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Variability of Selected Mineral Contents in Marine Fish from Local Markets in Tanzania

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Abstract

Mineral contents (K, Na, Ca and Mg) in selected marine fish species (*Alectis ciliaris*, *Lethrinus harak*, *Rastrelliger kanagurta* and *Siganus canaliculatus*) from local fish markets were analysed in wet and dry seasons. The processing methods (frying and boiling) were also assessed for their influence on the mineral contents. Samples were randomly collected from Tanga, Bagamoyo, Dar es Salaam and Mtwara seaports, analysed using established methods and determined by Graphite Furnace Atomic Absorption Spectrometry. Mean mineral contents in individual and all analysed fish species were high during dry season compared to wet season except Ca and the difference was statistically significant ($p < 0.05$). Mean K, Na and Mg contents in all fish were decreasing after processing (raw > fried > boiled), while those of Ca were similar. Mineral contents in all fish species between raw and frying as well as between raw and boiling processing methods varied significantly for K only. Variation of mineral contents in all fish species between frying and boiling was not significant. Pearson correlations and Principal component analyses have indicated significant close relationships between minerals (except Ca) and seasonal variations. In addition, significant relationship between processing methods and K mineral only was observed. Derived models have accurately predicted variations of mineral contents due to seasons and variations of K content due to processing methods. Further research is required to determine effects of using steaming and microwaving on mineral contents and what factors control variations of Ca, Na and Mg using frying and boiling in these fish species.

Keywords: Marine fish, wet season, processing methods, *Siganus canaliculatus*, frying.

Introduction

Fish contain among others, essential minerals such as K, Ca, Na, Mg and P (Ahmad et al. 2018) that have to be preserved with little or no change (Njinkoue et al. 2016). As such, the edible portion of fish has to depict little or no variation in the biochemical composition. The mineral composition of fish may be altered by, among others, fish feeds, salinity, geographical location, season and processing methods (Khitouni et al. 2014, 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 seawater 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). Variation can occur in fish of the same species or different species at different geographical locations (Balogun and Talabi 1986). The feeding habit and climatological differences between seasons may affect the biochemical composition of the fish species (Balogun and Talabi 1986).

Processing (sun drying, smoking, salting, boiling, grilling, frying) of fish improves the flavour, taste and hygienic quality (Abdulkarim et al. 2015), inactivate pathogenic microorganisms and increases shelf life (Bognár 1998). However, these processes could lead to biochemical changes (Weber et al. 2008), which include oxidation during heating and additional enzymes and trace metals (Loughrill and Zand 2016), that are added through solubilisation (Gladyshev et al. 2007). Furthermore, processing can cause modification in the proximate, amino acids, minerals and thus change the biochemical composition of fish (Laly and Venketeswarlu 2016).

Changes of the composition of fish due to seasonal variation and processing methods have raised concern to human health (Ozogul et al. 2011, Aberoumand and Ziaei-Nejad 2015). As a result, various studies have been conducted in different types of fish to study the effect of changing seasons and processing methods. For example, studies done by Abdulkarim et al. (2015) observed seasonal variations of Ca, K, P, Na and Mg in tilapia fish (*Oreochromis niloticus*). Ersoy and Özeren (2009) and Adelakun et al. (2017) who worked on African catfish (*Clarias gariepinus*), observed that K and Mg contents were high and Ca was low in the wet season than in dry season. Furthermore, Paul et al. (2015) observed seasonal variation in Koi species (*Anabas testudineus*) from the marine water.

Steiner-asiedu et al. (1991) while working on flat sardine (*Sardinella* sp.) after frying observed that K content varied from 20.3 g/kg to 15.1 g/kg, Na content varied from 27.3 g/kg to 11.8 g/kg, Ca content varied from 16.2 g/kg to 12.8 g/kg and Mg content varied from 1.9 g/kg to 1.5 g/kg. On the other hand, Gall et al. (1983) observed no variation of mineral contents due to processing methods in red snapper (*Lutjanus campechanus*). Marimuthu et al. (2014) observed that Na and K contents were increasing while Ca and Mg contents were decreasing in Asian sea bass (*Lates calcarifer*).

The coast (north and eastern parts) of Tanzania experiences two distinct wet periods with short rainy periods from October to December and long rains from March to May (McSweeney et al. 2017). The remaining months of the year are dry months. The coastal communities of Tanzania are occupied by more or less the same cultures and traditions. Life-earning activities of these communities are mainly agriculture, livestock keeping and fishing. Common fish consumed by the communities include African pompano (*A. ciliaris*), snappers (*L. harak*), Mackerel (*R. kanagurta*) and rabbit fish (*S. canaliculatus*). However, little information is available on the variations of mineral contents in *A. ciliaris*, *L. harak*, *R. kanagurta* and *S. canaliculatus* due to changing seasons and processing methods. Therefore, the aim of this study was to evaluate the effect of changing seasons (wet and dry) and processing methods (frying and boiling) on the contents of K, Na, Ca and Mg in the selected fish.

Materials and Methods

Sampling

The sampling was conducted at the Indian Ocean seaports of Tanga, Dar es Salaam, Mtwara and Bagamoyo (Figure 1) that experience rainy season with heavy precipitation, low salinity and vice versa

during the dry season. A total of 4 sampling campaigns were conducted: 2 in wet season (27th March and 26th April 2017) and 2 in dry season (4th August and 1st September 2017). For each species, African pompano (*A. ciliaris*), snappers (*L. harak*), mackerel (*R. kanagurta*) and rabbit fish (*S. canaliculatus*) four fish samples of appropriate length (28 - 30 cm) and weight (1.0 – 1.2 kg), were purchased offshore from the fishermen at each of the four locations (Tanga, Bagamoyo, Dar es Salaam, and Mtwara) during each sampling campaign (Figure 1).

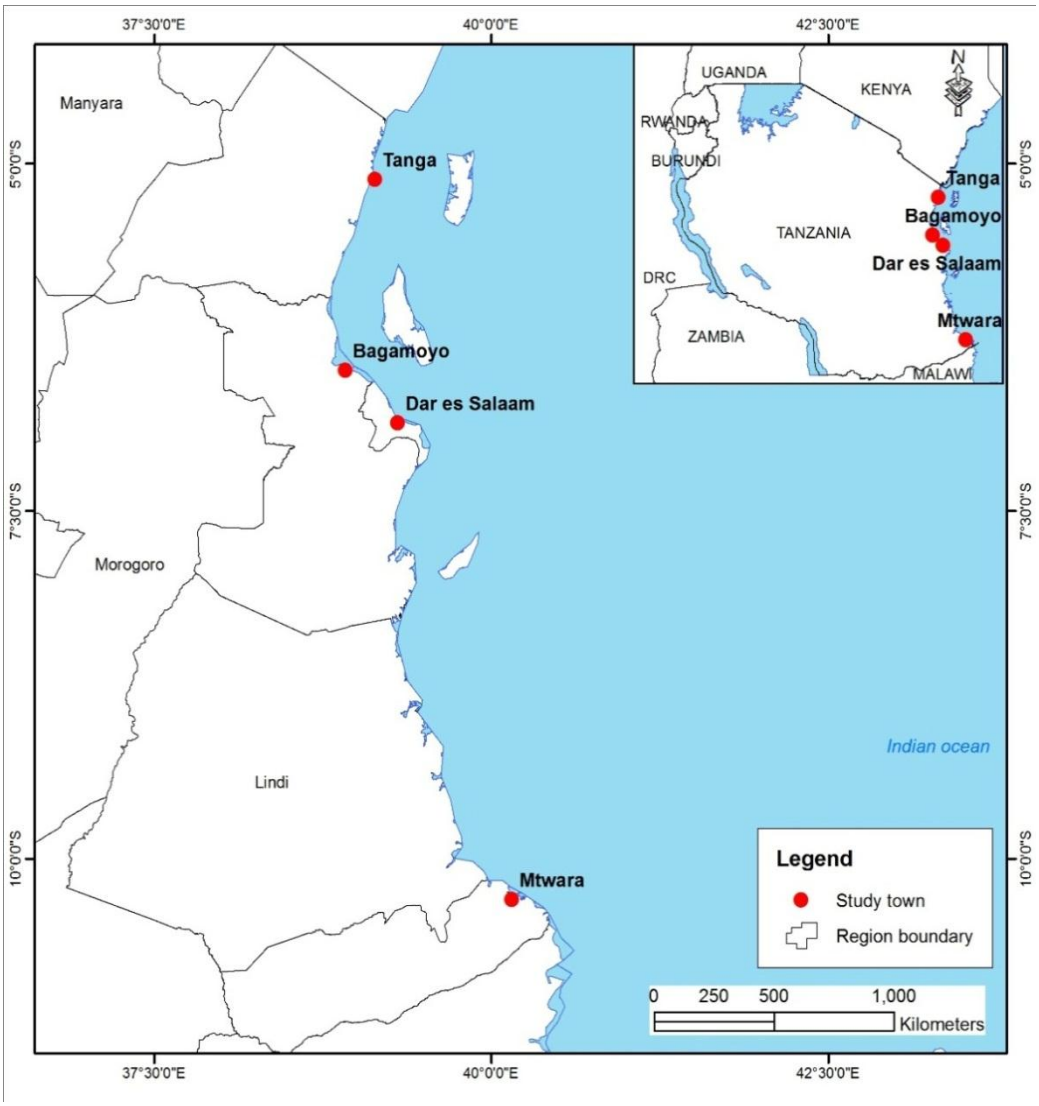

Figure 1: Map of the Coast of Tanzania showing the study areas.

A total of 32 fish samples were collected per site per season, making a total of 256 fish samples for the study. The choice of the fish species for this study was based on their abundance, availability, popularity and ease recognition by consumers. The fish samples were put in prior labelled polythene bags and then stored in a cool box filled with ice cubes. The samples were later transported to the Chemistry Department, University of Dar es Salaam for further storage, processing and analysis.

Sample preparation and analysis

The fish samples were washed several times with clean tap water to remove slime and adhering blood. Then, the head, scales, gills, tail, fins, bones and internal organs were removed using clean plastic knife. Each fish sample was then filleted and the fillet mixed together forming a composite sample. The composite sample of each fish (2.0 g) in duplicate was then divided into three equal portions: one portion was left uncooked (raw), while the other two portions were processed under normal household practices (one portion fried and the other boiled).

Deep frying was performed in a domestic frying pan (25 cm diameter and 2 litres capacity) at initial temperature of 180 °C for 15 minutes (Marimuthu et al. 2014). Sunflower cooking oil extracted from the fatty kernels of *Helianthus annuus* was used as the medium of frying with no other additional ingredients. Each fish sample in duplicate was fried for 15 min using separate portion of cooking oil. Before frying the next sample, the frying pan was thoroughly cleaned with detergents and then rinsed with deionised water. Then, the samples were drained of oil using stainless steel grills, air cooled and then packed in prior labelled aluminium foil ready for mineral analyses.

A saucepan covered with a lid containing clean tap water (1.0 L) was used for boiling of the fish sample with no additional ingredients. Boiling was performed at a temperature ranging from 99 to 101°C for 12 minutes (Marimuthu et al. 2014). Prior to boiling, the saucepan was washed with detergent followed by thorough rinsing with tap water. Each fish sample was boiled separately in duplicate. Thereafter, the samples were drained of water, left to cool and then packed in prior labelled aluminium foil ready for mineral analyses. Both raw and processed (fried, boiled) fish samples were then stored in laboratory freezer at –20 °C until analysis.

Prior to analysis, the fish samples were left to thaw and then oven-dried at 105 °C to 109 °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 kept in a desiccator ready for further analyses. Analysis of K, Na, Ca and Mg minerals in fish involved digestion of the sample, dilution as well as instrumental analysis. In each dry sample (1.0 g) concentrated HNO_3/HCl mixture (1:1, 10 mL, purity > 95%) was added followed by perchloric acid (10 mL). Then, the sample was subjected to digestion process for 30 minutes. After digestion, the sample was filtered into volumetric flask (50 mL) and then diluted to the mark with deionised water ready for analysis. Throughout the analysis blank samples were added in the batch analysis and treated the same as samples.

The analysis of the minerals in fish in duplicate was done using standard methods (Poitevin 2016). Mineral contents were determined by Graphite Furnace Atomic Absorption Spectrophotometer (Model 5000, Perkin-Elmer). Working standard solutions were prepared from the stock solutions by serial dilutions. The working standards together with the blanks were included in the analysis of every batch after every 5 samples. For each mineral five working standard solutions (0.01, 0.03, 0.05, 0.07 and 0.1 ppm for K, Na, Mg and 0.01, 0.05, 0.10, 0.15 and 0.20 ppm for Ca) were prepared and used to generate the respective calibration curves. The regression lines obtained from the respective calibration curves were used to determine the amount of minerals in the fish samples.

Quality assurance and control

The quality assurance and quality control, QA/QC, procedures were followed throughout the analytical steps. Blanks and recovery tests were determined to check for the accuracy of the method and reliability of the results obtained. Procedural blank samples (tap water, cooking oil and reagents) were included in every batch and were subjected to similar treatments like normal samples. Blank correction of the samples was done where the blank samples used contained some levels of the minerals. Percentage recoveries of all the minerals were between 90.0% and 95.1%, which is within the acceptable recovery range (Åkerblom 1995). Calibration curves of the minerals gave linear relationships with $r^2 > 0.99$.

Data analysis

Data from this study were analysed using IBM SPSS package (Version 23). Levene's test was performed to determine the homogeneity of the variances. An independent sample t- test was used to compare the mean mineral contents of the fish in the seasons and different processing methods. The effects of processing methods on mineral contents in each fish species was determined using Analysis of Variance (ANOVA) at 5% significance level. Pearson correlation and Principal Component Analysis (PCA) were used to detect similarities as well as differences of mineral levels in fish species. Concentrations of each mineral in the fish tissue samples and dummies of seasons and processing methods were fitted in simple linear and multiple regression models respectively to estimate the parameters.

Results and Discussion

Variations of mineral contents in fish between seasons

The mean mineral contents in individual and all analysed fish species were high during dry season compared to wet season except Ca. In the fish samples, the seasonal difference was statistically significant (K: $t = 21.323$, $df = 182$, $p < 0.00$; Na: $t = 18.778$, $df = 184$, $p < 0.00$; Mg : $t = 16.083$, $df = 184$, $p < 0.00$) except in Ca ($t = 6.974$, $df = 184$ $p > 0.05$). The mean concentrations of K, Na, Ca and Mg minerals in the different fish tissues between seasons are given in Figure 2.

The levels of K in all fish were more or less similar in both seasons, with slightly lower values in *R. kanagurta*. Na contents in all fish were more or less similar in both seasons with the exception of *R. kanagurta* where they were slightly lower values. The Ca values in all fish in both seasons were more or less similar except in *S. canaliculatus* where slightly lower values were observed. Mg contents in all fish species in wet season were more or less similar while Mg levels in fish in dry season were high in *A. ciliaris* and lower in *S. canaliculatus*. There was a significant difference in mineral contents in fish species between the seasons ($p < 0.05$) except Ca. The levels of minerals in all fish species in both seasons are given in Table 1.

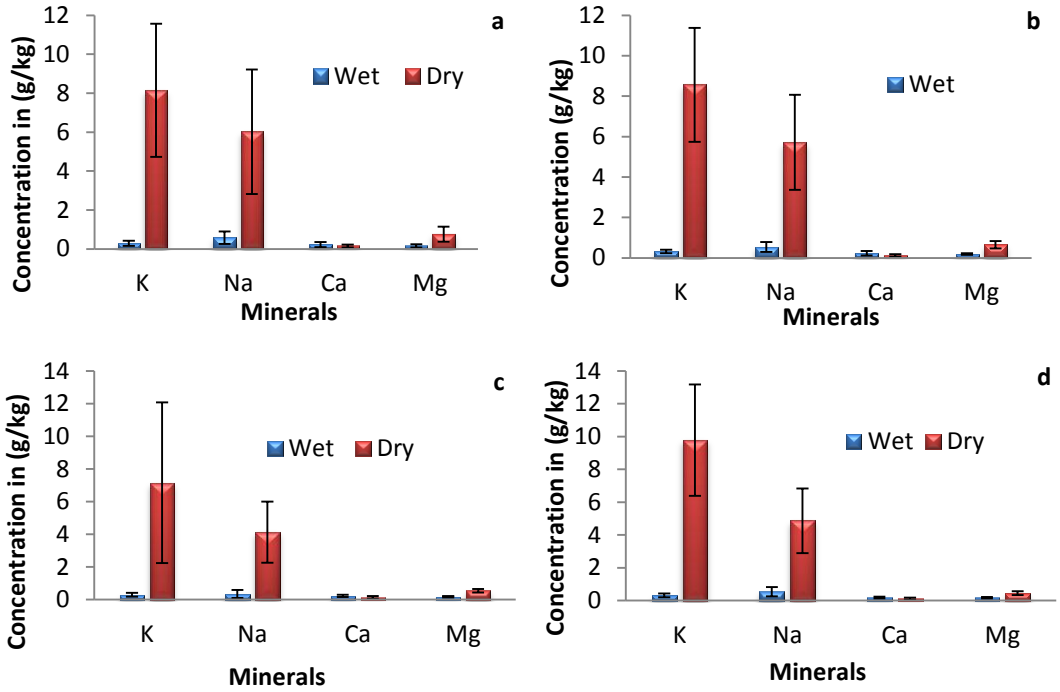

Figure 2: Seasonal variation of mineral contents (mean ± standard deviation) in *A. ciliaris* (a), *L. harak* (b), *R. kanagurta* (c) and *S. canaliculatus* (d).

The variations of mineral contents in fish species could probably be explained by the differences of the fish species' ability to assimilate the feed (Prabhu 2015), the environmental conditions like the coral reefs and mangroves, near river banks as well as the on the amount of minerals brought in by freshwater from rivers (Bunnett 2014). The difference of water temperature between wet and dry season, for example, can cause variation of minerals in the fish body because of its influence on the fish feed consumption, metabolic rate and energy expenditure. Temperature variation may as well accelerate evaporation of seawater causing variation of mineral salts between locations and between parts of the ocean (Bunnet 1988). During the rainy season, temperature is low and increased freshwater inflow into the sea could have a dilution effect on the seawater. As a result, it is not surprising to observe that the amounts of K, Na and Mg are relatively low in all the selected fish during wet season. Such observed variations of the minerals between seasons have also been observed by Olgunoglu et al. (2014) and Paul et al. (2015) on *Silurus triostegus* and Koi fish species, *Anabas testudineus*, respectively.

Table 1: Variation of mineral contents (g/kg) in fish species between seasons

Mineral	Season	*A. ciliaris* (*n* = 64)	*L. harak* (*n* = 64)	*R. kanagurta* (*n* = 64)	*S. canaliculatus* (*n* = 64)
K	Wet	0.29 ± 0.12	0.32 ± 0.09	0.30 ± 0.12	0.32 ± 0.11
	Dry	8.15 ± 3.49	8.56 ± 2.82	7.15 ± 4.93	9.78 ± 3.40
Na	Wet	0.57 ± 0.32	0.52 ± 0.24	0.34 ± 0.24	0.54 ± 0.28
	Dry	6.03 ± 0.21	5.72 ± 2.35	4.13 ± 1.87	4.87 ± 1.97
Ca	Wet	0.22 ± 0.14	0.23 ± 0.11	0.22 ± 0.07	0.18 ± 0.06
	Dry	0.15 ± 0.07	0.12 ± 0.06	0.14 ± 0.07	0.11 ± 0.07
Mg	Wet	0.16 ± 0.08	0.19 ± 0.04	0.16 ± 0.06	0.17 ± 0.05
	Dry	0.76 ± 0.39	0.65 ± 0.18	0.54 ± 0.11	0.45 ± 0.12

Variations of mineral contents in fish species due to processing methods

The mean K and Na contents in all selected fish species decreased due to processing methods (raw > frying > boiling) except in *S. canaliculatus*. Variations of mean mineral levels in all the selected fish species due to processing methods are presented in Figure 3. Whereas Ca contents were more or less the same even after varying processing methods, Mg contents decreased more when using frying method except for *R. kanagurta* and *S. canaliculatus* (Figures 3c and d). The observed variations of minerals in all fish species were not statistically significant (K: t = 2.02, p = 0.84; Na: t = 0.72, p = 0.943; Mg: t = 0.085, p = 0.932; and Ca: t = 0.206, p = 0.837; all at 93 degrees of freedom). When variations of minerals were compared based on processing methods, the variations of minerals between raw and fried fish were not statistically significant for all minerals (K: t = 0.953, df = 117, p = 0.342; Na: t = 0.345, df = 124, p = 0.731; Mg: t = 0.141, df = 117, p = 0.888; Ca: t = 1.397, df = 120, p = 0.166). Furthermore, the variations between raw and boiled fish were only statistically significant for K (t = 1.74, df = 126, p = 0.05). Moreover, the variations between fried and boiled fish were not statistically significant for all minerals (K: t = 0.846, df = 114 , p = 0.399; Na: t = 0.104, df = 123, p = 0.917; Mg: t = 0.05, df = 124, p = 0.996; Ca: t = 0.273, df = 124, p = 0.785).

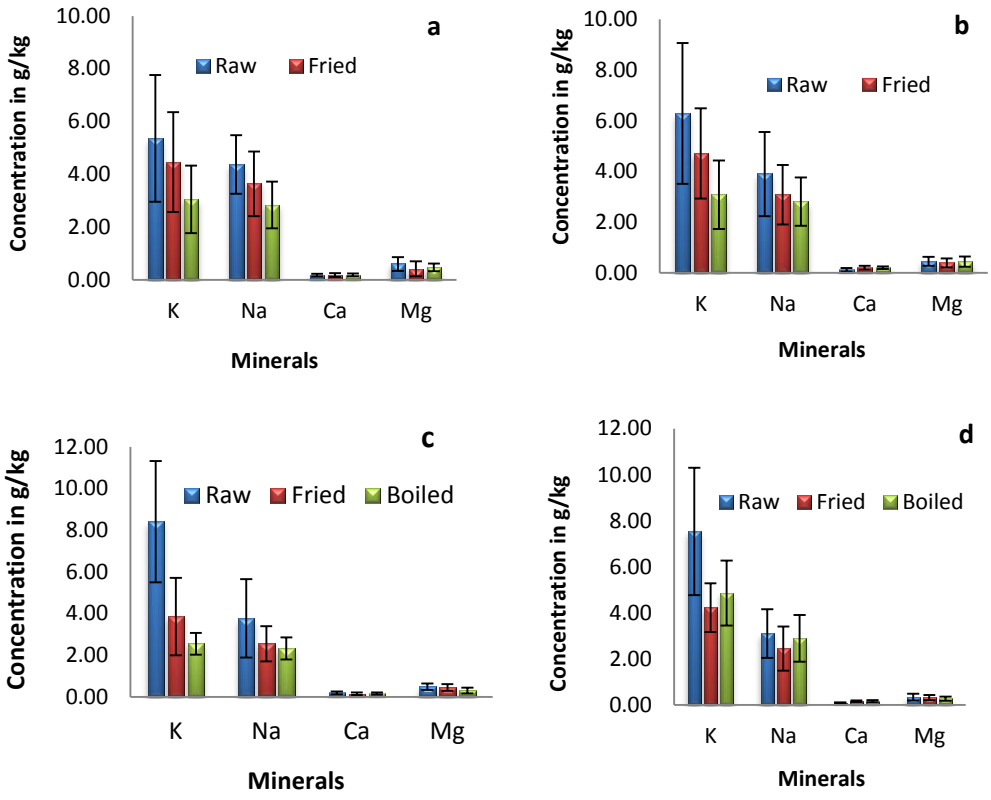

Figure 3: Variations of mineral contents (± SD) due to processing methods in *A. ciliaris* (a), *L. harak* (b) *R. kanagurta* (c) and *S. canaliculatus* (d).

The mean K, Na and Mg contents in all fish were decreasing after processing methods (raw > fried > boiled), while those of Ca were similar. Mineral contents in fish species between the processing methods varied insignificantly ($p > 0.05$). Mineral contents in all fish species between raw and frying as well as between raw and boiling processing methods varied significantly for K only. The variation of mineral contents in all fish species between frying and boiling was not significant. The mean contents of minerals in fish species in different processing methods are presented in Table 2.

In all fish the K and Na contents decreased after frying and boiling compared to raw fish. This can be explained by the leaching out of minerals. The applied heat during cooking may result into leaching out of minerals into the cooking medium (Karimian-khosroshahi et al. 2016). The heat may increase mineral solubilisation as observed by Bastías et al. (2017), thus decreasing a specific mineral in the analysed fish. In addition, the observed changes of minerals between fried and raw fish could be due to frying temperature. It has been reported by Kristy and Allison (2007) that temperature may cause minerals loss.

Processing methods may have little or no change and sometimes may increase the mineral contents. For example, Ca contents in the analysed fish were more or less the same. Previous studies by Gall et al. (1983) and Steiner-asiedu et al. (1991) have reported little or no effect of processing methods on the variations of minerals similar to the findings

of this study. Ikanone and Oyekan (2014) observed that frying may increase the mineral contents in the fish. These observed differences could be due to interspecies differences.

Table 2: Variations of mineral contents (g/kg) in fish species due to processing methods

Mineral	Processing method	*A. ciliaris* (n = 64)	*L. harak* (n = 64)	*R. kanagurta* (n = 64)	*S. canaliculatus* (n = 64)
K	Raw	5.36 ± 2.40	6.29 ± 2.78	8.41 ± 2.91	7.54 ± 2.77
	Frying	4.46 ± 1.89	4.71 ± 1.78	3.86 ± 1.86	4.23 ± 1.06
	Boiling	3.05 ± 1.28	3.08 ± 1.35	2.55 ± 0.52	4.86 ± 1.41
Na	Raw	4.37 ± 1.11	3.90 ± 1.66	3.77 ± 1.88	3.10 ±1.06
	Frying	3.64 ± 1.22	3.08 ± 1.17	2.55 ± 0.84	2.44 ± 0.96
	Boiling	3.64 ± 0.89	2.81 ± 0.95	2.32 ± 0.53	2.90 ± 1.01
Ca	Raw	0.18 ± 0.05	0.11 ± 0.07	0.20 ± 0.07	0.09 ± 0.02
	Frying	0.18 ± 0.07	0.20 ± 0.08	0.15 ± 0.06	0.16 ± 0.04
	Boiling	0.19 ± 0.06	0.20 ± 0.05	0.16 ± 0.05	0.16 ± 0.05
Mg	Raw	0.60 ± 0.26	0.46 ± 0.18	0.49 ± 0.15	0.34 ± 0.14
	Frying	0.42 ± 0.29	0.39 ± 0.18	0.45 ± 0.16	0.33 ± 0.11
	Boiling	0.47 ± 0.15	0.44 ± 0.20	0.31 ± 0.14	0.27 ± 0.09

Pearson correlations coefficients and principal component analysis

In determining the relationship between minerals composition, seasons and processing methods, correlation coefficient and Principal Component Analysis (PCA) were employed. Pearson correlation coefficient was determined to all minerals in different seasons and processing methods. The Pearson correlation coefficients of the minerals are given in Table 3. Table 3 has indicated that with the exception of Ca, the other minerals have high positive significant correlations ($r > 0.74$) to each other, indicating their relationships in terms of their sources. Ca, on the other hand, has low positive correlations to these minerals (up to $r = 0.44$), an indication that it has weak relationship. Unlike Ca, the other analysed minerals have relatively high positive significant correlation ($r > 0.41$) to season, indicative of strong relationship to season. Calcium correlation to season was not significant indicating that season does not affect the variations of Ca in the analysed fish. This can be explained by the fact that there could be a continuous supply of Ca in the seawater, probably from calcite originating from calcareous rocks and other non-marine sources such as fertilisers during wet season as well as industrial and municipal wastes during the both seasons. Ichikuni, (1978) reported that Ca from calcite rock and non-marines sources can be a reliable source in the marine fish.

Table 3: Pearson correlation coefficients of the analysed variables (n = 192)

	Fish species	Moisture	K	Na	Ca	Mg	Process	Location	Season
Fish species	1								
Moisture	–0.047	1							
K	0.022	0.045	1						
Na	–0.061	0.067	**0.852**	1					
Ca	–0.077	–0.106	**0.310**	**0.331**	1				
Mg	–0.109	0.022	**0.743**	**0.752**	**0.444**	1			
Processing methods	0.002	**–0.461**	–0.119	–0.035	0.120	–0.012	1		
Locations	–0.001	0.012	0.006	–0.129	–0.003	0.012	0.002	1	
Seasons	–0.002	**0.215**	**0.502**	**0.475**	–0.093	**0.411**	0.004	–0.002	1

Note: Bold means significant correlation at the 0.01 level (2-tailed).

Processing methods, on the other hand, had low correlations to all the minerals (from r = -0.035 to r = 0.12), which were not strong and statistically not significant. Furthermore, processing methods had strong negative correlation with moisture content (Table 3).

In order to determine the relationship between variables, multivariate analysis such as Principal component analysis (PCA) after varimax rotation with Kaiser Normalisation was used to study relationships between variables. A principal component (PC) or varifactor was considered significant when its eigenvalue was greater than 1.0 (Singh et al. 2004, Shrestha and Kazama 2007). The measured values were used as variables (total 6) with the concentrations of the minerals in the different sampling stations as objects (total 86). Kaiser–Meyer–Olkin (KMO) and Bartlett's sphericity tests were determined to check for suitability of the data for PCA prior to analysis. The KMO value obtained was 0.751 and the Bartlett's test of sphericity was 0.0, indicating that such a statistic can be useful (Varol 2011, Shrestha and Kazama 2007, Li et al. 2013). 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 51.4% of the total variances in the original data sets (Table 4). Based on the PCA, K, Na, Mg and season constituted one related group (PC 1) that contributed 34.0% of total variances. Similarly, processing methods and moisture constituted a second related group (PC 2), explaining 17.4% of the total variances (Table 4). Ca content was not in either of the two principal components.

Table 4: Rotated loadings of the Principal components

	Principal Components (51.4%)	
	PC 1 (34.0%)	PC 2 (17.4%)
Na	**0.922**	0.009
K	**0.917**	–0.044
Mg	**0.890**	0.099
Seasons	**0.597**	–0.300
Fish species	–0.082	–0.026
Moisture	0.093	**–0.815**
Processing methods	–0.054	**0.762**
Ca	0.449	0.466
Locations	–0.044	–0.046

The loading plot (Figure 4) has also revealed that K, Na and Mg are very close to each other and closer to season than Ca. This is indicative of the fact that they might be affected by similar effect. For K, Na and Mg being in one PC with season, this indicates that these minerals are probably more affected by season compared to Ca. This is also supported by their strong positive correlations with season (Table 3). The scatter plot has also shown that processing method is very far from all the minerals. This probably indicated that processing methods have no effect to all the analysed minerals in this study. Similarly, the type of fish (fish species) and locations have shown to have low correlations (Table 3) and very low loadings (Table 4), which indicated that they are not determinants of the variations of K, Na, Ca and Mg contents in these fish. Processing methods and moisture contents are in one PC (PC 2), and as expected, they are negatively related to each other.

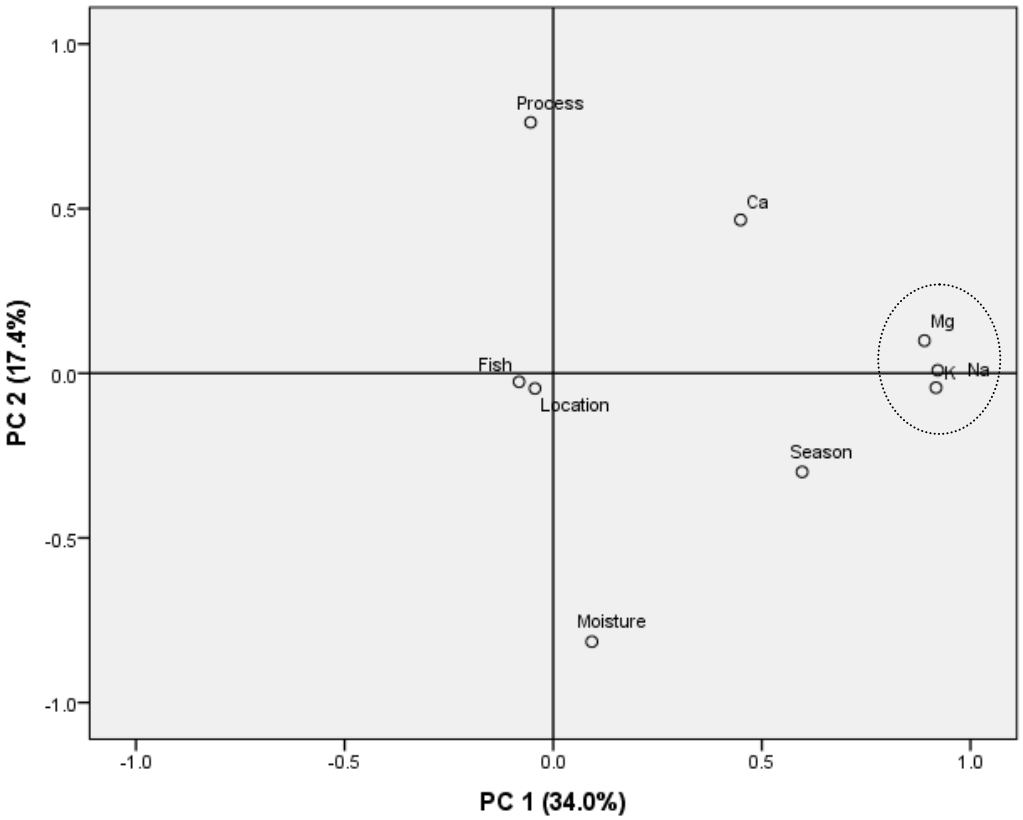

Figure 4: Two dimensional loading plot of studied variables.

Predicting variations of mineral contents due to seasons

Simple regression analysis was applied to predict the relationship between observed mineral contents in fish species and seasonal variations. The findings have shown that the predictive model values of minerals in seasons can be determined by the regression equation;

$$Y_i = b_0 + bx + \varepsilon_i \qquad \textit{Equation 1}$$

where: Y = predicted value of the mineral i (dependent variable), b_0 = mineral content irrespective of change of season, b = unstandardised coefficient that denotes the variation in mineral contents following change of season, x = season (dependent variable) and $\mathcal{E}_i$ = Statistical value that corresponds to absence of a mineral and effect of season (y = 0).

The predicted model results are presented and summarized in Table 5. The variances of the mineral composition in tissues of the fish species between seasons as explained by the predictive model are 67.6% for K, 62% for Na, 19.3% for Ca and 55.1% for Mg.

Table 5: Linear regression analysis of minerals in fish by seasons

Mineral	R^2	(b_0)	Wet Dummy (bx)	F value	p value	Predicted value
K	0.676	8.91	–8.04	172.85	0.00	0.87
Na	0.620	5.45	–4.65	136.87	0.00	0.80
Ca	0.193	0.13	0.08	20.13	0.00	0.21
Mg	0.551	0.62	–0.43	103.20	0.00	0.19

Using the model, K contents are predicted to decrease by 8.04 g/kg in wet season compared to dry season and the change is expected to be statistically significant ($p < 0.05$). Similarly, Na contents are predicted to decrease by 4.65 g/kg in wet season compared to dry season. The predicted difference is expected to be statistically significant ($p < 0.05$). The contents of Ca in wet season are predicted to increase by 0.08 g/kg compared to dry season and the change is expected to be statistically significant ($p < 0.05$). The Mg contents are predicted to decrease by 0.43 g/kg in wet season relative to dry season, the change is expected to be statistically significant ($p < 0.05$). The predicted values indicated a statistical significant contribution ($p < 0.05$) of seasons in the variations of mineral contents in the selected fish similar to observed values. Using the regression model, the predicted values were similar to the experimental values. This indicated that the model can accurately predict the variation in mineral contents using seasons as a predictor. The derived model can provide realistic estimates of variation of selected mineral contents in these fish due to seasonal variations.

Predicting variations of mineral contents due to processing methods

Multiple regression analysis was used to predict the relationship between mineral content and the different processing methods. The findings have shown that the predictive model values of the minerals due to varying processing methods can be determined by the multiple regression equation:

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

where Y = Predicted value of the mineral i (dependent variable), b_0 = Mineral content irrespective of processing methods, b = Unstandardised coefficient that measures the variation in mineral contents following a change of processing method (b_1, b_2, etc), x = Processing method (independent variable) and $\mathcal{E}_i$ = Statistical value that corresponds to absence of a mineral and effect of processing method (y = 0).

The predicted model results are summarised in Table 6. The individual variances of the mineral composition due to processing methods as explained by the prediction model are 9.5% for K, 2.2% for Na, 3.3% for Ca and 1.9% for Mg.

Table 6: Multiple regression analysis of minerals by processing methods

Mineral	Processing method	Model (*b*)	t value	*p* value	F value	R^2	Constant (b_0)
K	Frying Dummy (b_1)	–2.49	–1.95	0.05	4.29	0.095	7.03
	Boiling Dummy (b_2)	–3.67	–2.89	0.00			
Na	Frying Dummy (b_1)	–0.79	–0.99	0.32	0.92	0.022	3.76
	Boiling Dummy (b_2)	–1.04	–1.31	0.19			
Ca	Frying Dummy (b_1)	0.04	1.40	0.16	1.39	0.033	0.14
	Boiling Dummy (b_2)	0.04	1.52	0.13			
Mg	Frying Dummy (b_1)	–0.08	–0.99	0.33	0.79	0.019	0.47
	Boiling Dummy (b_2)	–0.09	–1.19	0.24			

The model predicted a decrease in K contents by 2.49 g/kg in fried fish and 3.67 g/kg in boiled fish. The changes predicted are statistically significant ($p < 0.05$) for both processing methods. Na contents were predicted to decrease by 0.79 g/kg in fried fish and 1.04 g/kg in boiled fish. The predicted changes predicted are statistically not significant ($p > 0.05$) for both processing methods. The Ca contents are predicted to increase by 0.04 g/kg in both fried and boiled fish, the change is expected to be are statistically not significant ($p > 0.05$). The Mg contents are predicted to decrease by 0.08 g/kg in fried fish and 0.09 g/kg in boiled fish. The predicted changes are expected to be statistically not significant ($p > 0.05$). The predicted values indicated a statistically significant contribution ($p < 0.05$) of processing methods to variations of K content only. Using the regression model, the experimental observations of variation of K due to varying selected processing methods were correctly predicted. However, experimental observations of the variations of Na, Ca and Mg were not correctly predicted, which clearly indicated that there are other variables that cause variations of these minerals in the selected fish. Indeed, this prompts more research on the area.

Conclusion

The variations of selected minerals contents due to seasons and processing methods in selected fish from marine waters have been established. The mineral contents in all analysed fish species were significantly high during dry compared to wet season except Ca mineral. Lack of variation in Ca contents in all fish implies that there could be a continuous supply of Ca from calcareous rocks and other non-marine sources in the studied area. These experimental observations were correctly predicted by the regression model, providing realistic estimates of selected mineral contents in these fish due to seasonal changes. Generally, whereas K, Na and Mg contents in all fish were insignificantly decreasing by varying processing methods (raw > fried > boiled), Ca contents in all fish were more or less similar even after changing the processing method. Multivariate analysis using PCA and correlation coefficients have indicated the close relationship of variation of seasons with the minerals except Ca. Similarly, correlation analysis and PCA indicated that varying processing methods have effect on the variation of K mineral only. Inability of the regression model to correctly predict the

experimental observations of variation of the other minerals due to processing methods is indicative of the availability of other factors that control the variations of these minerals in the selected fish.

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