Essential Mineral Content Evaluation in Fish Species Consumed in Jazan City, Saudi Arabia

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Abstract: Fish has a high nutritional value since it contains a range of vital metals, making it an important dietary ingredient. Recognizing the levels of essential metals in fish is crucial for preserving consumer health. This study aimed to examine the levels of four essential metals; Sodium (Na), Magnesium (Mg), Potassium (K), and Calcium (Ca) in fish species collected from a fish market in Jazan City, Saudi Arabia using Flame Atomic Absorption Spectrophotometer (FAAS). Plectropomus leopardus had the highest levels of Mg (1140.0 ± 7.20 mg/kg) and Ca (1842.8± 3.30 mg/kg), while Sphyraena flavicauda and Scomberoides lysan species had the highest levels of K (7729.3±141.66 mg/kg) and Na (1990.8±5.24 mg/kg), respectively. The results showed that the average levels of the minerals studied in fish species were 1402.6±9.05, 706.2±2.86, 5018.9±90.47, and 672.2±4.93 mg/kg for Na, Mg, K, and Ca respectively. Minerals concentrations in fish species declined in the following order: K > Na > Mg > Ca. The obtained results revealed that the average levels of Ca and Mg in all examined fish species were within the FAO's acceptable limits, however, K and Na levels were slightly higher in three species for each element. Additionally, The Na/K ratio was found to be less than one (< 1) in all fish species under investigation. Our results demonstrated that ingesting the selected fish species can support a balanced, healthful diet and may be used to treat hypertension and cardiovascular disease in humans.

Keywords: Essential Minerals Macroelements, Fish species, FAAS, Jazan, Saudi Arabia

تقييم محتوى المعادن الأساسية في أنواع الأسماك المستهلكة في مدينة جازان، المملكة العربية السعودية

الملخص: تتمتع الأسماك بقيمة غذائية عالية لأنها تحتوي على مجموعة من المعادن الحيوية، مما يجعلها مكونًا غذائيًا مهمًا. يعد التعرف على مستويات المعادن الأساسية في الأسماك أمرًا بالغ الأهمية للحفاظ على صحة المستهلك. هدفت هذه الدراسة إلى فحص مستويات أربعة معادن أساسية؛ الصوديوم (Na)، والمغنيسيوم (Mg)، والبوتاسيوم (K)، والكالسيوم (Ca) في أنواع الأسماك التي تم جمعها من سوق الأسماك في مدينة جازان، المملكة العربية السعودية باستخدام مطياف الامتصاص الذري باللهب ($FAAS$). كان لدى *Plectropomus leopardus* أعلى مستويات من المغنيسيوم (1140.0 ± 7.20 مجم / كجم) والكالسيوم (1842.8 ± 3.30 مجم / كجم)، بينما كان لدى نوعي *Sphyraena flavicauda* و *Scomberoides lysan* أعلى مستويات من البوتاسيوم (7729.3 ± 141.66 مجم / كجم) والصوديوم (1990.8 ± 5.24 مجم / كجم)، على التوالي. أظهرت النتائج أن متوسط مستويات المعادن المدروسة في أنواع الأسماك كانت 1402.6±9.05، 706.2±2.86، 5018.9±90.47، و672.2±4.93 ملغ/كغ لكل من الصوديوم والمغنيسيوم والبوتاسيوم والكالسيوم على التوالي. وانخفضت تركيزات المعادن في أنواع الأسماك بالترتيب التالي: البوتاسيوم > الصوديوم > المغنيسيوم > الكالسيوم. وكشفت النتائج التي تم الحصول عليها أن متوسط مستويات الكالسيوم والمغنيسيوم في جميع أنواع الأسماك المدروسة كانت ضمن الحدود المقبولة لمنظمة الأغذية والزراعة، ومع ذلك، كانت مستويات البوتاسيوم والصوديوم أعلى قليلاً في ثلاثة أنواع لكل عنصر. بالإضافة إلى ذلك، وجد أن نسبة الصوديوم/البوتاسيوم أقل من واحد (<1) في جميع أنواع الأسماك قيد الدراسة. وأظهرت نتائجنا أن تناول أنواع الأسماك المختارة يمكن أن يدعم نظامًا غذائيًا متوازنًا وصحيًا ويمكن استخدامه لعلاج ارتفاع ضغط الدم وأمراض القلب والأوعية الدموية لدى البشر.

1. Introduction

The quality of food is becoming increasingly important due to the growing consideration of the health benefits and risks of food consumption [1, 2]. Among the foods consumed in numerous countries is fish [3]. Global fish production increased to 179 million tons in 2018, and each person is thought to consume 20.5 kilograms of fish annually [4]. Recently, fish have received much interest as a food source due to their essential nutrient content that can fulfill a considerable portion of the daily requirements of humans [5].

Fish contains high-quality proteins, carbs, vitamins, micro and macro elements, low fat and cholesterol, and essential fatty acids, including omega 3, constituting a crucial component of a healthy diet [6-9]. Important components of fish muscle include heavy metals, microminerals, and macro minerals. The human body benefits greatly from consuming them through meals. While some macro and microminerals are beneficial to humans and required, others are harmful [10]. Therefore, fish consumption has beneficial health effects, such as a reduction in the incidence of diabetes and cardiovascular diseases, normal neurodevelopment, adequate enzyme reactions in metabolism, and an increase in antioxidant activity [11, 12].As a result, global consumption of fish has been rapidly increasing [13].

The content of essential minerals, especially calcium, phosphorus, magnesium, and potassium is in large quantities in the fish [14]. Many aspects, including age, the organism's nature and production, its relationship to other foods, its mineral consumption, and its growth and nutrition adaption, affect fish's mineral intake [15, 16]. Studies on the mineral elements in living organisms have biological significance since most of these elements are involved in the metabolic processes of the body and are essential for all living beings [17]. The most important mineral elements are calcium, magnesium, potassium, sodium, and phosphorus [18].

The macroelements magnesium, calcium, potassium, and sodium are essential and have a vital role in human health [19], but all elements are harmful at excessive levels [20]. The Na/K ratio is an excellent indicator for preventing or treating hypertension and cardiovascular disease [29]. For example, based on a Chinese cohort study, Du et al. [21] discovered statistically significant associations between the probability of hypertension and sodium intake as well as between the occurrence of hypertension and the sodium to potassium (Na:K) ratio. Kim et al. [22], revealed that the Na:K ratio and urine salt showed a significant correlation with blood pressure. Therefore, it is crucial to determine the level of macroelements in fish species to evaluate the potential advantages and possible negative consequences for consumers' health. The primary goals of the current study were to determine the level of Na, Mg, K, and Ca in six fish species that were collected from fish markets in Jazan City, Saudi Arabia using a FAAS and to compare the content of the essential macroelements under investigation in the fish species to the FAO-permitted levels. Evaluating the Na/K ratio in the fish species under study is another goal of this work.

2. Materials and methods

2.1. Reagents and materials

Ultrapure deionized water produced by a Milli-Q purification system was employed to prepare both standard solutions and the investigated samples. HPLC-grade nitric acid, which was acquired from Sigma-Aldrich, was utilized to prepare the fish sample for analysis. The following standard solutions were acquired from Merck, Germany: 1000 mg/L of Na, Mg, K, and Ca in 0.5% (v/v) HNO_3. All glassware was thoroughly cleaned with MilliQ water, allowed to air dry, and then immersed in 10% HNO_3 for the duration of the night.

2.2. Sample collection, preparation, and digestion

The fish species: Plectropomus leopardus; Atule mate; Sphyraena flavicauda; Scomberoides lysan; Scombridae, and Carangoides bajad used in this study were collected in polystyrene icebox from a fish market in Jazan City, Saudi Arabia**.** After that, the samples were cleaned with deionized water, put in polyethylene bags, and kept at -20 °C until the tests were completed.

The methods outlined in Periago et al. were used to extract the minerals under investigation from fish species for analysis from the dorsal muscle tissues[23]. For fish sample digestion, 5g of dry weight was carefully weighed into a crucible and then put in a cool muffle furnace for digestion. The temperature of the muffle is progressively increased to 450–500°C and kept there all night. 5 mL of HNO_3 was carefully added and mixed after the samples were removed and allowed to cool to room temperature. Gently evaporate until it's totally dry. To dissolve the ash, carefully boil the liquid after adding 10 mL of 1N HCl. The digested samples were then diluted to a final amount of 50 mL using deionized water. After that, the diluted solution was filtered and introduced to FAAS to detect the metals under investigation [24].

2.3. Essential macrominerals analysis

Metal levels were determined using FAAS (nov AA 350, Analytik Jena, Germany) in which acetylene gas and air were used as fuel and oxidizer, respectively. Metals concentrations were determined with the support of calibration curves. Calibrations were done by using standard solutions following the manufacturer's protocol. A hollow cathode lamp of Na, Mg, K, and Ca was employed as a light source at wavelengths 589, 285.2, 766.5, and 422.7 nm and a slit width of 0.8, 1.4, 0.8, and 1.4 nm respectively for analyzing the corresponding metals. A Particular volume of standard stock solution (1000 mg L^{-1}) for each metal was dissolved in acidified MilliQ water to produce new working standard solutions within the appropriate concentration range to generate metal calibration curves.

2.4. Analytical method validation

This study examined validation parameters for analytical procedures based on recommendations from prior studies [25-28]. Validation parameters, such as linearity, accuracy, precision, limit of detection (LOD), and limit of quantification (LOQ), were evaluated. To assess the method's linearity, calibration curves for Na, Mg, K, and Ca were created. The correlation coefficient (R^2), slope (S), and intercept (b) were calculated. The method's accuracy was tested using samples spiked with known Na, Mg, K, and Ca standards. Limits of detections (LODs) and limits of quantifications (LOQs) were calculated based on the standard deviation of the response (SD) of the calibration curve and the slope of the curve (S) using Eq. 1 and 2 [29]:

$$\mathrm{LOD} = \frac{3 * SD}{S} \quad (1)$$

$$\mathrm{LOD} = \frac{10 * SD}{S} \quad (2)$$

3. Results and discussion

3.1. Analytical method validation

The method's applicability for determining the selected metals in fish species was verified using important parameters such as FAAS calibration, linearity, Accuracy (recovery), Limits of detections (LODs), and limits of quantifications (LOQs). Calibrations were done by using standard solutions and shown in Fig. 1. The concentrations of each metal were determined with the support of its calibration curve. Linearity was examined for each element using the correlation coefficient of the corresponding calibration curve. The correlation coefficient (R^2) determination was calculated using the least-square analysis and summarized as shown in Table 1. Accuracy was examined for each element studied by computing the Recovery (R%) and summarized in Table 1. The correlation coefficient (R^2) values clearly show a good result ranging from 0.997 to 0.999. Recovery values show good results ranging from 97.58 % to 100.25 % falling within the recommended 80 –120% [30].

The accuracy results demonstrated that the analytical method was accurate for the quantification of the investigated minerals in the investigated samples. The samples were examined in triplicate and the relative standard deviation was computed as shown in Table 1. The method's RSD ranged between 0.8 % and 7.1 % as Table 1 indicates. Therefore, it can be stated that the analytical method exhibited good precision based on the obtained RSD values. These results were also confirmed by the limits of detection (LODs) and limits of quantification (LOQs) as shown in Table 1. The LODs and LOQs values range from 0.035 to 0.899 mg/kg and 0.11 to 2.99 mg/kg, respectively.

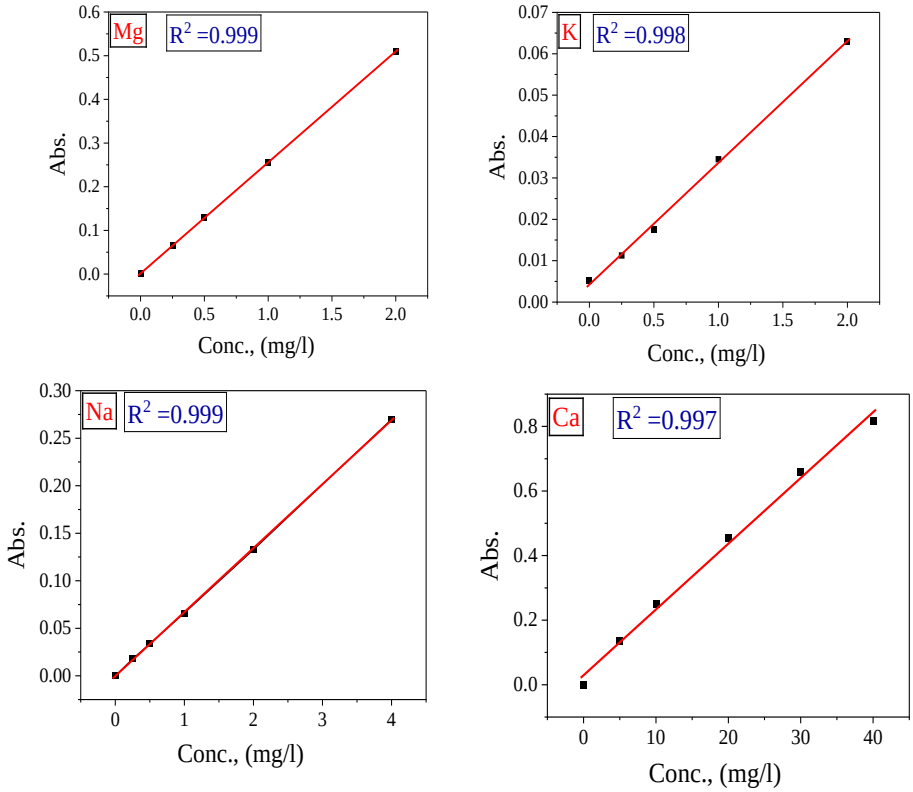

Fig. 1. Calibration curve of the investigated mineral macro-elements

Table 1: Summary of validation parameters; correlation coefficient (R^2), Mean recovery (R%), Mean precision, and limits of detection (LODs) and quantification (LOQs) for each studied metal.

Metal	relation coefficient	racy (Recovery) (	Precision (RSD%)	LODs (mg/L)	LOQs (mg/L)
Na	0.999	101.2	0.8	0.899	2.99
Mg	0.999	100.25	1.46	0.035	0.11
K	0.998	97.58	7.1	0.38	1.17
Ca	0.997	98.14	4.01	0.330	1.10

3.2. Essential minerals analysis

The concentration of essential minerals under investigation in fish species (mg/kg dry wt.) is shown in Figure 2. As noted in Figure 2, the current investigation provides information on the level of four metals; Na, Mg, K, and Ca —found in six distinct fish species. In this investigation, The level of the minerals analyzed increased in an ordered sequence: K > Na > Mg > Ca. Potassium had the highest concentration (7729.3 mg/kg) in the Sphyraena flavicauda, whereas Ca had the lowest concentration (259.4 mg/kg) in the Carangoides bajad.

Calcium

Calcium is involved in the strengthening of bones and teeth, blood clotting, and muscle contraction. It is also involved as a cofactor in metabolic and enzymatic processes [31]. Fish is a rich source of this microelement [9]. Calcium levels in the investigated fish species ranged between 259.44 ±3.06 and 1842.81±3.31mg/kg with a mean value of 672.2 mg/kg. Carangoides bajad muscle had the lowest calcium content (259.44 ±3.06 mg/kg) while Plectropomus leopardus species had the highest calcium content 1842.81±3.31mg/kg. All fish species under investigation had calcium content within the permissible limits set by FAO (8810 mg/kg). The Ca values observed in the current study are similar to previous investigations that showed comparable Ca concentrations in fish consumed in Douala, Cameroon (710 mg/kg), and fish from the Northeastern Mediterranean Sea (728.55 mg/kg)[32]. On the other hand, other studies found higher Ca levels in Ethmalosa fimbriata fish (4680.05 mg/kg)[33], fish from marmara sea (8483.78 mg/l)[34]. Conversely, previous investigations found lower Ca levels in Ilisha africana fish from the Cameroon coast (462.78 mg/l) [33], and fish from Manipur, India (93.5-242.5 mg/l) [18].

Magnesium

Magnesium activates more than 300 enzymes in the body and plays a role in energy metabolism, tiredness reduction, nervous system function, and cognitive abilities like focus, reasoning, and memory [27]. Magnesium in large levels can increase the risk of heart disease and stroke [35]. Inadequate magnesium intake can disturb physiological activities, leading to weariness, tension, and muscular diseases. It can also cause dizziness, nausea, and light-headedness, creating a sense of fainting, slowing blood clotting, and causing several diseases, such as osteoporosis, and anemia [9, 28]. Magnesium levels in the investigated fish species ranged between 327.98 ± 0.6 and 1140.97± 7.19 mg/kg with a mean value of 706.23 mg/kg. Atule mate muscle had the lowest magnesium content (327.98 ± 0.6mg/kg) while Plectropomus leopardus species had the highest Mg content (1140.97± 7.19 mg/kg). All fish species under investigation had magnesium content within the permissible limits set by FAO (4520 mg/kg). On the other hand, a previous study found higher Mg levels in fish from the Northeastern Mediterranean Sea (1658.9 mg/l) [32]. Conversely, another one found lower Mg levels in the fish from eastern Poland (97.6-226 mg/l)[36].

Sodium

Sodium is an essential nutrient that regulates blood pressure, balances acids and bases, and supports muscle and nerve function. It plays a vital role in transporting molecules and retaining water [23].

Sodium is involved in the maintenance of normal cellular homeostasis and in the regulation of fluid and electrolyte balance and blood pressure (BP). Its role is crucial for osmotic action and is equally important for the excitability of muscle and nerve cells and the transport of nutrients and substrates through plasma membranes [24].

The excess of sodium causes hypertension, heart failure, decompensated liver cirrhosis, renal failure diseases, chronic kidney disease, and gastric cancer [25]. Sodium deficiency can cause water retention issues, heart, kidney, liver, and hormone diseases, as well as severe neurological issues, including coma [37]. Sodium levels in the investigated fish species ranged between 855.95 ± 5.1 and 1990.75 ± 5.2 mg/kg with a mean value of 1402.61mg/kg. Atule mate muscle had the lowest Sodium content (855.951± 5.1 mg/kg) while Scomberoides lysan species had the highest Sodium content (1990.756 ± 5.2 mg/kg). As shown in Fig. 2 the sodium content in Plectropomus leopardus, Atule mate, and Sphyraena flavicauda fish species was within the permissible limits set by FAO (4520 mg/kg). Conversely, Scomberoides lysan, Scombridae, and Carangoides bajad fish species had sodium content higher than the permissible limits set by FAO. The Na values observed in the current study are similar to a previous study that showed comparable Na concentrations in fish from the Cienfuegos Bay (1301 mg/kg) [38].Other studies found higher Na levels in fish from the Mazurian Great Lakes, Poland (1483-3285 mg/l) [39], and in fish from Red Sea (1800 mg/kg)[5]. Conversely, a previous study found lower Na levels in fish species marketed in Varna (625.24 mg/l)[9].

Potassium

Potassium plays a role in enzyme activation, muscular contraction, osmotic regulation, membrane transfer, maintaining osmotic pressure and acid-base balance, and regulating osmotic pressure within the cell [23]. Excess potassium levels in the blood can lead to life-threatening cardiac rhythm abnormalities. Insufficient potassium intake can cause muscle weakness, paralysis, and respiratory failure [23].

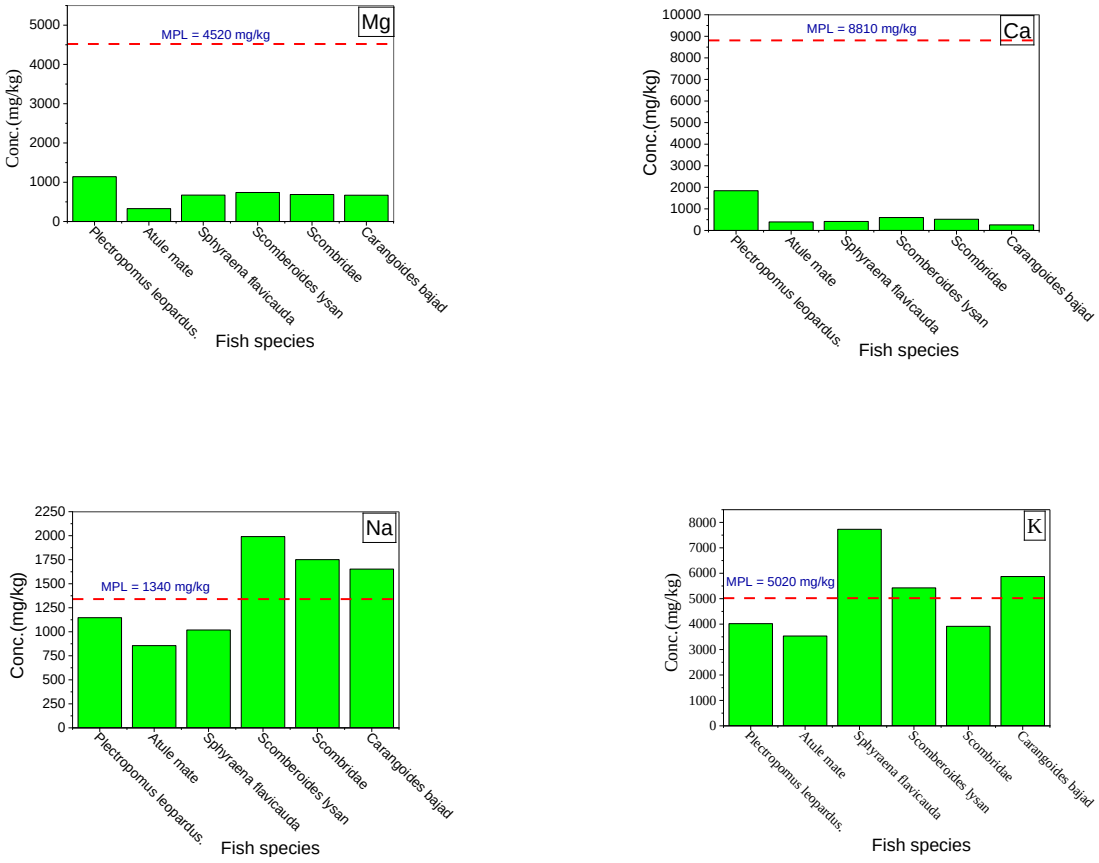

Figure 2. Concentration of essential macro elements under investigation in the selected fish species

Potassium levels in the investigated fish species ranged between 3532.083± 108.67 and 7729.331± 141.66 mg/kg with a mean value of 5081.82 mg/kg. Atule mate muscle had the lowest potassium content (3532.083± 108.67 mg/kg) while Sphyraena flavicauda species had the highest potassium content (7729.331± 141.66 mg/kg). Fig.2 indicated that the potassium content in Plectropomus leopardus, Atule mate, and Scombridaefish species was within the permissible limits set by FAO (4520 mg/kg). Conversely, Sphyraena flavicauda, Scomberoides lysan, and Carangoides bajad fish species had potassium content higher than the permissible limits set by FAO. The K values observed in the current study are similar to a previous study that showed comparable K concentrations in fish species sold in Erzurum, Turkey (4576 mg/kg) [15]. Another study found higher K levels in fish from the Cienfuegos Bay (13246 mg/l) [38]. Conversely, a previous study found lower K levels in Fish from Market in Okada, Nigeria (91.51-102.86 mg/l)[40], fish species consumed in Douala, Cameroon [41], and fishes from Bangladesh [42].

3.3. Sodium to potassium ratio (Na/K)

Low sodium and high potassium intakes together may have greater effects on blood pressure, hypertension, and associated variables than either nutrient alone [43, 44]. It was reported that any food component that has a Na/K ratio higher than one could provide health risks while a ratio less than one suggests that the food item poses no health risks [45]. Figure 3 shows the calculated Na/K ratio for the fish species under study.

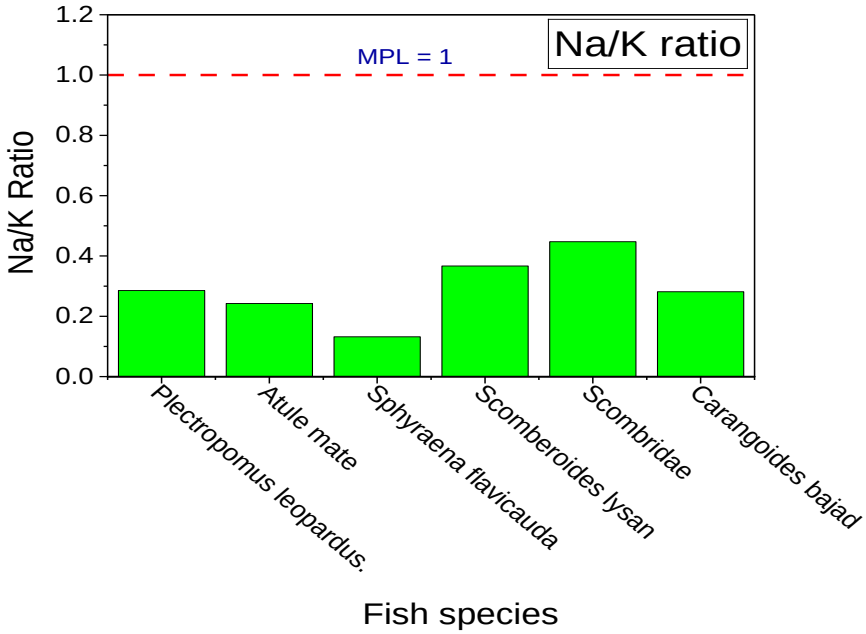

Figure 3. The Na/K ratio in fish species under investigation

The Na/K ratio in fish species under investigation was computed and depicted in Fig.3. As Fig. 3 shows, the Na/K ratio was less than one for all fish species examined in this study. The Na/K ratio observed in the current study is similar to previous investigations that showed Na/K ratio was less than one fish species from the Cameroon coast [33], fish consumed in Douala, Cameroon [41], and fishes from Bangladesh [42]. These findings suggest that ingesting fish species is a healthful diet and not harmful to human health.

Conclusion

The current investigation provided information about the level of Na, Mg, K, and Ca in the selected fish species Plectropomus leopardus; Atule mate; Sphyraena flavicauda; Scomberoides lysan; Scombridae, and Carangoides bajad. The level of studied minerals increased in an ordered sequence: K > Na > Mg > Ca. K. Potassium had the highest concentration (7729.3 mg/kg) in the Sphyraena flavicauda, whereas Ca had the lowest concentration (259.4 mg/kg) in the Carangoides bajad. The obtained results revealed that the average levels of Ca and Mg in all examined fish species were within the FAO's acceptable limits, however, K and Na levels were slightly higher in 50% of fish species. Additionally, The Na/K ratio was less than one (< 1) in all fish species under investigation. The study findings demonstrated that ingesting the selected fish species can support a balanced, healthful diet and may be used to treat hypertension and cardiovascular disease in humans.

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