

ESTIMATION OF MINERAL SAFETY INDEX IN THE WILD CRAB, *CALLINECTES AMNICOLA*: IMPLICATION FOR SEAFOOD QUALITY CONTROL

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ABSTRACT

The study investigated the mineral contents, ratios, and safety indices of the shell and flesh of *Callinectes amnicola* from Lagos Lagoon. Using a flame photometer, the mineral elements were determined, while ratios and safety index were calculated using standard formula. Calcium (Ca) and magnesium (Mg) are predominantly concentrated in the shell (3799.07mg/100g and 34,675.35mg/100g respectively) compared to the tissue, reflecting their roles in structural integrity and exoskeletal formation. However, phosphorus (P) and sodium (Na) also display higher concentrations in the shell (7821.83mg/100g and 3932.32mg/100g, respectively). Potassium (K) exhibits lower concentrations in both shell and tissue, indicating a relatively stable distribution (CV% = 55.88). The shell's overall mineral dominance (50,862.18mg/100g) highlights its biological and ecological roles. The Ca/K ratio aligns with acceptable ranges, supporting a balanced relationship, while other ratios (Ca/Mg, Ca/P, Na/Mg) fall below ideal values, indicating deficiencies in calcium and sodium relative to magnesium and phosphorus. Sodium content significantly exceeds safety thresholds, with high calculated Mineral Safety Index in both shell and flesh, suggesting potential health risks if consumed excessively. Variability in mineral levels (CV% up to 126.40) is likely influenced by environmental and dietary factors. The study emphasizes the shell's mineral enrichment for ecological functions and highlights concerns about mineral safety for human consumption, necessitating caution in dietary applications of *C. amnicola*.

Keywords: Crab, Mineral safety, Shell and tissue analysis, Lagos lagoon, Nigeria

INTRODUCTION

Seafood is a vital source of nutrition, contributing significantly to global food security and providing essential nutrients, including high-quality proteins, omega-3 fatty acids, vitamins, and minerals (Pradeepkiran, 2019). Among seafood, crabs are highly valued for their unique taste and nutritional benefits. The Lagoon crab, *Callinectes amnicola*, commonly found in estuarine and coastal waters of West Africa, plays a crucial role in the region's fisheries economy. However, the safety and quality of seafood have garnered increasing attention due to the potential accumulation of harmful levels of minerals and heavy metals in aquatic organisms (Moruf, 2024).

Minerals are essential for physiological functions, but their imbalance, whether deficiency or excess can have detrimental effects on human health. Trace elements such as iron, zinc, copper and selenium are vital in small amounts, while exposure to toxic metals like lead, cadmium and mercury poses significant health risks. Thus, the mineral safety index (MSI), which evaluates the concentration of minerals relative to established safety thresholds, has emerged as a critical parameter for seafood quality control and public health risk assessment (Rangasamy *et al.*, 2024).

In aquatic environments, mineral bioaccumulation in marine organisms is influenced by various factors, including water quality, sediment composition, feeding habits, and trophic interactions (Kolarova and Napiórkowski, 2021). *C. amnicola*, being both a benthic feeder and a highly consumed seafood resource, is a potential bioindicator of mineral contamination in its habitat. Therefore, a comprehensive assessment of its MSI is imperative for ensuring seafood safety and informing regulatory frameworks.

This study focuses on estimating the MSI in *C. amnicola* from Lagos Lagoon. By analyzing the mineral composition and comparing it to safety thresholds, the research aims to elucidate the implications for seafood quality control. The findings will provide valuable insights into the safety of consuming *C. amnicola* and contribute to broader discussions on sustainable fisheries and public health policies.

MATERIALS AND METHODS

Sample collection and preparation

A total of 90 specimens of *C. amnicola* were harvested using wire basket trap from the Lagos Lagoon (6°31.228'N and 3°24.044'E) during 2024 wet season. The crabs were thoroughly washed, measured, de-shelled and carapace region was discarded. The specimens were kept in ice-chest before being taken to Marine Sciences Department, University of Lagos, for further analysis.

Analytical procedures

Both crab parts were dried at 105° C and homogenised. Using a flame photometer (model 405, corning, U.K), the macro minerals were determined. Mineral Ratios and Mineral Safety Index were calculated according to Watts (2010) and Hatcock (1985), respectively (Equation 1).

$$MSI = [TMSI (\text{Standard}) / RAI]. Rr, \quad (1)$$

Where: MSI - Mineral Safety Index; TMSI - Tabulated MSI; RAI - Recommended Adult Intake; Rr - Research results

Statistical analysis

Data were analysed using the descriptive and inferential statistic SPSS (version 20). Each value was a mean of six (6) replications. Differences in means were tested using t-test with the significance level set at P<0.05. Results were expressed as means, standard deviations, percentage difference and coefficient of variation.

RESULTS AND DISCUSSION

Mineral Composition and Safety Index

The variations in the mineral composition of the shell and flesh of *C. amnicola* from Lagos Lagoon are shown in Table 1. Calcium predominantly concentrated in the shell (3799.07 mg/100g) compared to the tissue (1069.21 mg 100g⁻¹), likely due to its role in shell formation and rigidity. The high percentage difference (71.86 %) underscores the shell's function in calcium storage. Magnesium is the most abundant mineral overall, with a much higher concentration in the shell (34,675.35mg/100g) than the tissue (1944.33 mg 100g⁻¹). The large coefficient of variation (CV% = 126.40) suggests significant variability in magnesium distribution. Potassium was found in lower concentrations in both shell and tissue (633.61 mg 100g⁻¹ and 274.69 mg 100g⁻¹, respectively), with a moderate CV% (55.88), suggesting relatively stable levels compared to other minerals. Like calcium, phosphorus is more concentrated in the shell (7821.83 mg 100g⁻¹) than in the tissue (2749.42 mg 100g⁻¹), contributing to structural integrity and metabolic functions. Sodium displays a similar distribution pattern, with a higher concentration in the shell (3932.32 mg 100g⁻¹). However, its CV% (91.55) reflects significant variability. The summation shows an overall dominance of minerals in the shell (50,862.18 mg 100g⁻¹) compared to the tissue (6879.51 mg 100g⁻¹). Studies on crab and shrimp have similarly reported higher concentrations of calcium and phosphorus in shells, attributed to the exoskeleton's composition (primarily chitin and calcium carbonate). For example, Fabritius *et al.* (2016) found that crustacean shells are richer in calcium and magnesium than soft tissues, aligning with this data. Phosphorus levels in the shell are also consistent with findings in Chinese mitten crab (*Eriocheir sinensis*), where phosphorus supports shell formation and metabolic activities (Liu *et al.*, 2022).

Table 1: Mineral Composition (mg/100g) of *Callinectes amnicola* from Lagos Lagoon

Minerals	Shell	Tissue	Mean	SD	CV%	D	% D
Calcium	3799.07	1069.21	2434.14	1930.30	79.30	2729.86	71.86
Magnesium	34675.35	1944.33	18309.84	23144.33	126.40	32731.02	94.39
Potassium	633.61	274.69	454.15	253.79	55.88	358.92	56.65
Phosphorus	7821.83	2749.42	5285.63	3586.74	67.86	5072.41	64.85
Sodium	3932.32	841.86	2387.09	2185.29	91.55	3090.46	78.59
Total Mineral	50862.18	6879.51	28870.85	31100.44	107.72	43982.67	86.47

Keys: Standard deviation (SD), Coefficient of variation per cent (CV %), Percentage difference (D)

Mineral Ratio

Table 2 presents mineral ratios of *C. amnicola* from Lagos Lagoon, with comparison to ideal and acceptable ranges based on Watt (2010). The ratios reflect nutritional balance and physiological relevance, allowing insights into the species' mineral composition in relation to human dietary needs. The observed Ca/K (6.00 and 3.89 for shell and flesh respectively) fall within the acceptable range (2.2 to 6.2), suggesting a balanced relationship. The shell has a slightly higher ratio, which aligns with the structural role of calcium in exoskeleton formation. The observed ratios, Ca/Mg, Ca/P and Na/Mg are lower than the ideal range, indicating an imbalance. This suggests that *C. amnicola* from Lagos Lagoon is relatively deficient in calcium/ sodium compared to magnesium and phosphorus, particularly in the shell. The high CV% (94.43) indicates considerable variability, likely influenced by environmental factors or dietary differences. The Na/K ratios exceed the ideal range, indicating higher sodium content relative to potassium. Adeyeye and Jegede (2017) reported a similarly low Ca/Mg ratio in *Neopetrolisthes maculatus* from Nigerian waters, suggesting a regional trend of magnesium dominance over calcium in aquatic species. The low Ca/Mg ratio in *Callinectes sapidus* from Chesapeake Bay was linked to dietary magnesium availability (Glandon *et al.*, 2018).

Table 2: Mineral Ratio of *Callinectes amnicola* from Lagos Lagoon compared to Ideal and Acceptable Ideal Ranges

Parameter	Ideal (Ref. balance)	Acceptable ideal range	Shell	Flesh	Mean	SD	CV%
Ca/Mg	7	3 to 11	0.11	0.55	0.33	0.31	94.43
Ca/K	4.2	2.2 to 6.2	6.00	3.89	4.94	1.49	30.08
Ca/P	2.6	1.5 to 3.6	0.49	0.39	0.44	0.07	15.66
Na/K	2.4	1.4 to 3.4	6.21	3.06	4.64	2.22	47.92
Na/Mg	4	2 to 6	0.11	0.43	0.27	0.23	82.72
[K/(Ca + Mg)]	2.2		0.28	0.36	0.32	0.05	16.56

Keys: Standard deviation (SD), Coefficient of variation (CV %). Source for Ref value: Watt (2010)

Mineral Safety Index

The values of the mineral safety index (MSI) in *C. amnicola* are shown in Table 3. The MSI is a tool used to assess the safety of mineral intake in terms of dietary recommendations. The MSItv for calcium in the shell (31.66) exceeds the safety threshold (MSItv = 10), leading to a high negative %D (-216.59), indicating excessive calcium concentration. This is consistent with the shell's role in structural integrity. However, in the flesh, calcium is within the safe range (MSIcv = 8.91; %D = 10.9), making it safer for direct consumption. The moderate CV% (79.3) reflects variability, likely influenced by environmental factors or the species' molting stage. Other minerals show potential risk if consumed in excessive amounts, as their levels exceed the safe limit in both shell and flesh, with negative %D values. Sodium concentrations are significantly above the safety limit in both shell (37.75; %D = -686.46) and flesh (8.08; %D = -68.37). Studies by Wu *et al.* (2021) on crustaceans also reported high calcium levels in shells, attributing this to the exoskeleton's calcium carbonate composition. This aligns with the observed MSIcv of calcium in the shell of *C. amnicola*.

Table 3: Mineral Safety Index (MSI) in *Callinectes amnicola*

Mineral	MSItv	Shell		Flesh		Mean	SD	CV%
		MSIcv	%D	MSIcv	%D			
Calcium	10	31.66	-216.59	8.91	10.9	20.28	16.09	79.3
Magnesium	15	1300.33	-8568.84	72.91	-386.08	686.62	867.91	126.4
Phosphorus	10	65.18	-551.82	22.91	-129.12	44.05	29.89	67.86
Sodium	4.8	37.75	-686.46	8.08	-68.37	22.92	20.98	91.55

Keys: MSIcv= Calculated value of Mineral Safety Index, MSItv= Tabulated value of Mineral Safety Index, SD= Standard deviation, %D= Percentage Difference, CV%= Coefficient of variation

CONCLUSION

The mineral profile of *C. amnicola* demonstrates significant variation between shell and tissue, reflecting both its structural requirements and ecological adaptations. The findings align with similar studies on crustaceans, highlighting the species' nutritional and ecological significance. The mineral ratios highlight both nutritional strengths and potential limitations. The mineral safety index analysis reveals that while the shell and flesh provide significant mineral benefits, their consumption may pose risks due to excessive magnesium, phosphorus, and sodium concentrations. These findings highlight the need for careful dietary management and potential processing methods to mitigate mineral excesses. Further studies could explore the environmental factors influencing these mineral distributions and their implications for conservation and aquaculture practices.

REFERENCES

- Adeyeye, E. I. and Jegede, T. (2017). Chemical composition (proximate, minerals, vitamins), mineral ratios and mineral safety index of the innards of male and female *Neopetrolisthes maculatus*. *Journal of Biology and Innovation*, 6(3): 479-498.
- Glandon, H. L., Kilbourne, K. H., Schijf, J. and Miller, T. J. (2018). Counteractive effects of increased temperature and pCO₂ on the thickness and chemistry of the carapace of juvenile blue crab, *Callinectes sapidus*, from the Patuxent River, Chesapeake Bay. *Journal of Experimental Marine Biology and Ecology*, 498, 39-45.
- Kolarova, N. and Napiórkowski, P. (2021). Trace elements in aquatic environment. Origin, distribution, assessment and toxicity effect for the aquatic biota. *Ecology & Hydrobiology*, 21(4): 655-668.
- Liu, S., Li, X., Wang, X., Bu, X., Li, E., Zhang, M. and Chen, L. (2022). Molting, tissue calcium phosphorus

- deposition and immunity of juvenile Chinese mitten crab (*Eriocheir sinensis*) fed different levels of calcium and vitamin D3. *Aquaculture*, 554: 738124.
- Moruf, R. O. (2024). Mineral safety index and functional proerty of the stomatopod shrimp (*Squilla aculeata* Holthuis, 1959) (Crustacea: Stomatopoda). In: Abu *et al.* (edited), Book of Proceedings 29th Annual Conference of Nigerian Society for Animal Production, held between 8 – 12 March 2024.
- Pradeepkiran, J. A. (2019). Aquaculture role in global food security with nutritional value: a review. *Translational Animal Science*, 3(2): 903-910.
- Rangasamy, E., Muthu, V. L., Dhanabalan, K. and Muniyandi, M. (2024). Determination of proximate composition on some edible crabs with special reference to nutritional aspects collected from coastal waters of Rameshwaram, Tamil Nadu. *Food Chemistry Advances*, 4: 100686.
- Watts D. L. (2010). HTMA Mineral Ratios. A brief discussion of their clinical importance. *Trace Elem Newsletter*, 21: 1-3.
- Fabritius, H. O., Ziegler, A., Friák, M., Nikolov, S., Huber, J., Seidl, B. H. and Neugebauer, J. (2016). Functional adaptation of crustacean exoskeletal elements through structural and compositional diversity: combined experimental and theoretical study. *Bioinspiration & biomimetics*, 11(5), 055006.
- Wu, D. H., Preskitt, C. and Gresham-Fiegel, C. (2021). Chemical and physiological change from calcium carbonate to calcium phosphate in skeletal structures. *Insights Biomed Res*, 5(1): 139-148.