyzed using method of Association of Official Analytical Chemists (AOAC, 2016) for proximate and mineral compositions. Results indicated that the highest crude protein content 21.51% was recorded in T. trachurus from Dambatta station, and moderate 18.04% was recorded in S. scombrus from Gwarzo station, while the least 15.28% was recorded in C. harengus from Bichi station respectively. In this study all the proximate composition parameters were affected by the species but not the collection station except carbohydrate. The mineral content composition showed that C. harengus recorded the highest Sodium content 1.69 mg/kg from Bichi Station, while S. scombrus had the least 0.38 mg/kg from Dambatta station. S. scombrus had the highest calcium content 1.24 mg/kg from Dambatta station, while C. harengus recorded the least 0.12 mg/kg) also from Bichi station. In this study all the minerals' parameters were affected by the species but not the collection station. The study recommends T. trachurus as the best for human consumption due to its h igher protein compositions, compared to S. scombrus and C. harengus. However, the study showed that proximate and m ineral compositions of these fish species studied are within the acceptable level and safety limits which cause no harm to human, therefore, they are healthy for human consumption.

Keywords: marine fish, frozen, proximate, minerals, compositions and consumption

INTRODUCTION

Fish is an important source of healthy and cheap animal protein, especially in developing countries (Dauda *et al.*, 2020). It is widely acceptable across all socio-economic classes, age and religions. An effort to ensure fish food security is a continuous process and food safety is a worldwide concern for consu mers and food industry (Amuneke *et al.*, 2020). The nutritional characteristics of fish and fishery products are of vital interest to consumers. Fishery products are highly nutritious and an excellent means of obtaining dietary essentials, like protein, minerals and vitamins. Fish fat contains a high proportion of polyunsaturated fatty acids, which may help to decrease the incidence of atherosclerosis, and heart related diseases. The flesh of a fish in good condition is made up of five main chemical components namely protein, lipid, water, minerals and vitamins (Babalola *et al.*, 2011).

Fish accounts for about fifty percent (50%) of total protein intake in Nigeria on average, and it is a nutrient-dense, affordable, available and much appreciated animal-source food commonly consumed across all income strata (NBS, 2020). Nigeria's fish supplies come from both domestic output and imports. Three major industries contribute to local production: artisanal fisheries in brackish and coastal waters as well as inland lakes, dams, and rivers; aquaculture and commercial marine fishing, in comparison, industrial fishing and marine trawling catch rates have decreased recently, potentially as a result of overfishing (Subasinghe *et al.*, 2021). Nigeria is among the leading aquaculture producers in Africa and its production in 2021 reached about 275.6 thousand tonnes in live weight, which account up to 11.9% of Africa's production (FAO, 2023). Nigeria produced 1.17 million metric tons of fish overall in 2018, up from 1.04 million metric tons in 2016, mainly as a result of artisanal fisheries (Subasinghe *et al.*, 2021). Nigeria imports about 45% percent of its net domestic fish supply due to the high foreign exchange expenditure on fish imports (Subasinghe *et al.*, 2021), Nigeria initiated measures such as quotas and tariffs to control the escalating foreign exchange demand for fish imports into Nigeria, starting in 2013. The imported fish include: pelagic fish mackerel, horse mackerel, hake, herring, stock fish, dried cod and stock fish heads from various exporting countries; such as Japan, Holland, Denmark, Norway and China (WorldFish, 2018).

The micro-nutrients present in living organisms are of biological significance because many of this nutrients take part in some metabolic activities and are crucial to all living organisms (Fakunle and Effiong, 2011). Fishes contain small amount of micro-nutrients some of them are essential nutrients, being components of many enzymes system and metabolic mechanisms that contribute to the growth of the fish. The most important macro-nutrients in form of mineral salts include Na, Ca and K while many others like Fe and Mn are required in trace amount. Deficiency in these principal nutritional mineral elements can causes a lot of malfunctioning as it reduces productivity and leads to diseases such as inability of blood to clot, osteoporosis, anemia etc (Fakunle and Effiong, 2011). Aquatic foods are important for a healthy and balanced diet with a significant positive nutritional impact by providing essential nutrients that are scarce in plant-based diets, depending on the species they provide high-quality proteins (FAO, 2022). One of the affordable sources of quality protein that is available worldwide for human consumption is fish, it is one of the main food components of humans for many centuries and still constitutes an important part of the diet of many countries (Afolabi *et al.*, 2020; Wall *et al.*, 2010).

Proximate Compositions of Fish

The determination of some proximate profiles such as protein content, lipid, ash and other nutrients is often necessary to ensure that they are within the range of dietary requirement and commercial specifications (Fakunle and Effiong, 2011). However, the knowledge of the chemical composition of marine fish species is of fundamental importance in estimating the quality of the raw material, storage stability and application of technological processes (Nurnadia *et al.*, 2011). The nutritional characteristics of fish and fishery products are of vital interest to consumers. Fishery products are highly nutritious and an excellent means of obtaining dietary essentials, like protein, minerals and vitamins (Babalola *et al.*, 2011; Maznah *et al.*, 2012). Gokoglu, (2021) stated that the composition of fish is basically composed of water, lipid and protein, which create the nutritional value, functional aspects and sensory characteristics of the flesh. Furthermore, the fish also contains vitamins and minerals, playing an important role in post-mortem biochemical changes (Babalola *et al.*, 2011; Gokoglu, 2021).

Factors Influencing the Proximate Compositions of Fishes

The nutritional profile of fish varies from species to species, size, age, and so forth, the knowledge of the proximate composition of fish gives an idea concerning the nutritional profile of the fish (Ahmed *et al.*, 2022). However, there are a number of factors that have a significant influence on the nutritional composition of fish and cause variation in their proximate composition. The factors affecting the proximate composition of fishes can be endogenous or exogenous.

The Endogenous Factors

The endogenous factors are mainly associated with the life cycle of the fish, that is, sex, size, age, life stage, anatomical position in the fish and are mostly hereditarily controlled (Ahmed *et al.*, 2022). These factors are mainly responsible for governing the majority of principles which are responsible for determining the composition of fishes (Khalili and Sampels, 2018).

The Exogenous Factors

The exogenous factors generally include various environmental variations and changes in composition and availability of feed in fish living regions (Ahmed *et al.*, 2022) and also include differences in the temperature and salinity (Khalili and Sampels, 2018). Among all these exogenous factors, the diet has been found to have an ample effect on the proximate composition of the fishes while as the other factors for example, variations in temperature, pH, light, oxygen concentration, salinity have been found to have a limited effect (Ahmed *et al.*, 2022). Variation in proximate composition also occurs within the same species depending upon the fishing ground, age and sex of the individual, geographical location of catch, environmental circumstances, sexual maturity, size and reproductive status of the fish (Padmavati, 2017). Difference in proximate composition of fish also varies with species, season, geographical location, age and feeding habit of the fish (Shija *et al.*, 2019). Seasonal variation has a great influence on the changes of proximate composition of fishes (Ganeshwade *et al.*, 2016; Rao and Simhachalam, 2018; Sharma *et al.*, 2020).

Mineral Compositions of Fish

All aquatic animals require minerals for their vital physiological and biochemical functions and to maintain their normal life processes. Fish lives in a wide range of salinity levels (0–35 0/00) in freshwater, seawater and brackish water environments, and, unlike other vertebrates, it absorbs minerals from the diet as well as the surrounding water (Esan, 2019). Most of the essential minerals are required for animals and other vertebrates. The essentiality of macro-minerals (calcium, phosphorus, magnesium, sodium, potassium and chloride) and micro-minerals(trace elements) such includes (cobalt, copper, iodine, iron, manganese selenium and zinc) have been confirmed in fish tissues (Lall and Kaushik, 2021).

Importance of Minerals to Human

Minerals play important role in maintaining body functions because they maintain acid–base balance, and help bond formation (hemoglobin formation). They also control the water balance in the body, help bones formation and teeth structure, and catalyze many metabolic reactions (Njinkoue *et al.*, 2016). The importance of minerals as food ingredients is not only their nutritional and physiological roles, but they also contribute to food flavor and also activate or inhibit enzyme-catalyzed and other metabolic reactions, and they affect the texture of food (Kiczorowska *et al.*, 2019). Fish muscle and bones serve as good sources of essential minerals (Raffic *et al.*, 2020). Fish minerals are mainly stocked in the skeleton and essentially in the vertebra with about 65%. Unfortunately, bones and heads are discarded parts of fish. Fish's bones were analyzed for their content in minerals and for a potential valorization of sub products from fish's flesh processing. However, there are people who eat both bones and flesh during their meal (Njinkoue *et al.*, 2016). The most important minerals are calcium, sodium, potassium, phosphorous and iron, while many others are also needed in trace amounts, the deficiency of these important mineral elements induces a lot of malfunctioning as it reduces productivity and causes diseases, such as inability of blood to clot, osteoporosis, anemia etc (Raffic *et al.*, 2020).

MATERIALS AND METHODS

The Design of the Study

This study was conducted using experimental research design with primary objective to evaluate the selected nutrient compositions of the frozen *C. harengus*, *S. scombrus* and *T. trachurus* sold in three peri urban areas of the Sudan Savannah zone of Kano state and specific objectives to:

1. Assess the proximate composition of the frozen marine fish species in relation to collection stations.
2. assess the composition of some mineral elements in the frozen marine fish species among the research stations.

Data Collection Method

The sampling was done on weekly basis for a period of three weeks in March, 2022. Each week three (3) samples of each fish species were collected from one major cold room/fish seller of each selected local government area/sampling station. The collection of the samples was done three times from each sample station, the first collection was done at the arrival of the stocks/products, second collection was done four days after the first collection while the third collection was done when their stocks is about to finished.

Validity of the Study

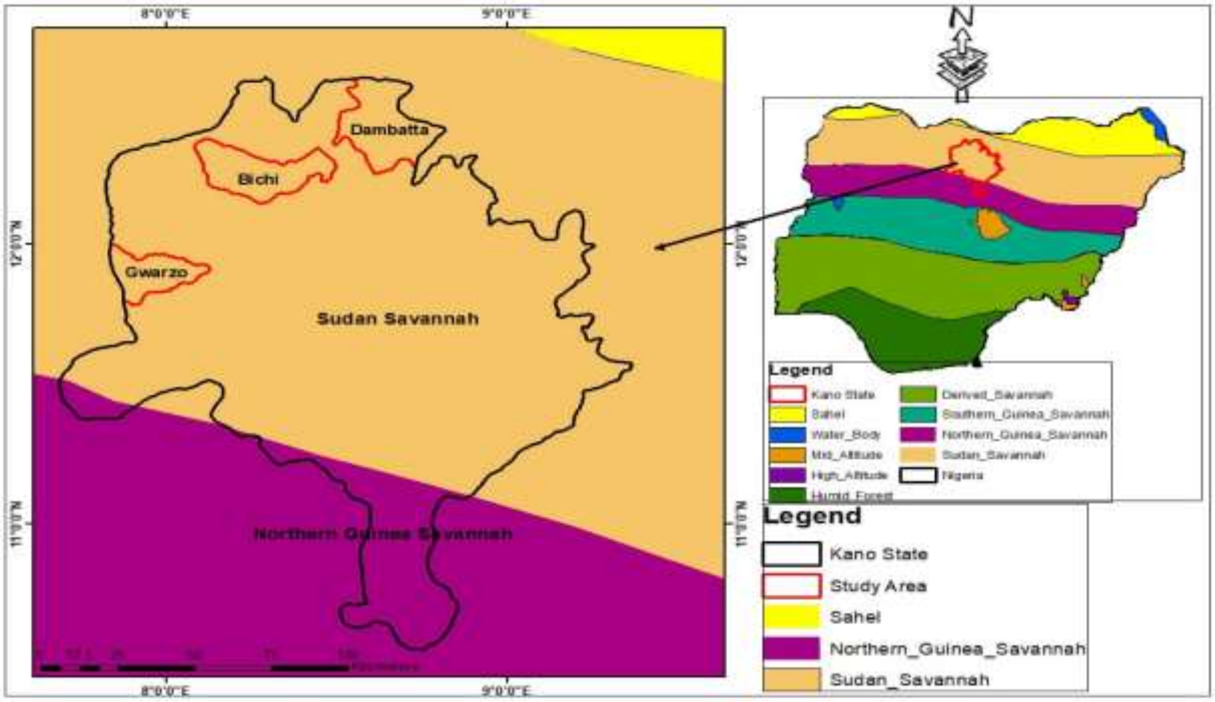
Procedure of analyzing proximate and mineral compositions ware designed by using Association of Official Analytical Chemists (AOAC, 2016) method and were given to Prof A. H. Bichi and Prof A. B. Dauda of Department Fisheries and

Aquaculture Federal University Dutsin-ma, Katsina State for validation. After they have gone through it they approve and validate the procedure to carry out the analysis.

Sampling Areas

The research was carried out in selected local government areas from the Sudan Savannah ecological zone of Kano and purposive sampling was used to select three peri-urban local government areas namely Bichi, Dambatta and Gwarzo Local Government Area's (Fig 2).

Figure 1: Map of Kano State Showing the Two Ecological Zones.



***Source**: Department of Geography UDUS*

DESCRIPTION OF THE SAMPLING AREAS

Bichi Local Government Area

Bichi is a Local Government Area and Headquarter of Bichi Emirate Council in Kano State, Nigeria. It is ranked to be second in population in Kano State with total of about 277,099 people (NPC, 2006). It has a total area of 612 km^2 and it lies between Coordinates: 12°14′03″N 8°14′28″E (Abdullahi *et al.*, 2020).

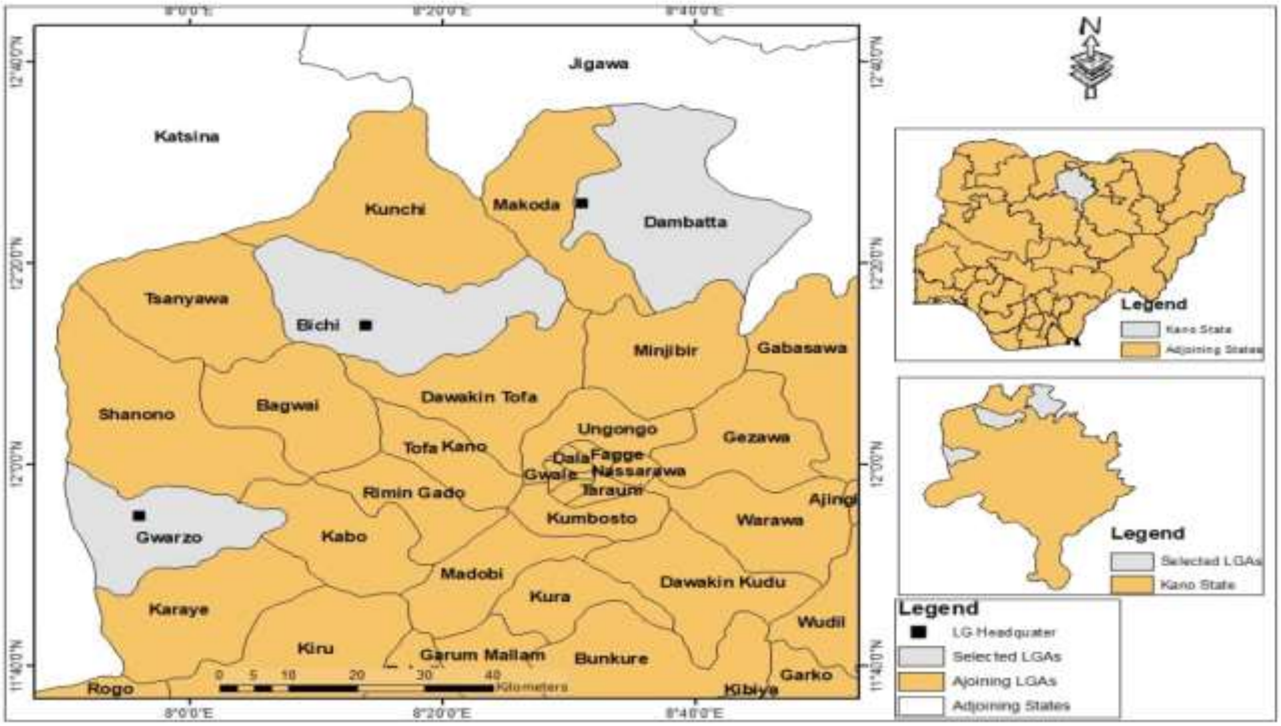
Dambatta Local Government Area

Dambatta is situated in the Northern part of Kano State. It is enclosed between latitude 12º25'N and longitude 8º35'E with a land mass of 2732km^2. It has a population of 207,968 and a growth rate of 2.4% per annum (NPC, 2006). It has a land mass area of 305.51km^2. Average daily temperature and rainfall are 26.8ºC and 700mm respectively. Most of the populations are small scale arable farmers (Onuwa *et al.*, 2020).

Gwarzo Local Government Area

Gwarzo Local Government Area is located in the Western part of Kano state. It has an area of 393 km^2 and a population of 183,624 (NPC, 2006). The area falls within latitudes $11^0$45'23.30"N and $12^0$5'30.30"N and longitudes $7^0$49'47.30"E and $8^0$8'36.30" E. It is bounded by Shanono to the North, Kabo in the East and Karaye in the South (Atakpa and Tanko, 2018).

Figure 2: Map of Kano State Showing Samples/Sampling Areas.



***Source**: Department of Geography UDUS*

SAMPLING SIZE

Three (3) most commonly sold frozen marine fish in the study areas were used. A total of eighty-one (81) samples comprising of twenty-seven (27) Atlantic herring (*Clupea harengus*), twenty-seven (27) Atlantic mackerel (*Scomber scombrus*) and twenty-seven (27) Atlantic horse mackerel (*Trachurus trachurus*) were sampled/purchased from the three sampling areas (Bichi, Dambatta and Gwarzo) respectively.

SAMPLING PROCEDURE

The sampling was done on weekly basis for a period of three weeks in March, 2022. Each week three (3) samples of each fish species were collected from one major cold room/fish seller of each selected local government area/sampling station. The collection of the samples was done three times from each sample station, the first collection was done at the arrival of the stocks/products, second collection was done four days after the first collection while the third collection was done when their stocks is about to finished. All the sample stations have gotten their stocks from same company found in Lagos and Port-Harcourt. The fish samples were collected into a sterile tinfoil paper individually and immediately transported in ice cooler/cold flask to retain the freshness to Umaru Musa Yaradu'a University, Katsina (UMYU) at Biochemistry laboratory and Microbiology laboratory for analysis on proximate compositions and microbial load.

PROXIMATE ANALYSIS

Proximate analysis, the moisture content, crude protein, crude lipid and ash content of fish sample were analyzed usi ng the method of analyses by Association of Official Analytical Chemists (AOAC, 2016).

Moisture (%) Content

Moisture content was determined in the fish muscle in replicate for which a known weight 5g of the sample was placed individually in a moisture dish and dried in a hot air oven at 60 °C until constant weight is obtained.

$$\% \text{ moisture} = \frac{Initial\ Weight - Oven\ Dried\ weight}{Initial\ Weight} \times 100$$

Crude Protein (%)

Crude protein content was determined by the standard AOAC method(AOAC, 2016). Known weight of moisture free sample was weighed and digested along with concentrated H_2SO_4 acid and a pinch of digestion mixture ($NaSO_4$: $CuSO_4$at the ratio of 9:1) in a Kelplus digestor at 350ºC for 4 h until the sample become colorless. The digested sample was then diluted to 100 ml in a volumetric flask with distilled water. About 5 ml of aliquots was distilled for 10 min with 40 s% sodium hydroxide in a Kelplus distillation apparatus and the distillate was collected in 2% boric acid solution containing mixed indicator. The nitrogen content was determined by titration against standard N/70 H_2SO_4solution. The crude protein content was calculated by multiplying with the factor 6.25.

$$\text{Crude protein} = \frac{(V2-V1)\times N\times 14\times 100\times 6.25}{1000\times W}$$

Where, V1 = volume of H_2SO_4 used in the blank titration; V2 = volume of H_2SO_4 used in the test titration; 14 = conversion factor from ammonium sulphate to nitrogen N 6.25 = conversion factor from nitrogen to protein; N = Nomality of H_2SO_4 used in titration; W= weight of dried sample

Crude Lipid (%)

Crude lipid content was determined by Soxhlet method. Approximately, known weight of moisture free sample was placed individually in a thimble and kept in the pre-weighed extraction flask. The flask was filled with $^2/_3$ volume of petroleum ether and the apparatus assembled. Extraction was carried out for about 2 h at 200°C. After the extraction, excess ether carefully collected and the residual ether was evaporated to dryness. The difference between the initial and the final weight gave the crude fat content.

$$\text{Crude lipid} = \frac{\text{Weight of Ether Extracted Fat}}{\text{Weight of Sample}} \text{ X } 100$$

Ash (%) Content

Ash content was determined by burning the organic components from the known weight 5gof the homogenized dried fish muscle by using a furnace at 550°C for 12-15 hours.

$$\%\text{ash} = \frac{Weight\ of\ Ash}{Weight\ of\ Sample} \times 100$$

Carbohydrate

The Carbohydrate content was calculated based on difference method. This was done by subtracting SUM of (%Moisture + %Crude Protein %+ Crude Lipid + %Ash) from 100 that is;

Carbohydrate = 100% – (%Moisture + %Crude Protein + %Crude lipid + %Ash)

MINERAL ANALYSIS

Samples Preparation

Fish were weighed before and after being cut into small pieces and ground well thoroughly to achieve homogeneity. 5gram of the sample were put in a 125-ml Erlenmeyer flask, added with 10 mL of concentrated nitric acid and warmed on a hot plate until the tissue solubilized. The temperature of the hot plate was increased to near boiling until the solution turned brown. Then, it was allowed to cool and an additional 5 ml of concentrated nitric acid was added for repeated heating and cooling. Another 2ml of nitric acid was added before being heated again on the hot plate until the volume of the sample reduced to 10ml. Once cooled, 2ml of 30% hydrogen peroxide was added. Once again, the sample was heated until the volume of the sample reduced to 5 to 10 ml. After allowed to cool, another 2ml of hydrogen peroxide was added. This step was repeated until a total of 10ml of hydrogen peroxide was added. After that the sample was allowed to cool before 2ml of concentrated hydrochloric acid was added. Then the sample was returned to the hot plate until the volume of the sample is reduced to 5 to 10 ml. The sample was allowed to cool and transferred into a 100ml volumetric flask. The sample was then topped-up with deionized water to the mark for atomic absorption spectrophotometer (AAS) and flame photometer analysis (Ismaniza *et al.*, 2012).

Mineral Determination and Procedure

Atomic absorption spectroscopy (AAS) is used which is an analytical method that is based on the absorption of UV-visible radiation by free atoms in the gaseous state. The sample to be analyzed is normally ashed and then dissolved in an aqueous solution. This solution is placed in the instrument where it is heated to vaporize and atomize the minerals. A beam of radiation is passed through the atomized sample, and the absorption of radiation is measured at specific wavelengths corresponding to the mineral of interest. Information about the type and concentration of minerals present is obtained by measuring the location and intensity of the peaks in the absorption spectra (Ismaniza *et al.*, 2012).

DATA ANALYSIS

Data was analyzed using descriptive statistics (mean ± standard deviation). The data was subjected to normality and homogenuity of variance tests, after which a two-way analysis of variance (ANOVA) was used to compare the fish species for each parameter among the three stations, also to compare the fish species for each parameter among the collection period for each of the sampling station at 95% level of probability ($P < 0.05$). Whenever a significant difference was observed Turkey' HSD test was used to separate the different means using IBM SPSS Version 23.

RESULTS AND DISCUSSIONS

RESULTS

The result of the proximate compositions of *C. harengus*, *S. scombrus* and *T. trachurus* is shown in table 1, Highest moisture content (75.59 ± 1.81%) was observed in *C. harengus* from Bichi station, while the least measurement (68.66 ± 0.65%) was recorded in *T. trachurus* from Dambatta station. Generally, the moisture content was higher in *C. harengus* and was significantly different ($P<0.05$) from other species but differences in moisture due to station was not significant ($P>0.05$). However, there was significant interaction ($P<0.05$) between the species and stations of collection. The highest crude protein, 21.51 ± 0.53% was recorded in *T. trachurus* from Dambatta, while the least, 15.28 ± 0.38% was recorded in *C. harengus* from Bichi. Crude protein was significantly higher ($P<0.05$) in *T. trachurus* than other species, but there was no significant difference ($P>0.05$) among the station. The interaction between species and stations was also significant ($P<0.05$).

Table 1: Proximate Compositions of three Frozen Marine Fish Species from Bichi, Dambatta and Gwarzo Stations

Overall Stations and Fish Species					Two-way ANOVA		
Parameters (%)	**Stations**	***C. harengus***	***S. scombrus***	***T. trachurus***	**Species (P value)**	**Stations (P value)**	**Species * Stations (P value)**
Moisture	BCH	75.59 ± 1.81[a]	71.76 ± 1.20[b]	69.80 ± 1.05[c]	0.000	0.220	0.000
	DBT	74.44 ± 2.53	73.17 ± 0.47	68.66 ± 0.65			
	GRZ	73.61 ± 1.77	74.46 ± 0.94	70.19 ± 0.65			
Crude Protein	BCH	15.28 ± 0.38[c]	20.67 ± 1.56[b]	20.03 ± 1.58[a]	0.000	0.726	0.000
	DBT	18.07 ± 0.48	16.52 ± 1.49	21.51 ± 0.53			
	GRZ	17.76 ± 0.64	18.04 ± 1.05	19.66 ± 0.96			
Crude Lipid	BCH	4.70 ± 1.14[ab]	4.07 ± 0.29[b]	4.70 ± 0.40[a]	0.046	0.106	0.664
	DBT	3.71 ± 1.41	3.93± 0.89	4.44 ± 0.65			
	GRZ	4.31 ± 1.13	4.26 ± 0.43	4.84 ± 0.40			
Total Ash	BCH	2.33 ± 0.15[b]	2.31 ± 0.36[b]	2.72 ± 0.21[a]	0.000	0.623	0.064
	DBT	2.15 ± 0.46	2.45 ± 0.26	2.76 ± 0.11			
	GRZ	2.42 ± 0.36	2.18 ± 0.28	2.58 ± 0.22			
Carbohydrate	BCH	2.17 ± 0.56[B,b]	1.24 ± 0.61[b]	2.75 ± 0.54[a]	0.000	0.000	0.000
	DBT	1.40 ± 0.95[A]	1.91 ± 0.51	2.54 ± 0.55			
	GRZ	1.99 ± 0.69[B]	1.07 ± 0.79	2.77 ± 0.29			

*Values are presented as the means ± standard deviation
*Different small letters as superscripts across the rows indicate significant differences (P <0.05) among the fish species.
*Different capital letters as superscripts within the column for each parameters indicate significant differences (P <0.05) among the stations

Key: BCH - Bichi
DBT - Dambatta
GRZ - Gwarzo

The results of the mineral compositions of *C. harengus, S. scombrus* and *T. trachurus* is shown in table 2. Highest Sodium content (1.69 ± 0.65 mg/kg) was observed in *C. harengus* from Bichi, while the least content (0.38 ± 0.07 mg/kg) was recorded in *S. scombrus* from Dambatta. Generally, the Na was higher in *C. harengus* and was significantly different (P<0.05) from other species, but the differences in Na due to station was not significant (P>0.05). However, there was significant interaction (P<0.05) between the species and stations of collection. The Ca content of 1.24 ± 0.51 mg/kg was recorded in *S. scombrus* from Bichi and was the highest, while 0.12 ± 0.01 mg/kg observed in *C. harengus* from Bichi was the least. The Ca was significantly higher (P<0.05) in *S. scombrus* than the other species, but the differences was not significant among (P>0.05) the stations. There were no significant (P>0.05) interaction in Ca between the stations and the species. The Potassium content (K), 0.70 ± 0.19 mg/kg was recorded in *C. harengus* from Gwarzo, while the least content 0.49 ± 0.09 mg/kg was recorded in *S. scombrus* from Dambatta. K was significantly higher (P<0.05) in *C. harengus* than other species, but there was no significant difference (P>0.05) due to station. The interaction between species and stations were not significant (P>0.05). The highest Fe content 0.98 ± 0.09 mg/kg was recorded in *C. harengus* from Gwarzo, while the least, 0.35 ± 0.28 mg/kg was recorded in *S. scombrus* from Dambatta. Fe was significantly higher (P<0.05) in *C. harengus* than other species, but there was no significant difference (P>0.05) due to station and in interaction between species and stations.

Table 2: Mineral Compositions of three Frozen Marine fish Species from Bichi, Dambatta and Gwarzo stations

Overall Stations and Fish Species					Two-way ANOVA		
Parameters (mg/kg)	**Stations**	***C. harengus***	***S. scombrus***	***T. trachurus***	**Species (P value)**	**Stations (P value)**	**Species * Stations (P value)**
Sodium (Na)	BCH	1.69 ± 0.65^{,a}	0.39 ± 0.07^{b}	0.50 ± 0.08^{b}	0.000	0.144	0.008
	DBT	1.44 ± 0.67	0.38 ± 0.07	0.51± 0.08			
	GRZ	1.05± 0.66	0.39± 0.05	0.52± 0.09			
Calcium (Ca)	BCH	0.12 ± 0.01^{b}	1.24 ± 0.51^{a}	0.14 ± 0.03^{b}	0.000	0.537	0.077
	DBT	0.13 ± 0.04	1.17 ± 0.43	0.14± 0.03			
	GRZ	0.15± 0.04	0.95± 0.43	0.15± 0.03			
Potassium (K)	BCH	0.64 ±0.21^{,a}	0.52 ± 0.12^{b}	0.56 ± 0.14^{b}	0.004	0.354	0.372
	DBT	0.69 ± 0.19	0.49 ± 0.09	0.58± 0.15			
	GRZ	0.70± 0.19	0.58± 0.16	0.61± 0.14			
Iron (Fe)	BCH	0.68 ± 0.12^{a}	0.82 ± 0.43^{b}	0.63 ± 0.22^{b}	0.000	0.081	0.000
	DBT	0.93 ± 0.18	0.35 ± 0.28	0.50± 0.05			
	GRZ	0.98± 0.09	0.61± 0.17	0.56± 0.13			
Manganese (Mn)	BCH	0.23 ± 0.06^{c}	0.22 ± 0.05^{b}	0.35 ± 0.03^{a}	0.000	0.103	0.003
	DBT	0.19 ± 0.06	0.24 ± 0.03	0.39± 0.02			
	GRZ	0.18± 0.06	0.28± 0.04	0.41± 0.05			

*Values are presented as the means ± standard deviation
*Different small letters as superscripts across the rows indicate significant differences (P <0.05) among the fish species.
*Different capital letters as superscripts within the column for each parameters indicate significant differences (P <0.05) among the stations

Key: BCH - Bichi
DBT - Dambatta
GRZ - Gwarzo

DISCUSSION

PROXIMATE COMPOSITIONS OF FISH

Fish has been a food source for human worldwide from time immemorial, especially as an inexpensive source of animal protein. Therefore, the proximate compositions of the fish species help to provide important nutritional profile (Nurnadia *et al.*, 2011). Several researchers have reported proximate composition of different fish species and documented differences due to species (Abubakar, 2016; Babalola *et al.*, 2011; Bello *et al.*, 2019; Elaigwu, 2019; Mohammad *et al.*, 2019; Palani *et al.*, 2014). In this study all the proximate composition parameters were affected by the species, but not the collection station. For instance, highest amount of moisture was reported in *C. harengus* which was significantly higher than that of *S. scombrus* and *T. trachurus*. This is similar to study of Bello *et al.*, (2019) who studied on *C. harengus*, *T. trachurus*, *S. scombrus* and *M. undulates*. *T. trachurus* had reported higher protein content, lipid, total ash and estimated carbohydrate. This observation may be due to difference in species of fish experimented. This is in line with observation of Elaigwu, (2019) who reported differences in proximate composition of fresh water fish species (*Schilbe mystus, Bagrus bayad, Oreochromis niloticus, Clarias anguillaris* and *Petrocephalus bane bane*). The result also is line with the study of Babalola *et al.*, (2011) who reported differences in proximate composition of marine and fresh water fish species (*S. scombrus, T. trachurus, S. aurita, M. furnieri* and *C. gariepinus*). In contradictory to this study Omolara and Omotayo, (2009) reported differences in proximate compositions of marine water fish species with *T. trachurus* having higher moisture values over *S. aurita*. They also reported *S. scombrus* to have higher protein content over *T. trachurus and C. harengus* (Omolara and Omotayo, 2009).

However, there are no differences due to collection station; this might be due to relatively close method of handling and storing the fish. Protein is the major nutrients in fish, but composition varies depending on age, sex, environment and seasonal migration of which their percentage level helps to define the nutritional status of a particular organism (Aberoumand and Pourshafi, 2010; Ahmed *et al.*, 2022). The variation in proximate composition also occurs within the same species depending upon the fishing ground, age and sex of the individual, geographical location of catch, environmental circumstances, sexual maturity, size and reproductive status of the fish (Padmavati, 2017). However, most of the parameters were not affected by the collection stations, but were affected by collection time. The differences observed in these proximate composition values may be due to the duration of freezing storage and different methods of handling (Aubourg *et al.*, 2012). However, the biochemical composition of fishes could greatly affect the postharvest processes and storage. Understanding this may assist in determining the suitability of different species to specific processing and storage methods (Malik *et al.*, 2021). Generally, the proximate compositions of these fish species studied are within the recommended and safety level for consumption.

MINERAL COMPOSITIONS

Minerals play important role in maintaining body functions because they maintain acid base balance, and help blood formation (hemoglobin formation). They also control the water balance in the body, help bones formation and teeth structure, and catalyze many metabolic reactions (Njinkoue *et al.*, 2016). All aquatic animals require minerals for their vital physiological and biochemical functions and to maintain their normal life processes (Lall and Kaushik, 2021). The importance of minerals as food ingredients is not only for their nutritional and physiological roles, but they also contribute to food flavor and also activate or inhibit enzyme catalyzed and other metabolic reactions, and they affect the texture of food (Raffic *et al.*, 2020). Frozen storage of fish and fish products has direct effects on mineral composition, because of the losses of mineral during slow freezing to the separation of water from colloidal solution or plasma and its conversion to pure ice (Malik *et al.*, 2021). Similarly, the variation in minerals contents of fish species during storage condition could be attributed to differences in concentration of the mineral ions in the fish flesh, feeding behavior, migration, environment and ecosystem (Malik *et al.*, 2021).

Several researchers have reported mineral compositions of different fish species and documented differences due to species (Achionye-Nzeh *et al.*, 2011; Guizani and Moujahed, 2015; Haizhou *et al.*, 2022; Okpanachi *et al.*, 2018; Stanton *et al.*, 2020; Tenyang *et al.*, 2014). In this study all the mineral compositions parameters were affected by the species but not the collection station. For instance, highest amount of Sodium (Na) was reported in *C. harengus* which was significantly higher than that of *S. scombrus* and *T. trachurus*. Furthermore, the highest amount of Calcium (Ca) was reported in *S. scombrus* which was significantly higher than that of *T. trachurus* and *C. harengus* and the highest amount of Manganese (Mn) was reported in *T. trachurus* which was significantly higher than that of *S. scombrus* and *C. harengus*. This is similar to the observation of Stanton *et al.* (2020) who studied on *C. harengus, C. aper* and *M. poutassou* and that of Achionye-Nzeh *et al.* (2011) who studied on *S. scombrus, T. trachurus, K. Pelamis* and *G. lineates. C. harengus* and *T. trachurus* had the highest Sodium (Na) and Manganese (Mn) contents and this observation may be due to differences in species of fish studied. The mineral compositions in this study varied significantly among the species this may be due to the fact that variations in concentrations of these mineral elements varies from one species of fish to another and also due to the chemical forms of the elements and their concentrations in the local environment (Babalola *et al.*, 2011). Expectedly, all fishes absorb minerals not only from their diets but also from the surrounding aquatic environment via their gills and skin (Nurnadia *et al.*, 2013).

CONCLUSION

The proximate composition varied among the species but most of the parameters were not affected by the collection stations. *T. trachurus* had the best proximate composition among the fish species. The minerals compositions of these fish species were also affected by the fish species. However, they were all within the recommended levels, while *T. trachurus* had the best proximate compositions among the experimented fish species, all the fishes had proximate and mineral compositions within the safety levels and fit for human consumption.

RECOMMENDATION

The study recommends the following;

i. *T. trachurus* is recommended as the best for human consumption due to its higher protein composition and the least microbial load compared to *S. scombrus* and *C. harengus.*

ii. Local government health officers and food safety agencies such as NAFDAC should increase awareness on the risks of frozen food contaminants and their effects on human health if they are not properly handled.

iii. Further research is recommended on the study of Nutritional compositions and mineral analysis of some frozen marine fish species from other Local Government Areas of Kano State, Nigeria.

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