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Preservation Methods and Storage Period Affect the Mineral and Moisture Composition of Freshwater Fish Species

Joseph Mphande, Lackson Chama*

School of Natural Resources, Department of Zoology and Aquatic Sciences, Copperbelt University, Kitwe, Zambia

Abstract The study was designed to investigate the effect of both the duration of storage and preservative methods on moisture and minerals (Ca, Mg and K) composition of five different fresh water fish species namely, Red Breasted Bream (*Tilapia rendalli*), African Catfish (*Clarias gariepinus*), Mabusi (*Chrysichtys mabusi*). Three Spotted Bream (*Oreochromis andersonii*) and Nile Tilapia (*Oreochromis niloticus*). These fish species were collected from Lake Kariba, a fishery located in the Southern province of Zambia. Each fish species was subjected to four months of both frozen and salted storage and analyzed for moisture and mineral composition at intervals of one month. Moisture decreased in salted fish, but increased in frozen fish with increasing duration of storage. Mineral composition (Ca, Mg and K) in both treatments decreased variedly with duration of storage across species. Generally, the nutrients reduced more in the first month of storage and immediately after treatment. The results suggest that these preservation methods and together with the storage period do have a negative effect on the nutritional values of fish species. Hence, fish should be consumed while fresh and if it is to be stored, the period must be as short as possible to provide optimal levels of nutrients, particularly minerals.

Keywords Fish, Salting, Freezing, Storage period, minerals, Moisture, Catfish, Bream

1. Introduction

Fish is one of the most important sources of animal protein available in the tropics and has been widely accepted as a good source of other elements needed for the maintenance of a healthy body [1]. In Africa, about 35 million people (i.e. approx. 5 percent of the population), depend wholly or partly on the fisheries sector, mostly artisanal fisheries, for their livelihoods [2]. The less developed countries, including Zambia, capture at least 50% of the world's harvest, a large proportion of which are consumed internally [3].

Although the country also allows imports of sea fish, the main source of fish in Zambia remains its abundant freshwater bodies, including dams, lakes and rivers (capture fisheries). In recent years, capture fisheries is increasingly being supplemented by aquacultural sources to ensure a sustained supply of fish to meet national demands [4, 5]. The country's national fish consumption per capita is approximately 6kg [6]. In some regions of the country, such as Luapula province, at least 40% of households depend entirely on fish as their source of both income and essential nutrients. Many species of Breams (Tilapia spp.) are among the most preferred fish species because of their good taste and shape [5]. In contrast, Catfish (*Clarias spp.*) or related species are among the most unpopular primarily due to its snake-like structure and sometimes, religious beliefs which suggests that these fish species are unclean based on the Mosaic Law.

Irrespective of these human preferences, however, fish is an extremely perishable food item, as it begins to spoils soon after death [7]. Hence, Fish deterioration or spoilage is one of the greatest problems affecting the fishing industry, not only in Zambia, but the world over. Generally, wastage of fish through spoilage has been estimated to range from 18% to 30% in developing nations [7]. However, attempts are often made to reduce fish spoilage to the barest minimum [89] through various storage methods. Among the commonly used storage methods include salting, roasting, drying and freezing. Although Fish is an important component in the diets of many communities in Zambian, the availability of its vital nutrients has been shown to largely depend on the methods of storage [10-12] highlighted above. Storage time and temperature have particularly been shown to be the major factors affecting the rate of loss of quality and shelf life of fish [13]. Reductions in the nutritional values of fish caused by the processing and preservation methods have long been of interest and concern. These range from denaturation and reduction in available nutrient to the destruction of essential vitamins. Several studies [14-16]

* Corresponding author:
Lackson.chama@cbu.ac.zm (Lackson Chama)
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have been done to determine the effect of preservation methods and storage periods on nutritional values of fish species mainly focusing on proteins, ash, lipids, moisture and carbohydrates alike. The studies depict great efforts that are being directed towards understanding the nutritional values of different fish species. However, most of these studies have focused on marine species under varying storage conditions. Yet, larger proportions of fish that is consumed in landlocked countries such as Zambia comes mainly from freshwater bodies, most of which are preserved either by freezing or salting. And after preservation, the fish can be stored for several months pending either consumption or selling on the market to generate income. Studies examining the consequences of these preservation methods and storage period on the nutritional values of freshwater fish are still rare.

The objective of this study was to investigate the effect of both preservative method and the duration of storage on moisture and mineral (Ca, Mg and K) composition of five different fresh water fish species namely, Red Breasted Bream (*Tilapia rendalli),* African Catfish *(Clarias gariepinus),* Mabusi *(Chrysichtys mabusi),* Three Spotted Bream *(Oreochromis andersonii)* and Nile Tilapia *(Oreochromis niloticus)*, in Zambia. Further, the study elucidated more on the importance of freshwater fishes as good sources of minerals and broadened our knowledge on the nutritional values of some freshwater fish species that are often disliked potentially because of their appearance or religious beliefs. We predicted that both the preservation method and the storage period will have a negative effect on the fish mineral composition, due to (1) the likely loss of fresh quality and (2) impact of shelf life on fish.

2. Materials and Methods

2.1. Fish Species

Samples of Red Breasted Bream (*Tilapia rendalli*), African Catfish (*Clarias gariepinus*), Mabusi (*Chrysichtys mabusi*),Three spotted bream (*Oreochromis andersonii*) and Nile tilapia (*Oreochromis niloticus*) of similar weight (3kg) were collected in fresh condition from lake Kariba and then transported to the Copperbelt University's Chemical Engineering laboratory for preparation, analysis and storage. A considerable amount of specimen of fish muscles was separated from the fish body using a sharp knife and each species were cut into two equal parts, where one was stored in a freezer at a temperature of – 19°C while the other part was exposed to Common salt (1kg; [17]) for five days, then exposed to sunlight for one week so that the fish can dry completely. The salted muscle of fish were ground and put in well labeled containers for storage during the period of analysis.

2.2. Sample Preparation

2.2.1. Salting Process

The fish were scaled, gutted and washed thoroughly and then analyzed for minerals and moisture while fresh to act as control. Salting was then done immediately by placing coarse salt in the tissues of the fish. The fish were arranged in a plastic container, and more salt were sprinkled on the fish layer by layer and left for five days. After salting, the fish were removed and spread out to dry in the sun for a week. The fish were ground and sieved, then put in an air tight bottle for storage awaiting further nutrient analysis.

2.2.2. Freezing Process

Similarly, the fish were scaled, gutted and washed thoroughly and then analyzed for minerals and moisture while fresh to act as control. Freezing was done immediately by putting the fish in a freezer at a temperature of – 19°C.

2.2.3. Moisture Composition Determination

Moisture composition of all the samples was determined using Oven-dry method. Empty moisture tins were weighed using an electronic balance and their masses recorded as A. Then ten grams (10g) of each sample were weighed and put into the moisture tins and recorded as B. After which the tins were put in an oven overnight at a temperature of 105 degrees Celsius. The tins were removed from the oven the following day and cooled in a desiccator for about 30 minutes and the total mass of the tins together with dried samples recorded as C.

Calculations

We recorded the result as the weight loss by the sample after evaporation of water using the following formula:

$$\% \text{ moisture} = 100 \frac{(B-A) - (C-A)}{(B-A)}$$

Where: A = weight of clean, dry tins (g), B = weight of tins + wet sample (g) and C = weight of tins + dry sample (g)

2.2.4. Mineral Composition Determination

Samples were placed in an oven to dry at 105°C for 6 – 8 h. After that, 2.5 grams of each sample transfer into digestion flasks and 25 ml of HNO_3 were added and the Digestion flask was placed on a hot plate at 120°C. The digestion flasks were kept on the hot plate till the sample was digested. The solution was then cooled and slowly added 10ml of 70% $HClO_4$. The solution was then boiled very gently until it was nearly colorless. The solution was then cooled, filtered and diluted to 100ml with deionized water. The residual analysis of Potassium (K), Magnesium (Mg) and Calcium (Ca) were determined in all treatments using an Atomic Absorption Spectrophotometry following the procedures recommended by AOAC [18].

2.3. Data Analysis

The data were entered, cleaned and analyzed descriptively (frequency and percentage) using Excel (2013 version). We used (1) preservation method and (2) duration of storage as predictor variables, while the mineral and moisture composition of fish species were used as response variables.

3. Results and Discussion

3.1. Effects of Salting on Fish Minerals and Moisture Composition over Time

All nutritional parameters including calcium (Fig.1a), potassium (Fig.1b), magnesium (Fig.1.c) and moisture (Fig.1.d) reduced similarly after salting and this reduction continued across species with increasing duration of storage.

However, there is an indication of considerable differences in the values of these nutrients across fish species. Calcium composition of salted fish seems to be similarly higher for Mabusi (*Chrysichtys mabusi*), Nile Tilapia (*Oreochromis niloticus*) and Red Breasted Bream (*Tilapia rendalli*) than that of African catfish (*Clarias gariepinus*) and Spotted Bream (*Oreochromis andersonii*) which were both similarly lower (Fig.1a). However, Nile tilapia seems to have higher potassium composition than Mabusi and Red Breasted Bream which had almost similar compositions (Fig.1b). African Catfish and Three Spotted Bream were similarly lower in potassium composition (Fig.1b). Magnesium composition seems to be similarly higher for Mabusi, Nile tilapia and African catfish than that of both Red breasted and Three spotted breams, although Three spotted bream had a much lower composition of the two fish species (Fig.1c). Moisture composition varied from species to species with Nile tilapia having the highest composition while three spotted bream had the lowest of all the five species (Fig.1d).

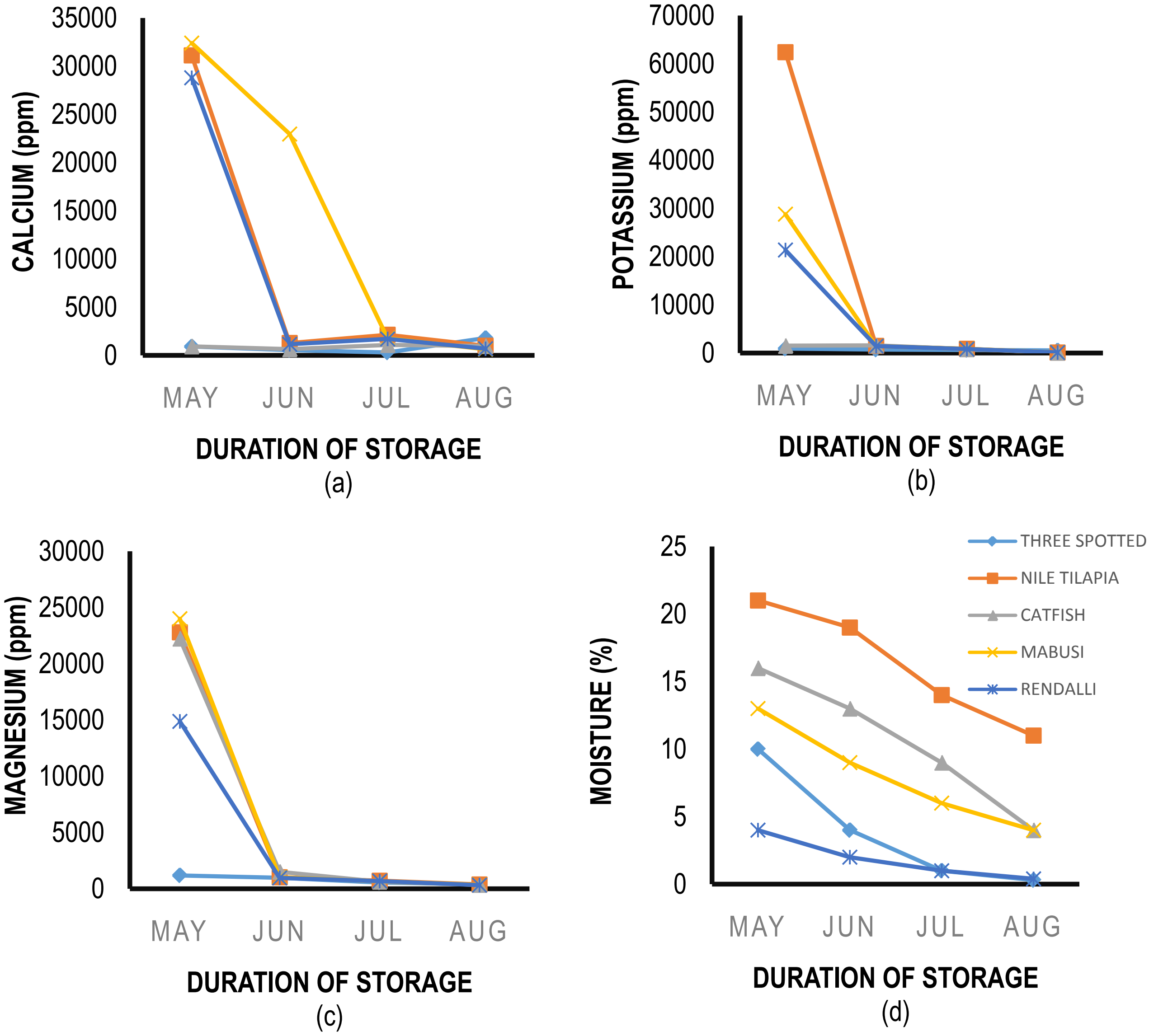

Figure 1. Shown are the effects of salting treatment on Calcium (a), Potassium (b), Magnesium (c) and Moisture (d) composition across fish species over time

Generally, these results shows that salting and storage period have a negative effect on the nutritional values of freshwater fish species. The negative effect is attributed to loss of water soluble nutrients which occurs during the exchange of water as it moves out and as salt enters into the fish [14-17]. The variations recorded in the concentration of minerals in the studied fish species are generally expected because of potential variations in the rate with which they are available in the water body and the ability of each fish species to absorb these inorganic elements [17]. It was also observed that reduction was greater in the first month of storage (June). This can be attributed to high microbial activities on the fish during the first month of storage due to the organisms that are naturally found on the fresh fish [17]. After the fish is stored for some time, the microbial activity reduces as their activity is lowered by temperature and some of these microbes die with increasing duration of storage [19]. Variations recorded in the values of calcium could be either due to their diet selection [20] or an increase in the proportion of bone to flesh as the fishes grows [21]. Although some previous studies [20, 21] reported higher levels of calcium in some fish species, the results of the present study seem to disagree with their findings. This can be attributed to the differences in size, weight and storage period of the fish species used and also due to the fact that the present study considered freshwater species while the other researchers considered marine water species. Overall, salting seems to have negative effects on the mineral composition of freshwater fish species.

Similarly, moisture composition reduced with storage period in all the species. These results are consistent with the findings of [22] who reported that water composition of the salted cod for all treatments decreased during the storage period of six weeks. The reduction in moisture compositions during storage can be attributed to protein denaturation and consequent loss of water-holding capacity of the protein in the used fish samples and also due to heavy uptake of salt [23]. The results of the current work are again in accordance with the findings of [24], on dry salted horse mackerel and [25] on salted Grey Mulle, suggesting that moisture composition in salted fish reduced with storage period. Moisture is important in palatability of fish species. Therefore, it must not reduce to considerably low levels as the fish can become very brittle and make palatability difficult. Broadly, our findings suggests that freshwater fish species should be consumed fresh or stored for a short time after salting in order to maximize the nutritional benefits to the consumer.

3.2. Effects of Freezing on Fish Minerals and Moisture Composition over Time

All nutritional parameters including calcium (Fig.2a), potassium (Fig.2b) and magnesium (Fig.2c) reduced similarly across fish species after freezing and this reduction continued across species with increasing duration of storage.

In contrast, moisture (Fig.2d) increased similarly across fish species after freezing and this increase continued with the duration of storage. Although there was a similar pattern of change in the nutritional parameters across species, there is also an indication of considerable differences in the values of these nutrients within fish species. The composition of all three minerals, namely calcium (Fig.2a), potassium (Fig.2b) and magnesium (Fig.2c) were all higher in frozen African Catfish than other three species. In contrast, moisture composition increased similarly across species following freeing (Fig.2d).

The variations recorded in the concentration of minerals in fish species examined could have been as a result of the rate in which they are available in the water body and the ability of the fish to absorb these inorganic elements, just like in the salting treatment. We can also attribute the variations to the differences in the feeding behaviour. This observation was supported by the findings of [26] which showed that such variations in concentrations of these mineral elements from one species of fish to another was due to the chemical forms of the elements and their concentrations in the local environment. The result again do agree with the findings of [27, 28] who observed that there was a slight change with respect to frozen period in fish minerals evaluated. This could be attributed to drip loss and dehydration that is associated with frozen storage [27, 28]. In contrast to previous studies which only found a slight change in minerals, the changes in minerals composition were stronger in the present study. The small differences can be attributed to the short period of storage which was two months in the previous studies while the present study had the fish stored for five months.

In contrast to salting, moisture composition of frozen fish increased similarly with storage period in all the species (Fig.2d). Indeed, moisture is vital for ensuring good palatability of fish. However, it must be watched carefully to ensure that it does not increase too much as it can create a conducive environment for microbial growth. The results of the present study, is consistent with the findings of [29] in Puntius species, who found an increasing trend in moisture composition with storage period. The increase in moisture composition could be attributed to the loss of water holding capacity of tissue [30] with increasing storage period. However, our findings contradicts those of both [28] who observed that moisture composition remained almost the same throughout the 60 days of frozen storage of Tilapia slices and [31] who reported a decrease in total moisture composition in Sea bass (*Dicentrarchus labrax*) fillets during frozen storage. Firstly, the observed differences in the results could be explained by the environment from which the fish was caught. For example, Sea bass is a marine fish while the present study was done on fresh water species. Secondly, this could be attributed either to duration of storage or temperature at which the fish specimen were stored. In the previous studies, specimen were only stored for two months while the present study had the specimen stored for five months. The fish in this study was stored at – 19 °C while the fish for [27] and [28] where stored at – 18 °C. This difference in temperature can bring about the slight difference in the findings.

Generally, our findings seem to suggest that freezing also has a negative effect on the nutritional values of freshwater fish species. The reduction can be likened to the negative effects of freezing and storage period which including freezer burn, product dehydration, rancidity, drip loss and product bleaching which can have an overall negative effect on the quality of the frozen foods [32]. And since moisture increased with time, this increased the microbial activity which in return caused the reduction to the other nutrients as the activity of micro-organisms increased due to conducive water activity. Freezing is a common practice in the meat, fish and other animal protein processing industries because it preserved the quality for an extended time and offers several advantages such as insignificant alterations in the product dimensions, and minimum deterioration in products color, flavor and texture [33]. However, our findings seem to broadly suggest that fish should be consumed fresh or stored for a short time after freezing in order to maximize the nutritional benefits to the consumer.

Interestingly, our results also show that the composition of calcium, potassium and magnesium, were far higher in frozen Catfish than other fish species. Yet, this is one of the less popularly consumed fish species in Zambia primarily due to its structure and religious beliefs. However, if one wishes to consume a species with a view to obtain enough calcium, then catfish will be the best fish to eat and preferably consuming it while fresh before any treatment.

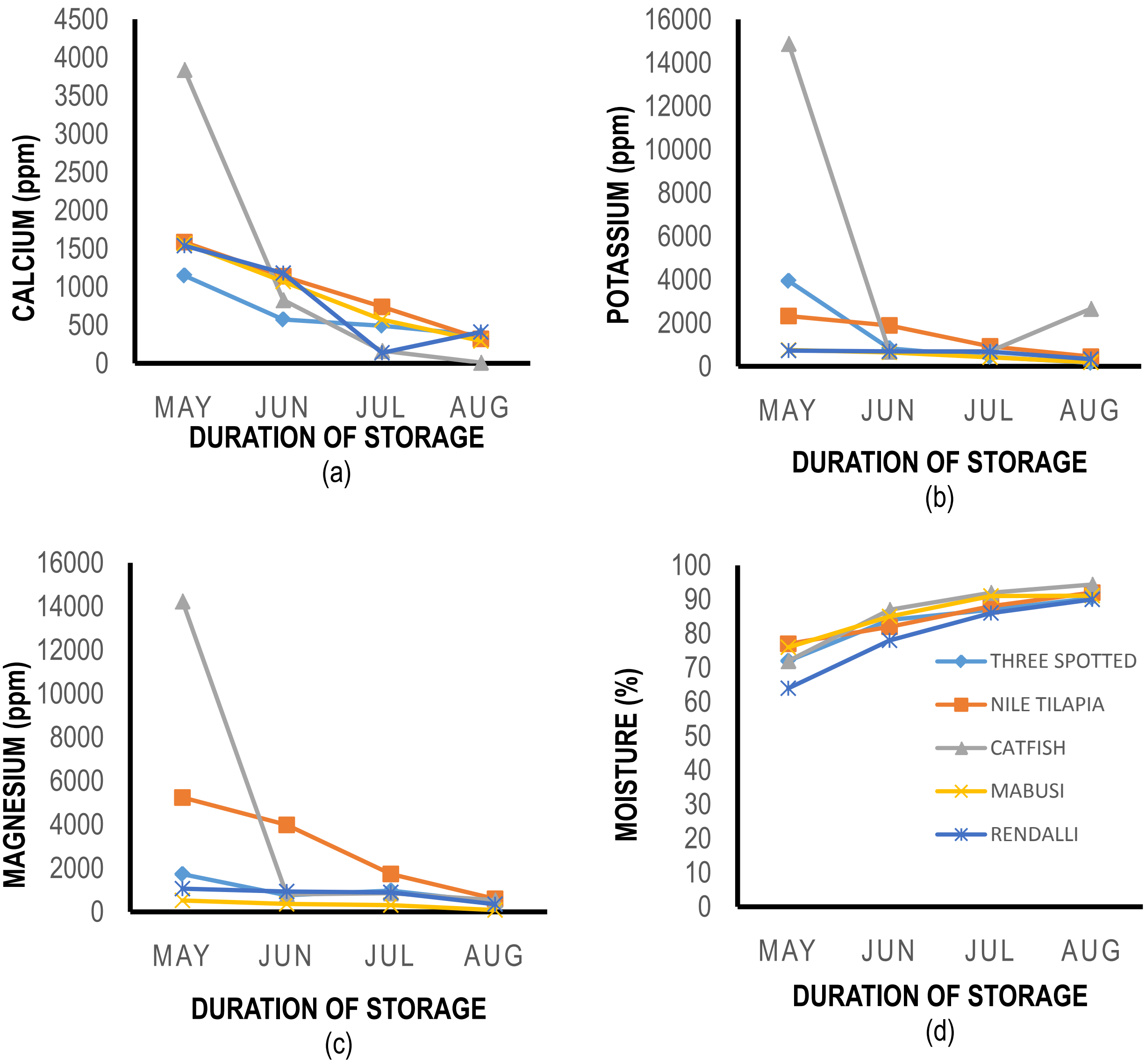

Figure 2. Shown are the effects of freezing treatment on (a) Calcium, (b) Potassium (c) Magnesium and (d) Moisture composition across fish species over time

4. Conclusions

The results of the investigation shows that freshwater fish species are good sources of minerals apart from proteins which are the main nutrient associated with fish. It was observed that processing and storage significantly affected the proximate composition of fresh water fish species and their effect varied from species to species. It is right to suggest that, the mineral elemental compositions of each species is a function of the availability of these elements in their local environment, diet absorptive capability as well as their preferential accumulation. Moreover, the study has also highlighted that the mineral composition of different fish species may be affected differently by the methods of preservation and duration of storage. For example, the mineral composition of frozen African catfish was higher than that of other species exposed to similar preservation conditions. It is therefore, important to equally consider the minerals status of fish and the persistence of food safety of the fish prior to consumption in addition to the prevailing choice of type, taste, size, and external morphology. Since deterioration increased with the duration of storage, we can conclude that fish is better eaten in its fresh conditions or shortly after preservation, as its quality remains better in earlier stages.

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