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Amino Acid Profile and Mineral Content Variations in Gastropod Species (*Archachatina marginata*, *Achatina achatina*, *Tympanotanus fuscatus*, and *Pachymelania aurita*): Implications for Dietary Enrichment

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Authors' contributions

This work was carried out in collaboration among all authors. Authors EOM, EEE, TTL and UAJ designed the study. Authors EOM, BNS, NUR and RUF conducted the research. Author EOM: wrote the article. Author EOM: has primary responsibility for final content. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

The global population surge increases the demand for daily protein requirements, emphasizing the need for cost-effective and readily available protein sources. The study investigated the amino acid, proximate, and mineral compositions of meat powders from four gastropod species (*Archachatina marginata*, *Achatina achatina*, *Tympanotanus fuscatus*, and *Pachymelania aurita*) procured from Offiong Market in Essien Udim Local Government Area of Akwa Ibom State, Nigeria. The samples were removed from their shells, and washed with deionized water and dilute acid. The meats were then dried at 65 – 70°C for 24 hours, ground into fine powder, and sieved to achieve uniformity in particle size. Amino acid, proximate, and mineral analyses were conducted. Significant differences ($p<0.05$) were observed in amino acid, proximate, and mineral compositions among the meat powders of the studied gastropod species. Most essential amino acids such as Leucine, histidine, isoleucine, phenylalanine, threonine, methionine, lysine, and valine were present. Proximate analysis revealed high protein and carbohydrate, and low fat and fibre contents among the gastropod species. Mineral analysis indicated high levels of Ca, P, Mg, K, and N, while Zn and Fe were significantly low across all species. The high protein and low fat and fiber contents suggest that gastropod meat powder could be used as additives for food fortification to meet the global demand for protein.

Keywords: Amino acid; chemical composition; snail; periwinkle; meat.

1. INTRODUCTION

Giant African land snails and periwinkles, both belonging to the phylum Mollusca and class Gastropoda, provide high-quality proteins containing essential amino acids necessary for human body growth, repair, and maintenance [1,2,3,4]. Seafood like periwinkle is particularly valuable due to its rich content of high-quality protein, n-3 polyunsaturated fatty acids, minerals, trace elements, and vitamins, crucial for the growth of the body, brain, and nervous system. Compared to other sources such as goat, sheep, cow, and poultry, seafood offers superior protein quality [5], highlighting its significant role in human nutrition and health.

The fatty acid composition of shell-bearing animals significantly contributes to a healthy diet [6]. Variations in the nutritional content of gastropods depend on factors such as species, sex, feeding habits, age, and seasonal conditions [7,8]. Periwinkles and giant African land snails, among the largest invertebrates after arthropods, exhibit diverse phenotypic traits and habitat preferences [2]. Periwinkles, commonly found in estuarine and sea waters, inhabit littoral regions and mangrove swamps, displaying passive behaviour during tidal changes [9,10]. In Nigeria's south-south region, *Typanotanus fuscatus* and *Pachymelania aurita* are prevalent periwinkle species, while *Archachatina marginata* and *Achatina achatina* are giant African land snails found in the forested areas of this region, suitable for domestication [2].

These shell-bearing animals hold economic significance in Nigeria, particularly in Akwa Ibom State, where they are harvested by hand-picking and marketed for their protein, minerals, vitamins, and essential amino acids [8,11,12]. Their affordability makes them a staple protein source for both low-income earners and wealthier individuals, with reported benefits for cardiac health due to their cholesterol-free meat [5,13].

Studies by [14] have shown that sub-chronic consumption of periwinkle extracts improves blood parameters without adverse effects on liver enzymes in anaemic albino rats. However, despite their regular consumption, awareness of the nutritional benefits of periwinkles and giant African land snails remains limited. Furthermore, the lack of processing methods for these meats restricts their utilization in food formulation and development. Therefore, this study aimed to evaluate periwinkle and giant African land snail meats for amino acid, proximate, and mineral compositions.

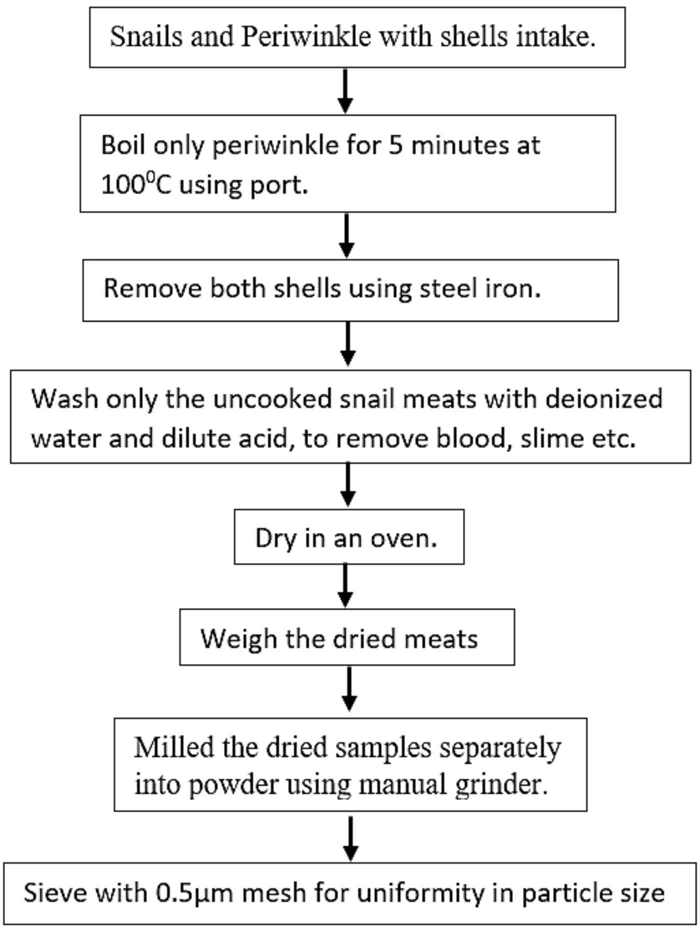
2. MATERIALS AND METHODS

2.1 Location and Experimental Animals

A total of forty (40) giant African land snails consisting of twenty (20) each of *A. marginata* (Fig. 1A), and *A. chatina* (Fig. 1B) respectively, were procured from Offiong Market in Essien Udim Local Government Area, (Lat. $5^{\circ}5^{1}$, 56N and Long. $7^{\circ}38^{1}$, 24E) in Akwa Ibom State, Nigeria. Also, four (4) cups of medium-sized Clappa cans, consisting of two (2) cups each of fleshly harvested *T. fuscatus* (Fig. 1C) and *P. aurita* (Fig. 1D), were procured from the same Market for this study. The research was conducted at the Animal house in the Department of Biological Sciences, Topfaith University, Mkpatak, Akwa Ibom State, Nigeria.

2.2 Preparation of Snails and Periwinkle Meats into Dried Meat Powder

The two species of giant African land snails obtained for this study were processed according to the method described by [15]. The snail meat was carefully removed using stainless iron from the shell, washed separately with deionized water and dilute acid that was prepared from 1M solution in order to remove blood, slime and any other adhering contamination, and allowed to dry, and then weighed. For the periwinkles, the whole bodies were washed properly with portable water to get rid of mud and any other adhered materials on the shells. Each sample of periwinkle was boiled in water for 5 minutes at 100^0C, using a pot, drained and allowed to cool to a temperature of 27^0C. The meat was carefully removed from the shells manually, using a stainless pin. The meat was washed in potable water and drained. Both snails and periwinkle meats were dried at 65 – 70^0C for 24 hours in an Oven (Model – TT-9023A Techmel and Techmel, USA). Dried samples were milled separately into fine powder using a manual grinder and sieved with a 0.5µm mesh size to achieve uniformity in particle size.



Flow Chart 1. The preparation stages of snails and periwinkle meats into dried meat powder

Fig. 1. Diagram of Gastropods species used in the study. A. *Archatchatina marginta*, B. *Achatina achatina*, C. *Tympanotanus fuscatus* and D. *Pachymelania aurita*

2.3 Amino Acid Analysis

The amino acid profile of the samples was determined using the method described by [16]. The samples for amino acid analysis were dried to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator (Model 800D, SearchTech Instruments, British Standard) and loaded into an Amino acid analyzer (Perkin and Elmer Model 403, USA). Essential amino acid scores were computed according to the FAO/WHO reference amino acid pattern [17].

2.4 Proximate and Mineral Analysis

The proximate analyses (crude protein, fat, ash and crude fiber) were analyzed by adopting the methods described in [18]. The carbohydrate content was calculated by subtracting 100 from the total of all the other proximate measurements (Crude protein, fat, fibre and ash). The minerals (Ca, K, Na, Mg, Fe, P, and Zn) were analyzed using an Atomic Absorption Spectrophotometer (Model 721, Medifriend, England) as described in [18].

2.5 Statistical Analysis

The data collected were subjected to statistical analysis using a statistical package for Social Sciences Version 18 statistical package (SPSS,Inc. USA). Analysis of Variance (ANOVA) was done to determine significant differences at ($P < 0.05$). The means were separated using the Least Significant Difference (LSD). The mean, standard deviation and standard errors were calculated according to [19].

3. RESULTS AND DISCUSSION

3.1 Amino acid Composition of the Four Gastropod Species

The results of the total amino acid composition of *A. achatina*, *A. marginata*, *T. fuscatus*, and *P. aurita* Meat Powders was 674mg/100g protein, 877mg/100g protein, 773mg/100g protein, and 784mg/100g protein, respectively, as summarized in Table 1. Glutamic acid was the highest contributor to the total amino acid content for both snail and periwinkle species.

For *A. achatina*, *A. marginata*, *T. fuscatus*, and *P. aurita* Meat Powders, the total essential amino acids with Histidine were 320mg/100g protein, 450mg/100g protein, 368mg/100g protein, and 393mg/100g protein, respectively. Without Histidine, the total essential amino acids for the same species of gastropods were 291mg/100g protein, 404mg/100g protein, 342mg/100g protein, and 368mg/100g protein, respectively, with arginine making the major contribution for all samples. Methionine was the least contributor to the essential amino acids in all species samples.

3.2 Proximate Composition of the Four Gastropod Species

The proximate composition of the meat powder derived from the edible portions of the four gastropod species is detailed in Table 2. Significant variations ($P < 0.05$) were observed in the proximate composition among the studied gastropod species.

The predominant organic constituent of the meat powders derived from the four gastropod species was protein. *A. marginata* exhibited the highest protein content at 84.80%, significantly differing ($P < 0.05$) from the other three gastropod species. Protein content was generally higher in the two snail species compared to the periwinkle species, with *T. fuscatus* displaying the lowest protein content at 47.01%.

3.3 Mineral Content of the Four Gastropod Species

The mineral composition analysis of the four gastropod species revealed varying quantities of all analyzed minerals in the meat powders, with significant differences ($P < 0.05$) observed among the species (Table 3). Among the minerals analyzed, calcium exhibited the highest concentration, with *A. achatina* species recording the highest amount at 472.41mg/100g, while zinc showed the lowest concentration at 3.51mg/100g for *P. aurita* species.

Table 1. Amino acid composition of *A. achatina*, *A. marginata*, *T. fuscatus* and *P. aurita* meat powder (Mg/100g protein)

Amino Acid	*A. achatina*	*A. marginata*	*T. fuscatus*	*P. aurita*
Leucine (Leu)[a]	23.50±0.03[c]	80.00±0.02[a]	71.50±0.03[b]	86.80±0.03[a]
Histidine (His)[a]	28.60±0.02[b]	46.00±0.11[a]	26.00±0.01[b]	25.40±0.10[b]
Lysine (Lys)[a]	59.80±0.06[a]	55.60±0.01[a]	47.20±0.01[c]	50.60±0.05[b]
Arginine (Arg)[a]	62.30±0.04[a]	60.00±0.04[b]	62.10±0.04[a]	60.30±0.11[b]
Threonine (Thr)[a]	21.40±0.12[d]	28.40±0.02[c]	34.00±0.02[b]	41.20±0.13[a]
Valine (Val)[a]	31.70±0.02[c]	70.50±0.10[a]	37.80±0.08[b]	37.40±0.04[b]
Methionine (Met)[a]	12.60±0.04[c]	21.30±0.06[a]	15.40±0.02[b]	15.80±0.01[b]
Isoleucine (Ile)[a]	43.80±0.06[a]	39.20±0.01[b]	39.10±0.04[b]	34.30±0.04[c]
Phenylalanine (Phe)[a]	36.00±0.01[c]	49.00±0.11[a]	35.30±0.10[c]	41.20±0.08[b]
Tyrosine (Tyr)	22.00±0.03[b]	30.00±0.06[a]	31.40±0.03[a]	31.00±0.05[a]
Cystine (Cys)	7.80±0.04[c]	11.40±0.03[b]	12.10±0.11[a]	10.10±0.03[b]
Alanine (Ala)	25.30±0.04[d]	52.10±0.01[a]	37.90±0.08[c]	41.20±0.03[b]
Glycine (Gly)	52.40±0.06[a]	45.90±0.08[b]	41.00±0.04[c]	40.40±0.01[c]
Proline (Pro)	31.20±0.04[c]	37.00±0.01[b]	40.30±0.03[a]	35.30±0.02[b]
Glutamic acid (Glu)	113.00±0.08[c]	142.00±0.06[a]	120.10±0.06[b]	118.70±0.07[b]
Serine (Ser)	32.10±0.13[b]	34.10±0.01[a]	35.30±0.01[a]	31.60±0.01[b]
Aspartic Acid (Asp)	70.30±0.11[d]	74.00±0.03[c]	86.20±0.04[a]	82.20±0.03[b]
Total Amino Acid (TAA)	674.00±0.07[c]	877.00±0.04[a]	773.00±0.06[b]	784.00±0.09[b]
Total Essential Amino Acid (TEAA)				
With Histidine	320.00±0.04[d]	450.00±0.08[a]	368.00±0.04[c]	393.00±0.06[b]
No Histidine	291.00±0.06[d]	404.00±0.03[a]	342.00±0.01[c]	368.00±0.03[b]

Means on the same row with different superscripts are significantly different at P< 0.05.
Abbreviations: TAA = Total Amino Acid; TEAA = Total Essential Amino Acid. The superscripts "a" on the amino acids indicate Essential Amino Acids.

Table 2. Proximate composition of *A. achatina*, *A. marginata*, *T. fuscatus* and *P. aurita* meat powder (dry matter basis)

Parameters	*A. achatina*	*A. marginata*	*T. fuscatus*	*P. aurita*
Crude Protein (%)	72.10±0.03[b]	84.80±0.05[a]	47.01±0.01[d]	52.12±0.08[c]
Fat (%)	6.20±0.05[a]	4.40±0.06[b]	4.00±0.05[b]	3.02±0.03[c]
Crude fibre (%)	1.40±0.01[a]	1.30±0.03[a]	0.43±0.02[b]	0.51±0.04[b]
Carbohydrate (%)	14.00±0.02[b]	3.40±0.01[c]	35.12±0.09[a]	34.02±0.06[a]
Ash (%)	3.50±0.03[c]	3.10±0.04[c]	13.01±0.01[a]	10.27±0.03[b]

Means on the same row with different superscripts are significantly different at P < 0.05.

Table 3. Mineral Content of *A. achatina*, *A. marginata*, *T. fuscatus* and *P. aurita* Meat Powder (Mg/100g)

Parameters	*A. achatina*	*A. marginata*	*T. fuscatus*	*P. aurita*
Ca	421.26±0.03^{b}	472.41±0.01^{a}	42.13±0.02^{d}	57.32±0.07^{c}
k	112.52±0.04^{a}	110.07±0.03^{a}	30.10±0.07^{c}	34.13±0.02^{b}
Na	52.08±0.11^{d}	62.41±0.03^{c}	73.13±0.01^{b}	83.09±0.05^{a}
Mg	270.00±0.03^{a}	279.08±0.01^{a}	142.03±0.04^{c}	159.24±0.06^{b}
Fe	6.00±0.05^{c}	6.41±0.03^{c}	10.41±0.05^{b}	14.05±0.01^{a}
Zn	7.08±0.01^{b}	8.32±0.02^{a}	4.06±0.06^{c}	3.51±0.02^{c}
P	231.90±0.03^{b}	263.10±0.08^{a}	161.21±0.01^{d}	184.26±0.03^{c}

Means on the same row with different superscripts are significantly different at P < 0.05.

3.4 Amino Acid Composition of *A. achatina*, *A. marginata*, *T. fuscatus* and *P. aurita* Meat Powder

Amino acids serve as the fundamental building blocks of proteins, essential for growth and development [20]. In the edible parts (meat powders) of *A. achatina*, *A. marginata*, *T. fuscatus*, and *P. aurita*, seventeen amino acids were identified, showing variations in individual, total, and essential amino acids among the four gastropod species studied [21,22,23,24].

[21] noted higher concentrations of amino acids like Lys, Asp, Arg, Ser, and IIe in Limicolaria compared to *A. achatina* and *A. marginata*, despite the smaller size of the species. [23] observed variations in amino acid quantity within and between different species of marine organisms, influenced by factors such as size, species, geographical location, and seasonal conditions [25].

Amino acids play vital roles in normal growth and development, with essential amino acids needing to be obtained from foods to promote normal growth and maintenance of nitrogen balance. Their absence in foods may impair tissue growth and repair [24,26]. The essential amino acid composition in this study differs from the report of [21], with arginine being the highest contributor to total essential amino acids in line with the findings of [21], who reported arginine as the major contributor from *A. achatina* species to essential amino acids.

A comparison of the essential amino acid content in this study with the [17] reference values revealed that the majority of the amino acids met the recommended range for infants and adults, and were significantly higher than the recommended amounts for preschool and school children, respectively. [27] attributed the availability of these amino acids to the lack of fibre and anti-nutritional properties in the samples, as noted by [28]. The high proportion of lysine recorded in this study for the four gastropod species aligns with previous works by [21,29], suggesting its potential for fortifying maize food products used for weaning children in some countries.

Furthermore, this research revealed that the four gastropod species were rich in histidine and arginine amino acids, which are essential for children, as reported by [17,30,31]. These findings indicate that the protein in *A. achatina*, *A. marginata*, *T. fuscatus*, and *P. aurita* Meat Powders is of very high quality, with balanced essential amino acids suitable for food fortification purposes.

3.5 Proximate Composition of *A. achatina*, *A. marginata*, *T. fuscatus* and *P. aurita* Meat Powder

The proximate composition of the meat powder derived from the edible portions of the four gastropod species is detailed in Table 2. Significant variations ($P < 0.05$) were observed in the proximate composition among the studied gastropod species, likely attributed to differences in feeding regimes, species, locations, and environmental factors such as temperature, given that gastropods are ectothermic animals [7,32,33]. This finding is consistent with previous reports by [33,34], which highlighted the influence of climate, location, and dietary variables on the physiology of gastropods. Similar variations in proximate composition within and between species of mollusks were also documented by [35] and among different species of gastropods [9,11,12,24,33,36].

The predominant organic constituent of the meat powders derived from the four gastropod species was protein. *A. marginata* exhibited the highest protein content at 84.80%, significantly differing

(P < 0.05) from the other three gastropod species. Protein content was generally higher in the two snail species compared to the periwinkle species, with *T. fuscatus* displaying the lowest protein content at 47.01%. The protein levels observed for *A. achatina* and *A. marginata* in this study fell within the range reported by [37], ranging from 71.66% for *A. achatina* to 85.12% for *A. marginata*, but were lower than the values reported by [33] for *A. achatina* meat, which stood at 22.20%.

The protein content recorded for *P. aurita* (52.12%) and *T. fuscatus* (47.01%) in this study aligned with values reported by [24], which were 51.30% for *P. aurita* and 46.51% for *T. fuscatus*, respectively, but were lower than the value (68.46%) observed by [38] for *T. fuscatus* meat. Conversely, the protein content for *P. aurita* (52.12%) in this study was higher than values reported by [9] at 49.54%, and by [11] at 48.62% for *P. aurita* species. Proteins serve as essential components and sources of amino acids in our diets, facilitating growth, development, and maintenance of living systems [1,24,33]. The observed high protein concentration in these four gastropod species suggests that their meat powders could be utilized for fortifying carbohydrate-based diets, potentially addressing the issue of protein-energy malnutrition among the populace.

The fat content observed in this study varied among the four gastropod species, ranging from 3.02% for *P. aurita* to 6.20% for *A. achatina*, with significant differences (P < 0.05) noted among the species, except for *A. marginata* and *T. fuscatus*, which did not differ significantly (P > 0.05) from each other. Generally, fat content was higher in the two snail species compared to the periwinkle species. The fat levels recorded in this study fell within the range of 4.37% for *A. marginata* and 5.06% for *A. achatina* reported by [37], but were lower than the value of 2.05% obtained by [33] for *A. achatina*. Conversely, the fat content of meat powder obtained for *T. fuscatus* and *P. aurita* in this study was higher than 3.11% (*T. fuscatus*) and 2.94% (*P. aurita*) observed by [24], and 1.16% (*T. fuscatus*) and 1.32% (*P. aurita*) reported by [39], but lower than 6.31% (*T. fuscatus*) and 6.73% (*P. aurita*) reported by [11], and 7.68% (*T. fuscatus*) by [38]. The low-fat content observed among the four gastropod species suggests their potential use in treating hypertension and arteriosclerosis by incorporating meat powder into foods for consumption [40].

A minimal crude fiber content was observed in all the meat powders of the gastropod species analyzed, ranging from 0.43% for *T. fuscatus* to 1.40% for *A. achatina*. This value was higher in the two snail species compared to the periwinkle species. Similar variations in crude fiber content have been noted by other authors across different species of gastropods and shell-bearing animals. The crude fiber content obtained in this study for *A. achatina* (1.40%) and *A. marginata* (1.30%) was consistent with the findings of [37], but higher than the range reported by [33].

Likewise, the crude fiber content of 0.43% for *T. fuscatus* and 0.51% for *P. aurita* obtained in this study aligned with previous reports. This low level of crude fiber concentration recorded in this study for the four gastropod species suggests their suitability for food complementation.

The carbohydrate content of the meat powder from *T. fuscatus* and *P. aurita* gastropod species significantly (P < 0.05) differed from that of *A. achatina* and *A. marginata*, respectively. *T. fuscatus* exhibited the highest carbohydrate concentration at 35.12%, while *A. marginata* had the lowest at 3.40%. These values for *T. fuscatus* and *P. aurita* were consistent with those reported by [24], but lower than those reported by [9,11]. Likewise, the carbohydrate concentrations for *A. achatina* and *A. marginata* in this study were slightly higher than those reported by [37] but exceeded the range reported by [33]. This discrepancy suggests a higher carbohydrate level in periwinkle species compared to snails, possibly due to their aquatic habitat providing ample hydrogen, oxygen, and carbon for carbohydrate synthesis, which fuels their muscular movement and regulates body temperature.

The ash concentration in this study was significantly (P < 0.05) higher in the two species of periwinkles (13.01% for *T. fuscatus* and 10.27% for *P. aurita*) compared to the snails' species (3.50% for *A. achatina* and 3.10% for *A. marginata*). The range of ash content among the four gastropod species varied from 3.10% to 13.01%, with *T. fuscatus* exhibiting the highest and *A. marginata* the lowest values. These results were consistent with those reported by [37] for *A. marginata* and *A. achatina* but exceeded the range reported by [33] for *A. achatina*. Conversely, the ash content for the two periwinkle species in this study surpassed the values reported by [24] for *T. fuscatus* and *P. aurita*, as well as those reported by other authors for *T. fuscatus* and *P. aurita* meat. The ash content serves as a vital indicator of the nutritional value and processing of food items. Higher ash content is typically associated with processed foods compared to natural foods with lower ash content. Additionally, ash content provides insight into the inorganic concentration of a sample and the origin of mineral elements. The elevated ash content observed in the meat powders of *P. aurita* and *T. fuscatus* in this study suggests a high concentration of mineral elements, indicative of processed foods.

3.6 Mineral Content in *A. achatina*, *A. marginata*, *T. fuscatus* and *P. aurita* Meat Powder

The mineral composition analysis of the four gastropod species revealed varying quantities of all analyzed minerals in the meat powders, with significant differences (P < 0.05) observed among the species (Table 3). Among the minerals analyzed, calcium exhibited the highest concentration, with *A. achatina* species recording the highest amount at 472.41mg/100g, while zinc showed the lowest concentration at 3.51mg/100g for *P. aurita* species. Contrary to the typical low calcium content of meats, as reported by[40] ranging from 9 to 11mg/100g, this study found a notable presence of calcium in all the gastropod species analyzed. Calcium content ranged from 42.13mg/100g for *T. fuscatus* to 472.41mg/100g for *A. marginata*. Additionally, potassium, sodium, magnesium, and phosphorus contents ranged from 30.10mg/100g for *T. fuscatus* to 112.52mg/100g for *A. achatina*, 52.08mg/100g for *A. achatina* to 83.09mg/100g for *P. aurita*, 142.03mg/100g for *T. fuscatus* to 279.08mg/100g for *A. marginata*, and 161.21mg/100g for *T. fuscatus* to 263.10mg/100g for *A. marginata*, respectively (Table 3). Furthermore, iron (Fe) and zinc (Zn) contents ranged from 6.00mg/100g for *A. achatina* to 14.05mg/100g for *P. aurita*, and 3.51mg/100g for *P. aurita* to 8.32mg/100g for *A. marginata*, respectively.

[24]reported elevated levels of calcium (Ca), potassium (K), and magnesium (Mg) in *T. fuscatus* and *P. aurita* species, with values of 41.38mg/100g and 56.74mg/100g for Ca, 29.51mg/100g and 33.62mg/100g for K, and 140.00mg/100g and 155.21mg/100g for Mg, respectively. Similarly, [41] found a high Ca content of 780mg/100g in A. fulica, while[42] recorded 750mg/100g of Ca in H. pomatia from the Cukurova region of Turkey. Dambo [42,43] also reported high Ca levels ranging from 650 to 700mg/100g and 585.80mg/100g, respectively, in various gastropod species, consistent with the findings of this study.

The mineral composition of gastropod meat is influenced by various factors such as biological cycle, species type, habitat, season, and nutrient availability [44]. Compared to other animal products like milk (120mg/100g), eggs (54mg/100g), liver (6mg/100g), and beef (7mg/100g), which have lower calcium concentrations, gastropods exhibit a rich calcium content [45]. Given the importance of calcium in bone and teeth development during infancy and childhood, it is recommended to incorporate powdered snail meat into diets for infants, as it can contribute significantly to their calcium intake [43].

Magnesium was the mineral with the next highest concentration after calcium among the gastropod meat powders studied. The values obtained in this study were lower than those reported by [37], who found 308.70mg/100g for *A. marginata* and 304.62mg/100g for *A. achatina*. Conversely, the results were higher than those reported by [46], who recorded 45.59mg/100g for *A. achatina* and 46.15mg/100g for *A. marginata*. However, these findings were consistent with the results of [24], who reported magnesium concentrations of 41.38mg/100g for *T. fuscatus* and 56.74mg/100g for *P. aurita*.

According to [47], calcium (Ca) and phosphorus (P) are crucial for bone formation during childhood and developmental stages, while manganese (Mn), zinc (Zn), and iron (Fe) are essential for disease prevention, growth, and fundamental cellular activities, respectively.

The iron (Fe) content was higher in *P. aurita* (14.05mg/100g) and *T. fuscatus* (10.41mg/100g) compared to *A. marginata* (6.41mg/100g) and *A. achatina* (6.00mg/100g) in this study. [37] reported Fe concentrations of 6.33mg/100g for *A. marginata* and 5.75mg/100g for *A. achatina*, which were similar to the results obtained in this study. Conversely, the values were slightly higher than those reported by[24] for *T. fuscatus* (10.19mg/100g) and *P. aurita* (9.05mg/100g). However, they were comparable to the values reported by [11] for periwinkle species (12.73mg/100g and 12.75mg/100g). Iron is an important mineral for the formation of the heme molecule in hemoglobin, which carries oxygen in the bloodstream to different parts of the body.

Sufficient iron intake in the diet is essential for reducing the incidence of iron deficiency anemia, especially in young children. Based on the findings of this study, it is recommended to include *P. aurita* and *T. fuscatus* in the diets of children due to their high iron content.

Zinc was found in significant concentrations in all the meat samples studied, with *A. marginata* exhibiting the highest level (8.32mg/100g), while the lowest value (3.51mg/100g) of Zn was recorded for *P. aurita* species. There was a significant ($P < 0.05$) difference in zinc composition among the gastropods studied. These findings were consistent with the reports of [37], who obtained Zn values of 8.41mg/100g and 6.28mg/100g for *A. marginata* and *A. achatina*, respectively. However, the Zn contents in this study were slightly higher than the values (3.08mg/100g and 2.64mg/100g) for *T. fuscatus* and *P. aurita* species, respectively, recorded by [24]. Conversely, the Zn values obtained in this study were lower than 12.42mg/100g and 10.42mg/100g recorded by [12] for smooth and rough periwinkle meat, respectively. Zinc plays a crucial role in dark adaptation and night vision in the human system [48,49]. It is also essential for the production of nucleic acids (DNA and RNA), proteins, insulin hormones, and the normal functioning of the immune system and enzyme activation [50].

The phosphorus concentration ranged from 161.21mg/100g to 263.10mg/100g in this study, with *A. marginata* exhibiting the highest P content and *T. fuscatus* the least (Table 3). There was a significant ($P < 0.05$) difference in the level of phosphorus in the meat powder among the gastropods studied. These results were largely consistent with the report of [37], who recorded P values of 268.53mg/100g and 241.90mg/100g for *A. marginata* and *A. achatina*, respectively. Phosphorus is also a component of teeth and bones, similar to calcium, with approximately 85% of phosphorus found in bones [51]. The phosphorus concentration in milk, beef, liver, and eggs was reported by [45] to be 95mg/100g, 156mg/100g, 313mg/100g, and 218mg/100g, respectively. Comparing the results obtained in this study for phosphorus shows that gastropods are a good source of phosphorus.

4. CONCLUSION

The study revealed significant variations in the amino acid profile, proximate composition, and mineral content among the meat powders derived from gastropods (*A. achatina*, *A. marginata*, *T. fuscatus*, and *P. aurita*). These gastropod species exhibited high protein content and low fat and fiber content. The essential amino acids identified in the study met the recommended ranges by FAO/WHO for both children aged 2 to 5 years and adults. Given the low crude fiber and high protein concentrations in the meat powders of these gastropod species, they can serve as valuable dietary supplements. Additionally, the low-fat concentration suggests their potential use as additives in diets for individuals with hypertension and other fat-related disorders. Strategically incorporating these meat powders into diet fortifications, formulations, and development efforts can effectively leverage these affordable, nutritious, and natural sources of meat protein.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors are hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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