Variation of Proximate Contents in Selected Marine Fish from Tanzanian Coast due to Seasonality and Processing Methods

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The effect of seasonality (wet and dry seasons) and processing treatments (frying and boiling) on proximate composition of selected fish species (Alectis ciliaris, Lethrinus harak, Rastrelliger kanagurta and Siganus canaliculatus) from Tanzania marine waters were assessed. The proximate composition of fish was proved to be altered by the fish feeds, salinity, geographical location, seasons and processing methods. Therefore, the fish samples were purposively collected from four selected locations (Tanga, Bagamoyo, Dar es Salaam and Mtwara) and treated as appropriately. Proximate parameters were determined using AOAC standard methods. The proximate contents varied with changing seasons in all the fish species. Crude protein and lipid contents increased in wet season while moisture and ash contents increased in dry season. The effect of changing seasons in proximate contents was significant ($p < 0.05$) except in ash. Frying process had a significant effect ($p < 0.05$) on proximate contents in the fish species than boiling process except in ash. The derived model accurately predicted the extent of variation of proximate contents with both dry and wet seasons and processing treatment in particular frying. However, it failed to predict the extent of variation of lipid, crude protein and moisture with boiling treatment. Further research is needed to establish the extent of variations of proximate contents due to other processing methods such as steaming and microwaving.

Keywords: *Alectis ciliaris,* processing methods, proximate contents, dry season, marine water

Introduction

Fish are a natural source of polyunsaturated fatty acids, dietary sources of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), a form of omega-3, that has great health benefits (Parker *et al.*, 2019). Fish are also highly proteinous as they contain essential amino acids, which are the building materials of proteins. These biochemical components to be preserved with little or no change (Njinkoue *et al.*, 2016) so that they are

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invariably more or less the same regardless of changing environment and species.

The biochemical composition of fish may be altered by, among others, fish feeds, salinity, geographical location, season and processing methods (Bogard *et al.,* 2015). Geographical locations and seasonal changes do affect the fish environment due to the availability and composition of feeds, which consequently affect the chemical composition of their muscle fillet. The general composition of fish body is the final function of the available food fed by fish and the assimilative capacity of individual fish. Likewise, the fluctuation of water temperature across the seasons (wet and dry) and the activities of fish (reproduction and migration) could influence the biochemical composition of muscles (Bandarra *et al.,* 2001; Olsson *et al.,* 2003). There is a relationship between location and availability of fish on one hand and the climate and oceanographic conditions on the other (Van Der Elst *et al.,* 2005).

The fish consumer consider the flesh texture, taste, protein and fat contents (Pal & Ghosh, 2013). However, fish can be eaten raw but preference is when treated under various processes such as boiling, grilling, frying and may other (Ersoy & Özeren, 2009). These processes tend to improve the flavor, taste, inactivate pathogenic microorganisms and increase shelf life (Bognár, 1998). This could lead to important biochemical changes in composition (Weber *et al.,* 2008). The principal changes that occur during processing are oxidation during heating, which is catalyzed by heat, light and additional trace metals or enzymes that generate free radicals (Loughrill & Zand, 2016). Heat may also cause denaturation and mineral solubilization (Gladyshev *et al.,* 2007).

Changes of the composition of fish due to seasonal variation and processing methods has raised concern to human health (Ozogul *et al.* 2011; Aberoumand & Ziaei-Nejad, 2015). The mineral content of fish is directly related to the type of feed, which can vary with seasons (Khitouni *et al.,* 2014). Similarly, processing methods can cause modification in the proximate, amino acids, minerals and thus change the biochemical composition of fish (Laly & Venketeswarlu, 2016). Variation can occur in fish of same species and different species at different geographical locations (Balogun & Talabi, 1986). The feeding habit and climatological differences between two seasons may affect the biochemical composition of the fish species (Balogun & Talabi, 1986).

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Fish have the ability to absorb minerals not only from their diets but also from water (Lall & Tibbetts, 2009). The exchange of ions from the aquatic environment across gills and skin of fish complicates the determination of the quantitative dietary requirements of minerals (Roy & Lall, 2006). The variation of minerals and proximate contents in tissues of marine and fresh water fishes at different locations and seasons has also been determined (Abdullahi, 2005, Olgunoglu *et al.* 2014, Abdulkarim *et al.*, 2015).

Common processing methods in fish include, among others, frying, boiling, sun drying and smoking. These processing methods usually improve the hygienic quality of the fish (Abdulkarim *et al.* 2015) and inactivate the pathogenic microorganisms (Bognár, 1998). The processing methods can have some effect on the biochemical composition of the fish. Little information is available on the variation of mineral contents in fish (*Alectis ciliaris, Lethrinus harak, Rastrelliger kanagurta and Siganus canaliculatus*) from Tanzania marine waters due to changing seasons and after being subjected to different processing methods. Therefore, the aim of the study was to evaluate the effect of variation of seasons (wet and dry) and processing methods (frying and boiling) on the proximate contents of the selected fish.

Materials and Methods

Sampling

The sampling was conducted at the Indian Ocean seaports i.e. Tanga, Dar es Salaam, Mtwara and Bagamoyo (Figure 1) that experiences wet and dry season annually. The hottest period extends between November and February while the coldest period occurs between May and August. In October to December, north and east of Tanzania experience two distinct wet periods with short rain periods and long rains from March to May. The southern, western and central parts experience one wet season that run from October through to May (Karmalkar *et al.,* 2003).

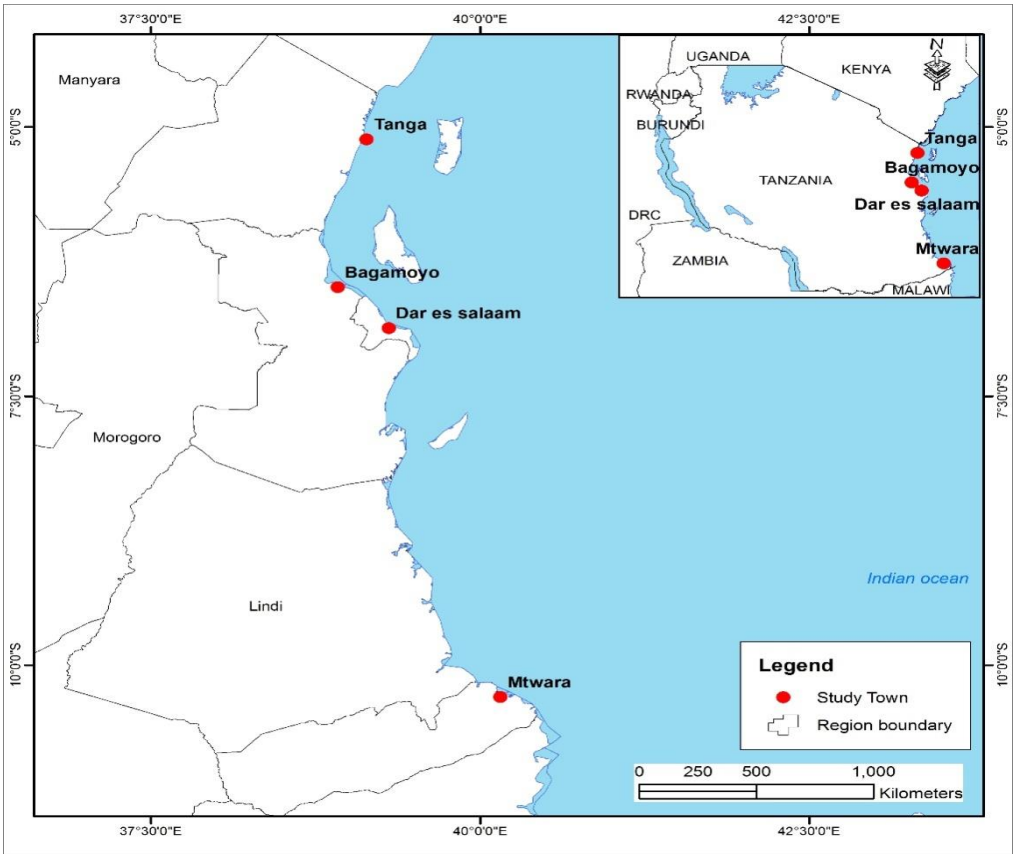

Figure 1: Map of the coast of Tanzania showing the Study areas

The coastal areas of Tanzania are occupied by communities with more or less the same cultures and traditions. Life-earning activities of the coastal communities are mostly agriculture, livestock keeping and fishing. Industrial activities that involve manufactures of textile, furniture, fertilizers, soap as well as mining are also practiced (Francis & Bryceson, 2001; Glauber & Jeppesen, 2014). The industries found in the coastal regions of Tanzania include Cement, Beverages and many others.

Four fish samples of appropriate length (28 - 30 cm) and weight (1.0 - 1.2kg) for each fish species were randomly purchased offshore from each of the four locations (Tanga, Bagamoyo, Dar es Salaam, and Mtwara) during wet and dry season of the year 2017. The selected fish species were the African pompano (*A. ciliaris*), Snappers (*L. harak*), Mackerel (*R. kanagurta*) and Rabbit fish (*S. canaliculatus*). The choice of the fish species for this study was based on their abundance, availability, popularity and ease recognition by consumers. Fishes were kept in polythene labeled bags in a cool box filled with ice cubes and transported to the laboratory for processing and analysis. Analysis of proximate composition was done at the Department of Animal Sciences and Production (DASP), Sokoine University of Agriculture (SUA) in Morogoro.

Sample Preparation
Four fish samples in each of the four species from the four sampling sites were washed several times with tap water to remove slime and adhering blood. The head, scales, gills, tail, fins, bones and internal organs of sampled fish were also removed using clean plastic knife. Only the edible portions of the muscle between the dorsal fin and lateral line were used for analyses. The muscles of the four samples were filleted and randomly mixed together forming a composite. The filleted muscle tissues by species and by location of the catch were then divided into three portions. The first portion were the uncooked therefore considered raw fish fillets while the other two groups were cooked using common household practices, namely frying and boiling.

Deep frying was performed in a domestic frying pan of 2 litres and 25 cm diameter capacity at an initial temperature of 180 °C for 15 minutes (Marimuthu *et al.,* 2014). Sunflower cooking oil extracted from the fatty kernels of *Helianthus annuus* with no other additional ingredients was used as the medium of frying whereby each fish sample was fried using separate cooking oil (oil used only once). After 15 minutes of frying, the fish fillet samples were drained on stainless steel grills, air cooled then packed in labeled aluminum foil in duplicates.

A saucepan covered with a lid was used in boiling of fish sample in one litre cold water with no additional ingredients at boiling point 99–101°C for 12 minutes (Marimuthu *et al.,* 2014). Each sample was boiled using clean (unused) water to avoid contamination and mixture of the nutrients. After boiling, the samples were drained and left to dry and cool then stored in labeled aluminum foil in duplicates. The raw and processed (fried, boiled) fish samples were then stored in laboratory refrigerator at -20 °C until analysis.

Analysis of Proximate Contents
Prior to analysis, the fish samples (boiled, fried and raw) were left to thaw and then oven-dried at 105^{o}C - 109^{o}C for 20 hours to a constant weight. Then, each sample was ground to fine powder using a mortar and pestle for homogeneity. Thereafter, fish sample were then kept in a desiccator ready for further analyses.

Proximate composition analysis was done using Association of Official Analytical Chemists-AOAC methods (Helrich, 1990). Dry matter was analyzed by using clean and dried crucibles that were left to cool in a

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moisture free desiccator. Each crucible was weighed, labeled (W_1) using an analytical balance and recorded. The samples were weighed 2g (W_2) in duplicates then put in the labeled crucibles. The labeled crucibles with samples were transferred using tongs to an oven at temperature105 ^{o}C for 24 hrs until no moisture left. The dried samples in crucibles were removed from the oven and left to cool in a desiccator for 10 minutes before re-weighed (W_3). The percentage of dry matter (DM) was calculated as follows:

$$DM\,(\%) = \frac{W_3}{W_2}\,n\,100 \qquad \textit{Equation 1}$$

where W_1 = Weight of empty crucible; W_2 = Weight of original sample; W_3 = Weight of dried sample and DM = Dry matter.

The ash content was determined in a sample dried in a muffle furnace and incinerated at combustion temperature 550 ^{0}C for 24 hours. Percentage ash content was computed by carrying out the following calculations:

$$Ash\,(\%) = \frac{(W_3 - W_2)}{(W_2 - W_1)}\,n\,100 \qquad \textit{Equation 2}$$

where W_1 = Weight of empty crucible; W_2 = Weight of fresh sample and W_3 = Weight of dried sample

The crude protein was analyzed by determining Nitrogen value through the Kjeldahl standard method according to AOAC. The Nitrogen percentage (% Nitrogen) contained in the samples was calculated by the following formula:

$$\%Nitrogen = \frac{(W_1 - W_2) \times Normality\ of\ HC1 \times N_2 \times 100}{W_3 \times W_4}$$

$$\%Nitrogen = \frac{Titre\ value \times 0.01 \times 14.007 \times 100}{0.5g \times 10\ ml} \qquad \textit{Equation 3}$$

where W_1 = Volume of HCl titrates sample; W_2 = Volume of HCl titrates blank; W_3= Sample weight (g); W_4 = Volume of known aliquot; N_2 = Nitrogen atomic weight and % crude protein = % Nitrogen x 6.25

Crude lipid in the fish samples was determined according to Helrich (1990). Briefly, fish sample (5 gms) (W_1) was placed into a pre - weighed labeled extraction thimble (W_2). Then, the sample dried in an oven at 105 ^{0}C for 30 minutes. Later, petroleum ether (40 mL) was poured into a labeled extraction cup. The labeled extraction thimble with the sample was fitted tallying with the cups and inserted into extraction unit, the Soxhlet Extraction apparatus at 115 ^{o}C for 15 minutes. After reflux extraction, the cups with the thimble were left to cool for 45 minutes. The thimble was moved lower and ether was reclaimed using the apparatus by distilling out some ether. Thereafter, the cup with the pure fat contents was cooled in a

desiccator and later weighed (W_3). The percentage crude fat was calculated as follows:

$$\text{Protein}(\%) = \frac{(W_3 - W_2)}{W_1} \text{n}\,100 \qquad \textit{Equation 4}$$

Where W_1 = Weight of sample; W_2 = Weight of thimble and W_3 = Weight of cup after extraction

Data Analysis

Data from this study were analyzed using IBM SPSS package (Version 20) where mean and standard deviations were determined. An independent sample t- test and Levene's test were used to compare the mineral and proximate contents of the fish between the seasons and different processing methods (between raw and fried fish and between raw and boiled fish). The effects of processing methods on mineral and proximate contents in fish species was determined by using Analysis of Variance (ANOVA) in each fish species at 5 % significance level. Concentrations of each mineral in the fish tissue samples and dummies of seasons were fitted in simple linear and multiple regression models to estimate the parameters. The Principle Component Analysis (PCA) as a multivariate analysis technique was used to detect similarities as well as differences of variables in the fish species.

Results and Discussion

Variation of Proximate Contents in Fish between Seasons

Mean contents of ash and moisture in *A. ciliaris* were low in wet season and high in dry season. On the other hand, protein and lipid contents were high in wet season and low in dry season (Figure 2a). There was a significant variation ($p < 0.05$) in means crude protein and moisture contents in *A. ciliaris* between seasons. However, the difference in the mean ash and lipid were not significant. The mean contents of ash and moisture in *L. harak* during wet season were lower than those in dry season. The mean contents of crude protein and lipids were high in wet season than in dry season (Figure 2b). There was a significant difference ($p < 0.05$) in the mean lipids and moisture contents in tissues of *L. harak* between seasons, while there was no significant difference in ash and crude protein contents.

The mean contents of ash and moisture in *R. kanagurta* during wet season were lower than the contents in dry season. On the other hand, crude protein and lipid were higher in wet season than in dry season (Figure 2c).

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There was no significant difference ($p > 0.05$) in mean proximate contents in tissues of *R. kanagurta* between seasons, while a significant difference was observed in lipid content.

The mean proximate contents in tissues of *S. canaliculatus* are summarized in Figure 2d. Ash and moisture contents were lower during wet season compared to dry season. Crude protein and lipid contents on the other hand were high in wet season compared to dry season. Except for ash content, there was a significant difference ($p < 0.05$) in the other proximate contents of *S. canaliculatus* between the seasons.

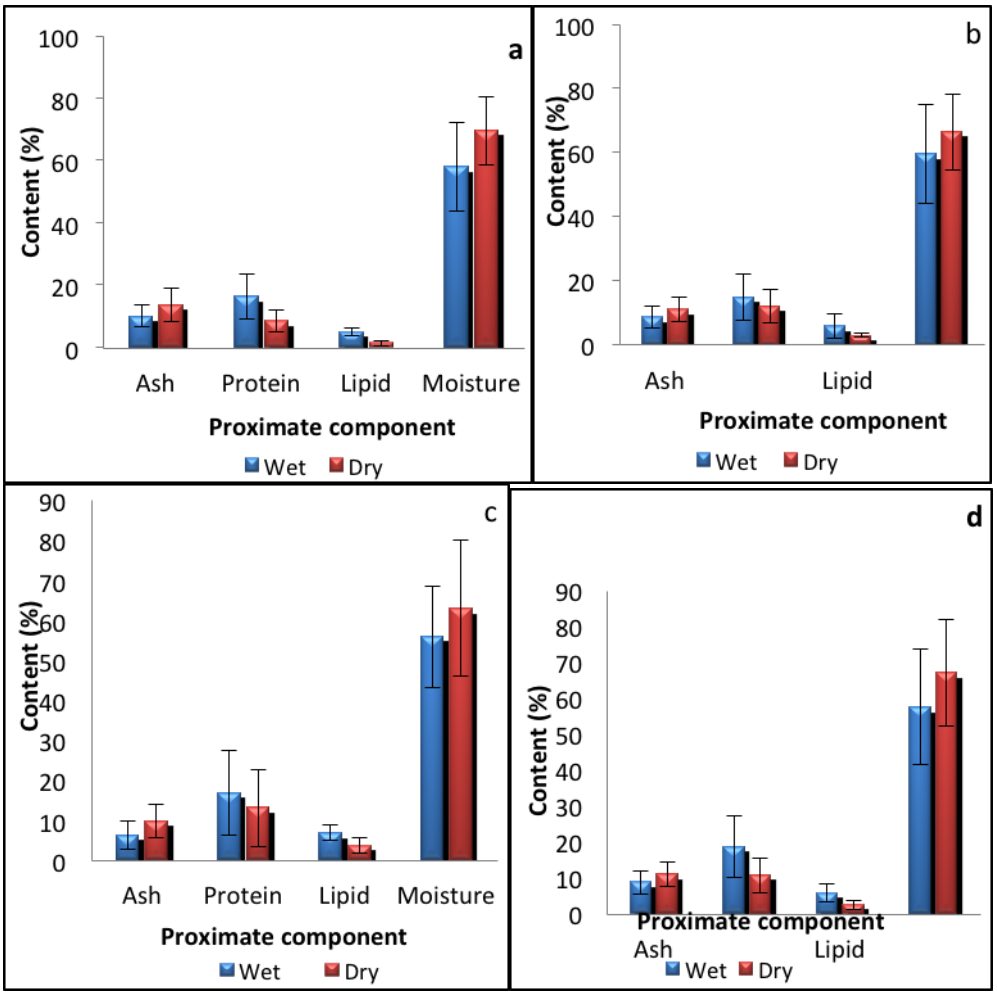

Figure 2: Seasonal Variation of proximate contents in *A. ciliaris* (a), *L. harak* (b), *R. kanagurta* (c) and *S. canaliculatus* (d)

The overall mean concentration of ash, crude protein, lipid and moisture in the selected fish species during wet season that were compared to those collected in dry season as shown in Table 1. Ash and moisture contents in

fish species collected in wet season were lower than in dry season, while crude protein and lipid contents were higher in wet season than those in dry season. There was a significant difference ($p < 0.00$) in lipid and moisture contents in fish between seasons. However, the observed differences in ash and protein contents were not significant ($p > 0.05$).

Table 1: Variation of proximate contents in fish species between seasons

	Ash	Protein	Lipid	Moisture
Wet (%)	8.46±3.51	3.20±1.30	5.89±2.62	57.81±14.41
Dry (%)	11.49±2.20	3.62±1.08	2.69±1.32	66.64±15.38
d.f.	179	190	189	189
F-value	0.00	32.18	57.26	40.20
p-value	0.98	0.00	0.00	0.00

The mean proximate contents results from the four fish species (*A. ciliaris, L. harak, R. kanagurta, S. canaliculatus*) recorded significant variations between season ($p < 0.05$) in some proximate parameters except in ash contents among all fish species, moisture in *R. kanagurta* and crude protein in *L. harak* and *R. kanagurta*. The variation of chemical composition of fish varies greatly with species, sex, age, environment and season (Alemu *et al.* 2013; Sonavane *et al.*, 2017). With these results, it can therefore be assumed that, seasonal variability causes temperature difference. This will apparently affect the fish feed consumption, metabolic rate and energy expenditure at the end, the results of proximate contents will change (Paloheimo & Dickie, 1966).

During wet season, the variation of nutrient contents may probably be due to flowing water exchange and nutrients (Blé & Arfi, 2009). Abundance of food supply can clearly change the biochemical composition of fish species while overcrowding may cause insufficiency of food resulting to variation of fish composition (Deka *et al.*, 2012). It has been reported that differences in quality of the fish diet presumably causes variations in the fish body constituents (Ayuba & Iorkohol, 2013). The results of the this study on ash, lipid and moisture contents concur with those reported by Olgunoglu *et al.*, (2014) who studied Mesopotamian Catfish (*Silurus triostegus*). However, Nargis (2006) who studied *Anabas testudineus* from Bangladesh did not conform with this study. The contrasting results may perhaps be explained by location differences as reported by (Bunnet, 1988).

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The effect of processing treatments on proximate composition

The mean proximate contents in processed fish were compared to those of raw fish as control (Figure 2). The mean ash contents in all fish species slightly decreased in boiled fish but were more or less similar with those in raw and fried fish. Crude protein and lipid contents in all fish species increased in both processing methods, more so in fried fish. On the other hand, moisture contents in all fish species decreased in both treatments, more so in fried fish (Figure 2). With the exception of ash content in *A. ciliaris* and *L. harak*, there was significant difference ($p < 0.05$) in the proximate contents between raw and cooked fish. Furthermore, there was significant difference ($p < 0.05$) in all analyzed proximate contents in *R. kanagurta* and *S. canaliculatus* between raw and boiling processing methods.

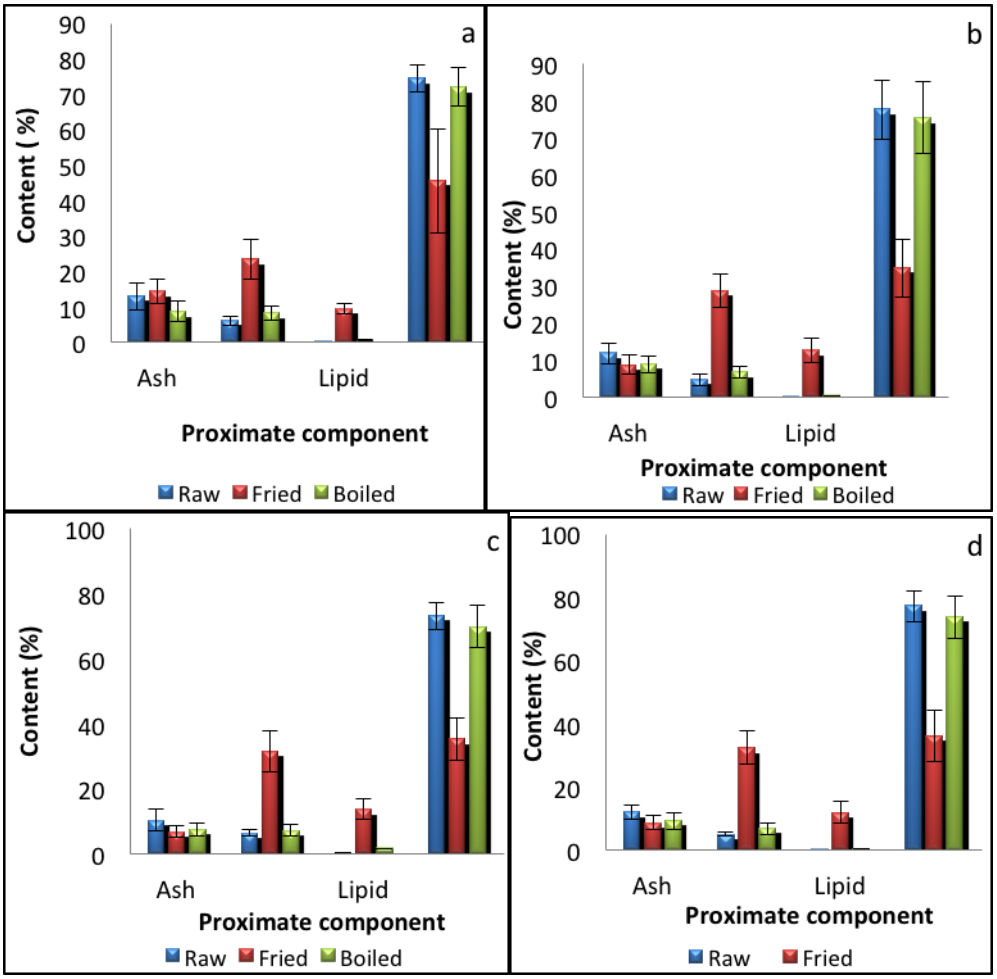

Figure 3: Variation of Proximate Contents due to Processing methods in* A. ciliaris *(a),* L. harak *(b),* R. kanagurta *(c) and* S. canaliculatus *(d)

The overall mean proximate contents in fried fish samples were compared to raw fish and summarized in Table 2. Ash and moisture contents in fried

fish were lower compared to the contents in raw fish. The fried fish showed high protein and lipid contents compared to raw fish.

There was a significant difference ($p < 0.05$) in proximate contents between fried and raw fish except in ash (Table 2).

Table 2: Variation of proximate contents in fried from raw fish

Processing method/ proximate content	Ash	Protein	Lipid	Moisture
Raw (%)	11.80±4.51	2.84 ±1.09	0.27±0.21	75.62±3.65
Frying (%)	9.57±7.99	5.21±2.73	11.89±7.66	38.06±19.28
d.f.	125	81.163	62.29	66.36
F-value	1.13	64.91	158.59	108.67
p-value	0.29	0.00	0.00	0.00

The changes of proximate contents when fish samples were boiled and compared to raw fish are outlined in Table 3. Ash, protein and moisture contents in boiled fish were lower compared to the contents in raw fish. Boiling increased lipid content compared to raw fish. Whereas there was a significant difference ($p < 0.05$) in lipid content between raw and boiled fish, there was no significant variation in other proximate contents between the two processing methods (Table 3).

Table 3: Variation of proximate contents in boiled from raw fish (%)

Processing method/ proximate content	Ash	Protein	Lipid	Moisture
Raw (%)	11.80±4.51	2.84 ±1.09	0.27±0.21	75.62±3.65
Boiled (%)	8.61±4.76	2.21±0.99	0.80±0.14	72.71±5.34
d.f.	125	125	70	109
F-value	0.39	1.36	13.16	6.81
p-value	0.53	0.25	0.00	0.10

The differences of proximate contents between fried and boiled fish samples are presented in Table 4. Ash, protein and lipid contents in boiled fish were lower compared to the contents in fried fish whereas moisture in boiled fish was higher than in fried fish. With the exception of ash content, there was a significant difference ($p < 0.05$) in all other proximate contents between fried and boiled fish and not in ash (Table 4).

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Table 4: Variation of Proximate contents between boiled and fried fish

Processing method/ mineral content	Ash	Protein	Lipid	Moisture
Frying (g/Kg)	9.57±7.99	5.21±2.73	11.89±7.66	38.06±19.28
Boiling (g/Kg)	8.61±4.76	2.21±0.99	0.80±0.14	72.71±5.34
d.f	124	125	124	124
F-value	0.67	133.21	127.35	189
p-value	0.42	0.00	0.00	0.00

The results of proximate composition of the current study showed a decrease of ash and moisture in fried compared to raw fish. Boiled fish had higher lipid content than other proximate contents when compared to raw. The t-test statistical outputs expresses a significant difference ($p < 0.05$) of proximate contents between raw and cooked fish except in ash for both processes and crude protein, lipids and moisture in boiled fish. The decrease of ash contents in processed fish species compared to raw, agreed with (Pomeranz & Meloan, 1994) who considered minerals as the total amount of minerals. The results of proximate contents in processed fish species were in agreement with the studies of (Karimian-khosroshahi *et al.,* 2016; Cristelle *et al.,* 2018). However, the findings of ash and protein contents in this study were not in accord with the report of (Aberoumand & Ziaei-Nejad, 2015) as well as results of ash in the study done by Gall *et al.,* (1983) and (Marimuthu *et al.,* 2012). Deviation of ash contents in the current study from other studies may probably be induced by the duration time used during frying.

Predicting Variation of proximate contents due to seasons

A predictive model was developed to establish the extent of changes in proximate parameters due to seasonal changes. Linear regression analysis was applied to assess the relationship between proximate contents in selected fish species and seasonal changes. The predictive model values of the proximate composition in seasons were determined by the regression equation:

$$Y_i = b_o + bx + \varepsilon_i \qquad \textit{Equation 1}$$

The predicted model results are summarized in Table 5. The percentage (%) of variance in the dependent variable (proximate content) that can be explained by the independent variable (seasons) are 6.3 % for ash, 4.1 % for crude protein, 5.3% for lipids and 4.6 % for moisture) as expressed by the predictive model.

Table 5: Linear regression prediction analysis of proximate composition between seasons

Proximate composition	R^2	(b_0)	Wet Dummy variable (bx)	F value	p value	Predicted value
Ash	0.063	11.50	-3.04	12.69	0.00	8.46
Crude Protein	0.041	11.16	5.56	8.18	0.00	16.42
Lipid	0.053	2.68	3.21	10.61	0.00	4.89
Moisture	0.046	66.67	-8.83	9.12	0.00	57.87

In wet season relative to dry season, ash content is predicted to decrease by 3.04 %, and the decrease is expected to be significantly lower ($p < 0.05$).

Crude protein content is predicted to increase by 5.56 % in wet season compared to dry season. The increase is expected to be significantly higher ($p < 0.05$). Similarly, lipid content in wet season is predicted to increase by 3.21 % compared to dry season, the change is expected to be significantly higher ($p < 0.05$). Furthermore, moisture content in wet season is predicted to decrease by 8.83 % compared to dry season and the change is expected to be statistically significantly lower ($p < 0.05$).

The predictive model values of proximate composition in the fish species between seasons will vary by 8.46 % for ash, 16.72 % for crude protein, 4.89 % for lipid and 57.84 % for moisture. There is a statistical significant contribution ($p < 0.05$) of seasons in variation of proximate contents. This is an indication that the model can accurately predict proximate contents using seasons as a predictor.

Predicting Variation of proximate contents due to processing methods

Multiple regression analysis was applied to assess the relationship between proximate contents found in tissues of the sampled fish species and processing methods (frying and boiling). The findings of the study showed that the predictive model values of the proximate composition due to varying processing methods can be determined by the multiple regression equation:

$$Y_i = b_0 + b_1x_1 + b_2x_2 + \varepsilon_i \qquad \textit{Equation 2}$$

The predicted model results are summarized in Table 6. The percentage (%) of variance in the dependent variable (proximate) that can be explained by the independent variable (processing methods) are 4.60 % for ash, 60.6 % for protein, 59.1 % for lipid and 68.3 % for moisture as described by the

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multiple regression model. The model predicted a decrease in ash contents by 2.14 % in fried fish and 3.09 % in boiled fish compared to raw fish. The changes are expected to be statistically significantly lower ($p < 0.05$).

Crude protein content is predicted to increase by 23.36 % in fried fish and 1.62 % in boiled fish compared to raw fish. The change is predicted to be statistically significantly higher ($p < 0.05$) for fried fish and not for boiled fish.

Table 6: Multiple regression prediction analysis of proximate contents due to processing methods

Proximate content	Processing Method	Model value (b)	t value	p value	F value	R^2	Constant (b_0)
Ash	Frying Dummy (b_1)	-2.14	-2.03	0.04	4.55	0.046	11.71
	Boiling Dummy (b_2)	-3.09	-2.94	0.00			
Crude protein	Frying Dummy (b_1)	23.36	15.31	0.00	145.15	0.606	5.63
	Boiling Dummy (b_2)	1.62	1.06	0.29			
Lipid	Frying Dummy (b_1)	11.62	14.66	0.00	135.66	0.591	0.27
	Boiling Dummy (b_2)	0.53	0.67	0.50			
Moisture	Frying Dummy (b_1)	-37.51	-18.15	0.00	202.46	0.683	75.56
	Boiling Dummy (b_2)	-2.85	-1.38	0.17			

Lipid contents were predicted to increase by 11.62 % in fried fish and 0.53 % in boiled fish. The predicted change is expected to be significantly high ($p < 0.05$) for fried fish and not for boiled fish. The moisture contents were

predicted to decrease by 37.5 % in fried fish and 2.85 % in boiled fish. Like lipids and crude protein contents, the change in moisture content is predicted to be statistically significant for fried fish and not for boiled fish.

The predicted proximate values due to processing methods were 6.48 % for ash, 30.61 % for crude protein, 12.42 % for lipid and 35.20 % for moisture. There is a statistical significance contribution ($p < 0.05$) of both frying and boiling methods to ash content and frying method to crude protein, lipid and moisture. The model can accurately predict the variation of ash content using both processing methods as predictors. However, the model can only predict accurately the variation of crude protein, lipid and moisture when frying processing method was used as the predictor.

Pearson Correlation Coefficients and Principal Component Analysis (PCA)
In determining the relationship between proximate composition, seasons and processing methods, Pearson correlation coefficient and PCA were employed. Table 7 indicates that significant positive correlations were observed for variables between crude protein and ash, lipid and crude protein, moisture and ash, processing method and ash, season and ash as well as season and moisture. However, there were significant negative correlations between lipid and ash, moisture and crude protein, moisture and lipid as well as season and lipid.

Table 7: Pearson Correlation Coefficients of the analyzed variables

	Ash	Crude protein	Lipid	Moisture	Process	Season
Ash	1					
Protein	**0.463**	1				
Lipid	**-0.200**	**0.540**	1			
Moisture	**0.286**	**-0.571**	**-0.926**	1		
Process	**0.218**	0.119	-0.032	0.058	1	
Season	**0.251**	0.097	**-0.230**	**0.215**	0.000	1

Bold values means significant correlation at the $\alpha = 0.01$ (2-tailed).

PCA after varimax rotation was employed in this study. A principal component (PC) was considered significant when its eigenvalue was greater than 1. The measured values were used as variables total six (6) with the concentrations of the nutrients in the different sampling stations as objects (total 192). Based on the loading distribution of the variables, the PCA results indicated that the variables can be represented by two principal components (PCs) that accounted for 67.7 % of the total variance in the original data sets (Table 8).

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Table 8: Rotated loadings of the Principal components

	Principal Component (67.7%)	
	PC 1 (40.2%)	**PC 2 (27.5%)**
Moisture	**-0.951**	0.214
Lipid	**0.942**	-0.175
Crude protein	**0.753**	**0.567**
Ash	-0.054	**0.889**
Season	-0.220	**0.526**
Process	0.024	0.432

Based on the results in Table 8 they indicate that crude protein, lipids (EE) and moisture that contributed 40.2 % of total variance and constituted related group (PC 1), indicating their relationship. Similarly, crude protein, ash and seasons constitute another related group (PC 2). This has been shown in Table 8 where these variables are significantly correlated to each other (p = 0.00). However, the changes of Ash content is related to processing methods and season while moisture and lipids (EE) are negatively related (Table 7).

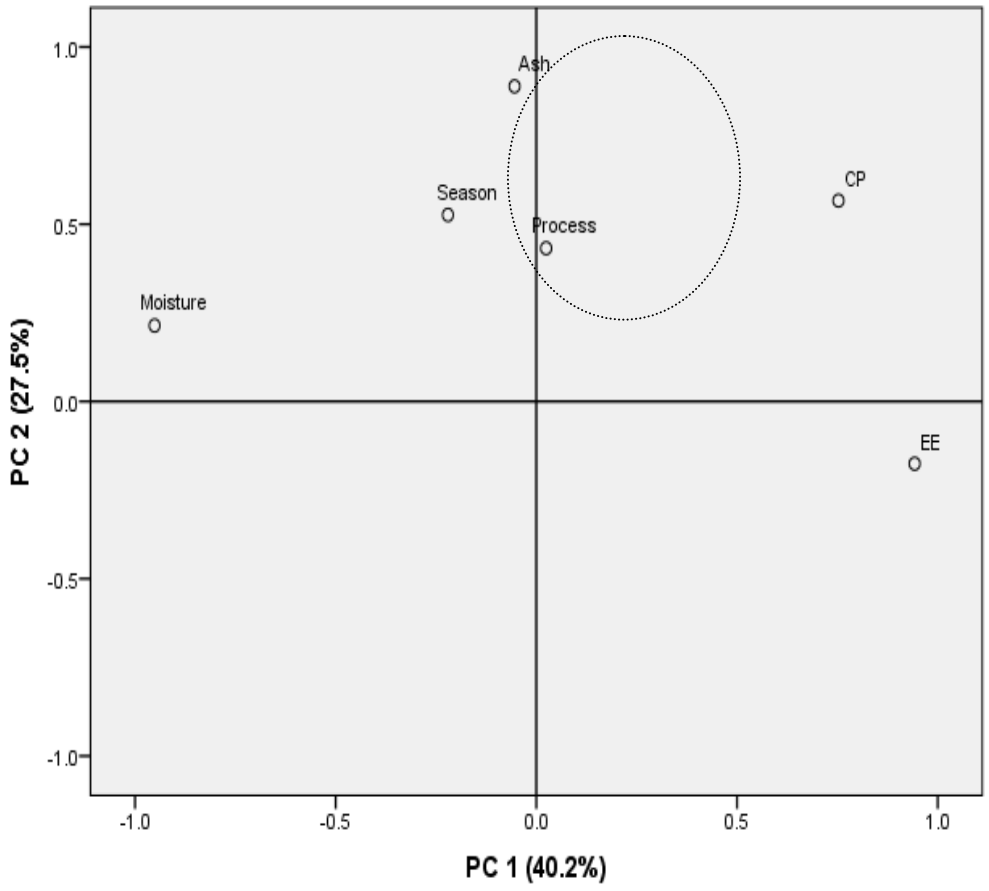

Figure 4: A two dimensional score plot for the variables in the study

The findings indicated that ash content in the fish was more affected by varying seasons as well as processing methods. This is supported by the significant positive correlation between the ash and season as well as ash and processing methods. On the other hand, moisture, lipid and crude protein were not mostly affected by seasons and processing methods.

Conclusion

The findings of the study have shown that proximate contents of fish species varied with changes in seasons (wet and dry). The results indicated an increase in crude protein and lipid contents during wet season but recorded an increase in moisture and ash contents in dry season. In addition, the effect of boiling treatment on proximate contents in fish was lower than that of frying treatment. Whereas ash content was affected by season and processing methods, moisture, lipid and crude protein were not affected by varying seasons and processing methods. The extent of changes in proximate contents due to changing of seasons was accurately predicted by the derived model. In addition, variation of ash contents was accurately predicted by the model in both processing methods. However, the model failed to predict variation of lipid, crude protein and moisture when using boiling processing method.

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