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Nutritional and Anti-Nutritional Profiles of Three Edible Snail Species in Awka Metropolis, Nigeria

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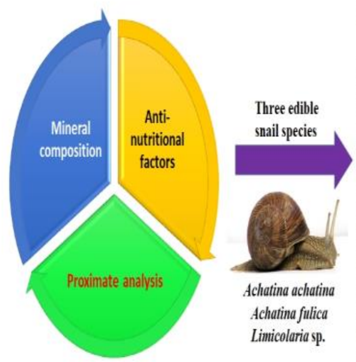
Abstract:- Three different fleshy snail species namely Achatina achatina (A. achatina), Achatina fulica (A. fulica), and Limicolaria specie (Limicolaria sp.), available within Awka Metropolis, Anambra State were subjected to analytical assessment of the nutrition and anti nutritional composition as a measure to appreciate their contribution to human food/meat. The proximate evaluation was carried out by adoption of standard analytical procedure as established by AOAC, Official Methods of Analysis, 17th edition. The mineral contents of the snail samples were determined using AAS. Identification and quantitative determination of anti-nutrients were done via gas chromatography-flame ionization detector (GC-FID) methods. The results showed Limicolaria sp had the highest crude protein (5.25%) followed by Achatina achatina (4.90%) with least, 4.55% crude fibre associated with Achatina Fulica sp. The fat contents were relatively the same for the three species ranging from 7.15 – 7.94%. The carbohydrate values of Achatina achatina and Limicolaria sp were within 64% range while A. Fulica was 42.5%. The trend observed in the average essential mineral content was Na(2.936ppm) > Mg(1.531ppm) > Ca(1.350ppm) > K(1.261ppm) > Fe(0.039ppm) while heavy metals Pb(0.024ppm < Cd(0.107ppm). Strong presence of Tannin, Terpenoid and cardiac glycoside were observed for A.achatina. Presence of flavonoid and alkaloid was also observed in the three species. Quantatively, the level of anthrocyanin, proanthocyanin and naringin in A.achatina occurred at none detectable limit of the instrumentation, but for A.fulica, 3.416, 13.911 and 6.182% respectively were obtained. The trend observed in the mean ocurrence of antinutritional factors was sponin (8.921%) > oxalate (7.188%) > phenol (6.865%) > tanin (6.635%) > phytate (6.280%) > Lunamarine (4.320%) > ribalinidine (3.333%). The research revealed appreciable concentration of essential minerals in the snail samples with high level of antinutritional factors. High amount of carbohydrate was implicated in the samples hence the consumption of these snail samples should be at a minimal level to avoid accumulation of antinutritional factors in the body system.

Keywords: *Snail, Nutrition, Anti-Nutrition, Protein, Proximate Analysis, Minerals.*

Graphical Abstract:-



Anti-nutritional Composition	*Achatina achatina*		*Achatina fulica*		*Limicolaria Sp.*	
	Concentration (µg/ml)	Concentration (%)	Concentration (µg/ml)	Concentration (%)	Concentration (µg/ml)	Concentration (%)
Rutin	0.960	1.465	0.000	0.000	0.000	0.000
Kaempferol	5.664	8.649	5.664	9.119	0.000	0.000
Catechin	7.680	11.727	4.800	7.728	0.000	0.000
Epicatechin	3.840	5.863	0.000	0.000	0.000	0.000
Anthocyanin	0.000	0.000	2.121	3.416	4.041	5.898
Proanthocyanin	0.000	0.000	8.640	13.911	5.760	8.406
Naringin	0.000	0.000	3.840	6.182	0.000	0.000
Naringenin	0.000	0.000	0.000	0.000	3.072	4.483
Flavonone	2.121	3.239	0.000	0.000	0.000	0.000
Flavan-3-ol	0.000	0.000	0.000	0.000	3.360	4.903
Spartein	0.771	1.177	7.065	11.376	8.745	12.763
Lunamerine	2.198	3.357	2.198	3.539	4.118	6.010
Ribelinidine	8.147	1.244	2.908	4.683	2.908	4.245
Tanin	4.900	7.482	5.860	9.435	2.048	2.988
Phenol	3.840	5.863	4.800	7.728	4.800	7.005
Saponin	5.760	8.795	7.680	12.365	3.840	5.604
Oxalate	3.840	5.863	1.920	3.091	8.640	12.609
Phytate	3.082	4.706	2.688	4.328	6.720	9.807

I. INTRODUCTION

The provision of enough food of acceptable quality for the world's rapidly expanding human population is one of the main challenges the world is currently facing [1, 2]. According to the most recent evaluation of the state of food security in the world, there are now 793 million people who are malnourished, defined as those who cannot receive enough food to meet the necessary daily nutritional energy requirements for a period of one year [3]. The situation is particularly dire in Africa, where the number of undernourished people surged from 175.7 to 217.8 million between 1992 and 2016 [4, 5]. The main cause of this is a diet deficient in macronutrients (protein, carbohydrate, and fat) as well as micronutrients (minerals, vitamins), which leads to particular micronutrient deficiencies [4, 6]. Consequently, it is crucial to take into account micro-livestock, such as snails, as a substitute source of animal protein as macro-livestock cannot resolve this dietary deficiency on its own.

Snails are a member of the phylum Mollusca, a class of invertebrate organisms with a shell, which also includes oysters, octopuses, squid, mussels, and cattlefish [7]. Since ancient days, people have eaten snails, and in many countries today, edible snails are still on the menu [8]. Unconventional food products that are traditionally consumed may complement a population's nutritional needs, thereby halting the onset of numerous diseases linked to malnutrition [9, 10]. Snail meat contains highly digestible protein and reduced fat, and it competes favorably with poultry eggs and flesh in terms of essential amino acids [11, 12]. Snails also contain several minerals, such as iron, potassium, and calcium, among others, which are essential to human [13].

Economically, snail farming (heliciculture) is a major player in the sustainability of many rural families, especially in Africa, contributing as much as 34–76% of rural income [14]. Heliciculture promotes high fecundity and low mortality while requiring less labor, capital, and specialized knowledge [15]. Snail is also traditionally used in the preparation of mixtures for a variety of conditions, including the alleviation of labor pains, the prevention of blood loss during childbirth, and the treatment of hypertension, anemia, high blood pressure, and other conditions associated with fat [16, 17].

In Nigeria, there is a growing market for edible snails, and as a result, snail farming is gaining popularity. Snails have been domesticated in the country in a variety of housing units, including pens, cages, and baskets, among others, as people have become more aware of the advantages that may be derived from them [18]. The most common edible snail species in Nigeria include *Archatina marginata* (giant African land snail), *Achatina achatina* (giant tiger land snail), *Achatina fulica* (giant African snail), and *Limicolaria* specie (garden snail). They are also the most prevalent species in the southern region of the country, where the climate is tropical and the vegetation is most suited to their growth [19, 20].

However, maintaining the product's degree of nutritional, hygienic, and sanitary quality is one of the challenges in developing suitable raising methods and diets. Despite the fact that eating snails is widespread in southern Nigeria, little is known about their nutritional value. The nutritional value of the snails will provide consumers with information about the quality and recommended intake of snails. This is also important because infections can employ snails as a secondary host and a means of spreading disease to humans [21]. Therefore, the aim of this study was to assess the nutritional value of three species of snails commonly consumed in the Awka metropolis. The snails include *Achatina achatina*, *Achatina fulica*, and *Limicolaria* specie.

II. METHODOLOGY

➢ *Sample collection and preparation*

The three species of snails, namely *Achatina achatina* (*A. achatina*), *Achatina fulica* (*A. fulica*), and *Limicolaria* specie (*Limicolaria* sp.), shown in **Figure 1**, were bought from Eke Awka market in Awka, Anambra state, Nigeria. They were washed in tap water, and all residual moisture was allowed to dry. Then, the shells were carefully removed so that the edible parts could be extracted. Afterwards, the samples were oven-dried, pulverized into a fine powder, and stored for subsequent analysis. All reagents used were of analytical grade.

Fig 1 The three species of snails

➢ *Proximate analysis*

Proximate analyses (moisture, crude protein, crude fibre, fat, ash, and carbohydrate) were determined following established procedures recommended by the Association of Official Analytical Chemists [22]. Briefly, the moisture percentage was estimated by drying the sample in an oven at 105 °C until a constant weight was obtained. The Kjeldahl method was used to determine the crude protein content, and the total protein was obtained by multiplying the total nitrogen amount by the 6.25 nitrogen-to-protein conversion factor. The soxhlet extraction method was used to calculate the percentage of fat. Sulfuric acid and sodium hydroxide were used in two separate digestions to assess the crude fibre content. Ash content was assessed by incineration in a muffle furnace for 5 h at 550 °C. The amount of carbohydrate was estimated by subtracting the sum of the values of moisture, protein, fat, fibre, and ash contents from 100%. All the analyses were performed in triplicate.

➢ *Mineral analysis*

The mineral content of the snail samples was determined using the atomic absorption spectrophotometer (Model AAS-200, Analyst Version 6, PerkinElmer). The samples were wet digested with a solution of sulphuric acid, nitric acid, and perchloric acid at a ratio of 1:10:4 before the mineral content analysis [23].

➢ *Qualitative determination of anti-nutrients*

Using the techniques recently described by Emenike and Onyema [24] and Iwuozor [25], the presence of the anti-nutritional components present in the samples, such as flavonoids, alkaloids, phenol, glycosides, tannins, saponins, resins, terpenoids, and steroids, was qualitatively determined.

➢ *Quantitative determination of anti-nutrients: gas chromatography-flame ionization detector*

Using gas chromatography and a flame ionization detector (GC-FID), the anti-nutritional components of the snail species under study were identified and quantified. In essence, 1 g of each sample was weighed and divided across three test tubes. The test tubes were filled with 10 ml of 50% w/v potassium hydroxide and 15 ml of ethanol. The test tubes were placed in a water bath set at 60 °C for 60 minutes. The test tubes' contents were then carefully transferred into various separatory funnels, and each funnel received a rinse of 10 ml each of cold water and hot water, 20 ml of ethanol, and 3 ml of hexane. They were again washed three times with a 10% v/v ethanol solution in 10 ml. The solvent was then removed from the solutions, which were subsequently dried with anhydrous sodium sulfate. Following the preparation of a sample of each solution soluble in 100 µl of pyridine, 20 µl was transferred into a vial on the gas chromatography machine (a Buck M910 with flame ionization) for anti-nutritional quantification analysis.

➢ *Statistical analysis*

A one-way analysis of variance (ANOVA) was used to analyze the results that were obtained from the proximate analysis. Additionally, significant differences between means were divided using the least significant difference (LSD).

III. RESULTS AND DISCUSSION

➢ *Proximate analysis*

The results of the proximate composition of the three snail species are presented in **Table** The highest composition of crude protein (5.25%) was recorded in *Limicolaria* sp., while *A. fulica* has the least composition (4.55%). The difference in protein content between the highest and lowest protein contents of all samples was not statistically significant. On the other hand, there is a significant difference ($p<0.05$) between the plant with the highest moisture content (*A. fulica*) of 39.48% and the sample with the lowest moisture content (*Limicolaria* sp.) of 16.84%. *Limicolaria* sp. also has the highest composition of fat (7.94%), while *A. fulica* has the lowest value (7.15%). With a significant variance in value, the ash content values vary from 2.96% in *A. achatina* to 1.10% in *Limicolaria* sp. All of the samples' carbohydrate percentages showed a substantial variance, with *Limicolaria* sp. having the greatest proportion and *A. fulica* having the lowest. Similar to this, there is a wide range of fibre content, with *A. fulica* having the highest value and *A. achatina* having the lowest. The comparison between the results from this study and those from earlier research on land snails is presented in **Table 2**.

Table 1 Proximate nutrient composition of the three snail species

Composition (%)	***Achatina achatina***	***Achatina fulica***	***Limicolaria* sp.**
Crude protein	$4.90^a \pm 0.12$	$4.55^a \pm 0.35$	$5.25^a \pm 0.33$
Moisture content	20.5 ± 1.46	39.5 ± 3.67	16.8 ± 2.45
Fat	$7.24^a \pm 0.25$	$7.15^a \pm 0.99$	$7.94^a \pm 0.52$
Ash	$2.96^a \pm 0.61$	$1.50^a \pm 0.89$	$1.10^a \pm 0.73$
Crude fibre	2.26 ± 0.17	$4.80^b \pm 0.52$	$4.60^b \pm 1.74$
Carbohydrate	$62.1^c \pm 4.36$	42.5 ± 2.68	$64.3^c \pm 3.87$

*Mean values in the same row with the same superscript do not differ significantly ($p<0.05$)

The nutritional composition of the various species of snails has been analyzed, and the findings are consistent with those of earlier research and demonstrate the snails' high nutritional value. The three samples were discovered to have significantly less protein than had previously been reported (**Table 2**). Some studies have reported the protein content of land snails to be over 50% (on a dry weight basis). Although lower figures have been recorded, such as 18.66% [26] and 15.68% [18], they are still much higher than the figures found in the current study. According to Ademolu et al. [18], the kind of management practice may be responsible for the variation in the protein composition of snails because those maintained on farms have access to decent diets and space, whereas this is not the case for snails sold at markets and on the side of the road. Proteins are destroyed at high temperatures; hence, continuous exposure to the sun's heat may cause the snails' bodies' proteins to denature. The recorded moisture content of the snails is comparable to other investigations. Moisture is used to measure the stability and susceptibility to contamination of microorganisms [27]. It is recommended to keep food's moisture content low because it extends the food's shelf life. Thus, the low moisture values obtained here (in comparison to others) make the snails an ideal food source. Ash is a measure of the non-volatile and non-combustible components of a sample and also measures the quality of the elemental content of the sample [28]. The ash values of *A. achatina* (2.96%) and *A. fulica* (1.50%), with the exception of *Limicolaria* sp. (1.10%), were greater than those reported for *Helix pomatia* (1.28%) [21] and *A. marginata* (1.28%) [18].

The fat content of all the samples under study is higher than all other samples reported in **Table 2**, except for those reported by Kalio and Etela [17]. Low-fat foods, however, are beneficial to the body because they do not promote or worsen cardiovascular disease. Similarly, higher values of crude fibre and carbohydrate were also observed in this study than in the previous study, which confirms the snail species as an energy-giving food. Crude fibre encourages peristaltic motions in the intestines, which improves health benefits by lowering the risk of gastrointestinal malignancies [29]. Due to the impression of fullness it provides even after a modest quantity of food has been consumed, a high-fibre diet has been suggested for weight control and fat reduction [27]. As previously stated, the natural conditions to which the snails were exposed, differences in diet type, and weather conditions could be the major factors for the variations observed in the nutritional compositions of the snails.

Table 2 Comparison of the nutrient compositions with other studies (%)

Snail	Protein	Moisture	Fat	Ash	Fibre	Carbohydrate	Ref.
A. fulica	72.86	90.27	1.52	4.88	0.00	-	[21]
Helix pomatia	15.35	20.41	1.15	1.28	0.00	-	[21]
Limicolaria. sp.	58.49	89.27	1.43	3.91	0.00	-	[21]
A. marginata	15.68	79.65	1.39	1.28	2.02	0.00	[18]
A. marginata	38.2	15.5	10.3	8.50	27.6	-	[17]
A. achatina	63.45	-	2.85	1.97	2.88	24.38	[20]
A. marginata	63.46	-	2.40	2.08	3.01	22.53	[20]
Limicolaria. sp.	18.66	78.68	1.17	1.35	-	0.15	[26]
A. achatina	19.27	77.54	1.43	1.34	-	0.42	[26]
A. achatina	4.90	20.54	7.24	2.96	2.26	62.1	This study
A. fulica	4.55	39.48	7.15	1.50	4.80	42.5	This study
Limicolaria. sp.	5.25	16.84	7.94	1.10	4.60	64.3	This study

➢ *Mineral composition*

Table 3 displays the results of the mineral analysis of the three samples of snails. As can be seen, lead, cadmium, and iron are present in less amounts than sodium, calcium, potassium, and magnesium in all of the species. There was no chromium found in any of the samples. Magnesium, potassium, and sodium are trace elements that are essential for preserving a healthy body [30]. The human body requires modest amounts of sodium, which is present in the highest quantity in all of the samples, to convey nerve impulses, contract and relax muscles, and keep the right ratio of minerals and water [31]. Magnesium plays a vital role in the biochemistry and operation of cells. Animals' acid-base balance and osmotic regulation of bodily fluids are both known to be significantly influenced by potassium, which also takes part in glucose metabolism and the excitation of muscles and nerves [20].

Calcium is an essential element because of the crucial functions that its phosphate salts play in various enzyme-mediated processes, including blood clotting and the formation of bones and teeth [4]. Iron, which helps in the production of red blood cells, is another crucial element present in all the snails species. Lead and cadmium, on the other hand, are non-essential elements present in the snails, albeit in a lesser concentration. Their presence can be attributed to the snails being exposed to some sort of pollutant in the environment. Both lead and cadmium have no known biochemical benefit to man [32] and have been reported to cause adverse health effects, including renal dysfunction, even at levels considered acceptable [33, 34]. As a result, caution should be exercised when using these sails as food. Nevertheless, the results of the mineral analysis point to the possibility of using the snails to replenish the essential and trace elements required by the human body for normal growth and development.

Table 3 Mineral compositions of the snail species (ppm).

Parameters	*Achatina achatina*	*Achatina fulica*	*Limicolaria* sp.
Lead	0.047	0.017	0.007
Cadmium	0.213	0.058	0.049
Magnesium	1.530	1.483	1.518
Iron	0.016	0.045	0.057
Chromium	0.000	0.000	0.000
Sodium	2.971	2.996	2.840
Calcium	1.449	1.569	1.032
Potassium	1.982	1.448	1.058

➢ *Qualitative anti-nutritional compositions*

In order to identify the substances responsible for the anti-nutrients' medicinal benefits and drawbacks, samples of snails were qualitatively tested. A number of anti-nutritional chemicals were found, according to the findings, which are shown in **Table 4**. The table shows that the amounts of tannins, terpenoids, and cardiac glycosides are higher in *A. achatina*. All of the chemicals, with the exception of tannins and saponins, are present in modest amounts in *A. fulica*. Similar amounts are seen in *Limicolaria* sp. as well, despite the absence of phenols, resins, and terpenoids. The specific elements of these factors were further demonstrated through quantitative analysis, which will be covered in the next section.

Table 4: Qualitative anti-nutritional compositions of the snail species

Parameters	*Achatina achatina*	*Achatina fulica*	*Limicolaria* sp.
Alkaloids	+	+	+
Phenol	-	+	-
Flavonoids	+	+	+
Tannins	++	-	+
Saponins	+	-	+

Resins	-	+	-
Cardiac glycosides	++	+	+
Terpenoids	++	+	-
Steroids	-	+	+
++ = present; + = mildly present; - = absent			

- *Quantitative anti-nutritional compositions*

Using GC-FID, the quantitative components of the anti-nutritional compounds were identified, and the results are presented in **Table 5**. The analysis revealed the presence of alkaloids (spartein, lunamarine, and ribalinidine), flavonoids (flavonone, rutin, kaemferol, catechin, epicatechin, anthocyanin, proanthocyanin, naringin, and flavon-3-ol), tannin, saponin, phenol, oxalate, and phytate. Flavonoids are widely known for their beneficial effects on health because of their anti-mutagenic, anti-oxidative, and anti-carcinogenic qualities, as well as their ability to modulate enzyme activity [35]. In the three species of snails, flavonoids are present in varied amounts. For instance, whereas proanthocyanin is completely absent in *A. achatina*, *A. fulica* contains the highest quantity of flavonoids overall. Catechin has concentrations of 11.73% and 7.73% *for A. achatina* and *A. fulica*, respectively, but is absent in *Limicolaria* sp., while kaempferol is also entirely absent in *Limicolaria* sp. despite having relatively high concentrations in the other samples In the digestive system, rutin is transformed into guercetin, a flavonoid with antioxidant, anti-inflammatory, antiviral, and anticancer properties [36]. It has been noted that catechin has the health benefits of reducing obesity, cancer, and diabetes and also has hepato- and neuro-protective effects [37]. However, flavonoids restrict digestive enzymes and may also precipitate proteins. They also chelate metals like zinc and iron and limit their digestion [38]. Alkaloids have been included in a variety of therapeutic mixtures because of their diverse spectrum of pharmacological effects [39]. Spartein, lunamarine, and ribalinidine are the alkaloids that were found in this investigation. Spartein levels are noticeably high in both *A. fulica* and *Limicolaria* sp. According to Rahmani and Sukari [40], lunamarine and ribalinidine possess radical scavenging function and immunomodulatory property. Alkaloids are also known to disrupt metabolic processes, which can have a negative impact on nutrient availability and growth [41].

Anti-nutritional factors typically hinder the utilization of many species for food since they have negative impacts on both humans and animals. Tannins have historically been thought of as being anti-nutritional; however, it is now understood that their nutritional benefits or harms depend on their chemical makeup and dosage [10]. Nevertheless, foods high in tannin are still regarded as having poorer nutritional value because they have been linked to decreased feed ingestion and productivity in experimental animals [37]. In the current investigation, *Limicolaria* sp. has the lowest concentration of tannin (2.9%), followed by *A. achatina* (7.48%) and *A. fulica* (9.44%). Phenol is another important anti-nutritional factor, and *A. fulica* has the highest percentage of it (7.73%). Phenol is easily processed throughout the digestive process. It affects the biodata in a number of subtle ways by impairing growth, decreasing reproduction, and reducing animal survival [10]. Saponins, which are present in both plants and lower animals, are known to interfere with the small intestine's ability to absorb protein, vitamins, and minerals, which can result in hypoglycemia [42]. All of the samples have reasonably high levels of saponin, with *A. fulica* having the highest content at 12.37%. Both oxalate and phytate are found in *Limicolaria* sp. in comparable high amounts. The anti-nutritional characteristics of oxalate and phytate are well documented. They have been shown to irritate and expand the tongue and throat, as well as produce crystals that mimic arthritis symptoms [37, 43].

It has been demonstrated that only high concentrations of these anti-nutrients hinder the intake of minerals such as iron, magnesium, potassium, and calcium, all of which are required for proper body metabolism [44]. All of the studied snail species had varying levels of these anti-nutrient components; as a result, consumers in the Awka metropolis should exercise adequate caution when purchasing them, especially those sold in markets and by the side of the road, which frequently don't have a good diet and sufficient nutrients.

Table 5 Quantitative anti-nutritional compositions with GC-FID

Components	***Achatina achatina***		***Achatina fulica***		***Limicolaria* sp.**	
	Concentration (µg/ml)	**Concentration (%)**	**Concentration (µg/ml)**	**Concentration (%)**	**Concentration (µg/ml)**	**Concentration (%)**
Rutin	0.960	1.465	0.000	0.000	0.000	0.000
Kaempferol	5.664	8.649	5.664	9.119	0.000	0.000
Catechin	7.680	11.727	4.800	7.728	0.000	0.000
Epicatechin	3.840	5.863	0.000	0.000	0.000	0.000
Anthocyanin	0.000	0.000	2.121	3.416	4.041	5.898
Proanthocyanin	0.000	0.000	8.640	13.911	5.760	8.406
Naringin	0.000	0.000	3.840	6.182	0.000	0.000
Naringenin	0.000	0.000	0.000	0.000	3.072	4.483
Flavonone	2.121	3.239	0.000	0.000	0.000	0.000

Flavan-3-ol	0.000	0.000	0.000	0.000	3.360	4.903
Spartein	0.771	1.177	7.065	11.376	8.745	12.763
Lunamarine	2.198	3.357	2.198	3.539	4.118	6.010
Ribalinidine	8.147	1.244	2.908	4.683	2.908	4.245
Tanin	4.900	7.482	5.860	9.435	2.048	2.988
Phenol	3.840	5.863	4.800	7.728	4.800	7.005
Saponin	5.760	8.795	7.680	12.365	3.840	5.604
Oxalate	3.840	5.863	1.920	3.091	8.640	12.609
Phytate	3.082	4.706	2.688	4.328	6.720	9.807

IV. CONCLUSION

A. achatina, A. fulica, and *Lamicolaria* sp. are among the most consumed edible snails in Awka, Anambra State, Nigeria. In this study, the nutritional value and anti-nutritional composition of the three snail species were evaluated. The findings revealed that all snail species are high in fibre, fat, and carbohydrates but comparatively low in protein. The mineral composition study also revealed a number of essential and minor elements, and anti-nutrients including alkaloids, tannins, and phenols were equally prevalent in a range of concentrations. The analysis' findings support the recommendation of using snails as a meat substitute and dietary supplement, while careful management of the snails is also essential.

REFERENCES

[1]. Iwuozor, K.O., V.U. Anyanwu, B.O. Olaniyi, P.S. Mbamalu, and A.G. Adeniyi, *Adulteration of Sugar: A Growing Global Menace.* Sugar Tech, 2022: p. 1-6.
[2]. Ogunfowora, L.A., K.O. Iwuozor, J.O. Ighalo, and C.A. Igwegbe, *Trends in the treatment of aquaculture effluents using nanotechnology.* Cleaner Materials, 2021. **2**: p. 100024.
[3]. WHO, *The State of Food Security and Nutrition in the World 2021: Transforming food systems for food security, improved nutrition and affordable healthy diets for all.* Vol. 2021. 2021: Food & Agriculture Org.
[4]. Ghosh, S., S.-M. Lee, C. Jung, and V. Meyer-Rochow, *Nutritional composition of five commercial edible insects in South Korea.* Journal of Asia-Pacific Entomology, 2017. **20**(2): p. 686-694.
[5]. Aibinu, A.M., T.A. Folorunso, A.A. Saka, L.A. Ogunfowora, K.O. Iwuozor, and J.O. Ighalo, *Green synthesis of CuO nanocomposite from watermelon (Citrullus lanatus) rind for the treatment of aquaculture effluent.* Regional Studies in Marine Science, 2022. **52**: p. 102308.
[6]. Iwuozor, K.O., P.S. Mbamalu, B.O. Olaniyi, V.U. Anyanwu, E.C. Emenike, and A.G. Adeniyi, *Fortification of Sugar: A Call for Action.* Sugar Tech, 2022: p. 1-11.
[7]. Adeyeye, S.A.O., O.T. Bolaji, T.A. Abegunde, and T.O. Adesina, *Processing and utilization of snail meat in alleviating protein malnutrition in Africa: a review.* Nutrition & food science, 2020.
[8]. Luo, F., R. Xing, X. Wang, Q. Peng, and P. Li, *Proximate composition, amino acid and fatty acid profiles of marine snail Rapana venosa meat, visceral mass and operculum.* Journal of the Science of Food and Agriculture, 2017. **97**(15): p. 5361-5368.
[9]. Mishra, N., N. Hazarika, K. Narain, and J. Mahanta, *Nutritive value of non-mulberry and mulberry silkworm pupae and consumption pattern in Assam, India.* Nutrition Research, 2003. **23**(10): p. 1303-1311.
[10]. Shantibala, T., R. Lokeshwari, and H. Debaraj, *Nutritional and antinutritional composition of the five species of aquatic edible insects consumed in Manipur, India.* Journal of Insect Science, 2014. **14**(1).
[11]. Ebenebe, C., W. Amaduruonye, D. Onunkwo, and G. Daniel-Igwe, *Haemolymph and mineral composition of East African land snail (Achatina fulica) fed sundried mango seed kernel meal.* Nigerian Journal of Animal Production, 2018. **45**(3): p. 210–217-210–217.
[12]. Ademolu, K., A. Idowu, C. Mafiana, and O. Osinowo, *Performance, proximate and mineral analyses of African giant land snail (Archachatina marginata) fed different nitrogen sources.* African Journal of Biotechnology, 2004. **3**(8): p. 412-417.
[13]. Kaldjob, M.C., N.A. Enangue, B.N. Siri, and K. Etchu, *Socio-economic perception of snail meat consumption in Fako division, south-west region Cameroon.* International Journal of Livestock Production, 2019. **10**(5): p. 143-150.
[14]. Adedoyin, A., O. Adedoyin, and M. Mosobalaje, *SHORT COMMUNICATION Challenges to increased Snail Production in Ibarapa Areas of Oyo State, Nigeria.* Nigerian Journal of Animal Production, 2016. **43**(1): p. 260-263.
[15]. Chah, J.M. and G. Inegbedion, *Characteristics of snail farming in Edo South agricultural zone of Edo State, Nigeria.* Tropical animal health and production, 2013. **45**(2): p. 625-631.
[16]. Eneji, C., A. Ogogo, C. Emmanuel-Ikpeme, and O. Okon, *Nutritional Assessment of Some Nigerian Land and Water Snail Species.* Ethiopian journal of Environmental studies and management, 2008. **1**(2): p. 56-60.

ISSN No:-2456-2165

[17]. Kalio, G.A. and I. Etela, *Nutritional and sensory profiling of the African giant land snail fed commercial-type and leaf-based diets in a rain-forest ecology*. African Journal of Food, Agriculture, Nutrition and Development, 2011. **11**(5): p. 5254-5265.

[18]. Ademolu, K., D. Onadeko, A. Aladesida, O. Odedara, and B. Adelabu, *Nutritional Value and Health Status of Giant African Land Snails (Archachatina Marginata) from Three Different Sale Points*. Ethiopian Journal of Applied Science and Technology, 2017. **8**(2): p. 28-32.

[19]. Uboh, F.E., I.O. Williams, and N.C. Essien, *Effect of processing on the proximate and mineral composition of Archachatina marginata and Achatina achatina*. Food and Public Health, 2014. **4**(1): p. 10-14.

[20]. Uboh, F., P. Ebong, and E. Mbi, *Cultural discrimination in the Consumption of black snail (Archachatina marginata) and white snail (Achatina achatina); any scientific justification*. International Research Journal of Microbiology, 2010. **1**(1): p. 013-017.

[21]. Anthony, A.A., C. Adebayo-Tayo, U. Inyang, A. Aiyegoro, and O.A. Komolafe, *Snails as meat source: Epidemiological and nutritional perspectives*. Journal of Microbiology and Antimicrobials, 2010. **2**(1): p. 1-5.

[22]. AOAC, *Official Methods of Analysis, 17th edn, Titratable acidity of fruit products, 942.15*. Association of Official Analytical Chemists International, Gaithersburg, 2000.

[23]. Iwuozor, K.O., *Heavy Metal Concentration of Aphrodisiac Herbs Locally Sold in the South-Eastern Region of Nigeria*. Pharmaceutical Science and Technology, 2019. **3**(1): p. 5.

[24]. Emenike, E.C. and C. Onyema, *Phytochemical, Heavy Metals and Antimicrobial Study of the Leaves of Calopogonium Mucunoides*. Journal of Chemistry Letters, 2022. **3**(1): p. 30-37.

[25]. Iwuozor, K.O., *Qualitative and Quantitative Determination of Anti-Nutritional Factors of Five Wine Samples*. Advanced Journal of Chemistry-Section A, 2019. **2**(2): p. 136-146.

[26]. Fagbuaro, O., J. Oso, J. Edward, and R. Ogunleye, *Nutritional status of four species of giant land snails in Nigeria*. Journal of Zhejiang University Science B, 2006. **7**(9): p. 686-689.

[27]. Chakravorty, J., S. Ghosh, K. Megu, C. Jung, and V.B. Meyer-Rochow, *Nutritional and anti-nutritional composition of Oecophylla smaragdina (Hymenoptera: Formicidae) and Odontotermes sp.(Isoptera: Termitidae): Two preferred edible insects of Arunachal Pradesh, India*. Journal of Asia-Pacific Entomology, 2016. **19**(3): p. 711-720.

[28]. Iwuozor, K.O., E.C. Emenike, J.O. Ighalo, F.O. Omoarukhe, P.E. Omuku, and A.G. Adeniyi, *Review on the thermochemical conversion of sugarcane bagasse into biochar*. Cleaner Materials, 2022: p. 100162.

[29]. Oduor, P., M.H. Struszczyk, and M.G. Peter, *Characterisation of chitosan from blowfly larvae and some crustacean species from Kenyan marine waters prepared under different conditions*. Discovery and Innovation, 2008. **20**(2): p. 129-136.

[30]. Afiomah, C.S. and K.O. Iwuozor, *Nutritional and Phytochemical Properties of Beta vulgaris Linnaeus (Chenopodiaceae)–A Review*. Nigerian Journal of Pharmaceutical and Applied Science Research, 2020. **9**(4): p. 38-44.

[31]. Oparil, S., *Low sodium intake--cardiovascular health benefit or risk*. N Engl J Med, 2014. **371**(7): p. 677-679.

[32]. Emenike, E.C., K.O. Iwuozor, and S.U. Anidiobi, *Heavy metal pollution in aquaculture: sources, impacts and mitigation techniques*. Biological Trace Element Research, 2022. **200**(10): p. 4476-4492.

[33]. Bouchard, M.F., D.C. Bellinger, J. Weuve, J. Matthews-Bellinger, S.E. Gilman, R.O. Wright, J. Schwartz, and M.G. Weisskopf, *Blood lead levels and major depressive disorder, panic disorder, and generalized anxiety disorder in US young adults*. Archives of general psychiatry, 2009. **66**(12): p. 1313-1319.

[34]. McKelvey, W., R.C. Gwynn, N. Jeffery, D. Kass, L.E. Thorpe, R.K. Garg, C.D. Palmer, and P.J. Parsons, *A biomonitoring study of lead, cadmium, and mercury in the blood of New York city adults*. Environmental Health Perspectives, 2007. **115**(10): p. 1435-1441.

[35]. Panche, A.N., A.D. Diwan, and S.R. Chandra, *Flavonoids: an overview*. Journal of nutritional science, 2016. **5**.

[36]. Nwankwo, O.L., O.C. Chukwuebuka, O.O. Collins, B.J. Samuel, J.C. Obasi, E.S. Iloh, and E.O. Nwankwo, *Quantitative phytochemical analysis of the fungus endophytic extracts isolated from Azadirachta indica using gas chromatography-flame ionization detector*. Journal of Drug Delivery and Therapeutics, 2021. **11**(5): p. 80-83.

[37]. Ugoeze, K.C., K.E. Oluigbo, and B.C. Chinko, *Phytomedicinal and Nutraceutical Benefits of the GC-FID Quantified Phytocomponents of the Aqueous Extract of Azadirachta indica leaves*. Journal of Pharmacy and Pharmacology Research, 2020. **4**(4): p. 149-163.

[38]. El Anany, A.M., *Nutritional composition, antinutritional factors, bioactive compounds and antioxidant activity of guava seeds (Psidium Myrtaceae) as affected by roasting processes*. Journal of Food Science and Technology, 2015. **52**(4): p. 2175-2183.

[39]. Alao, I.I., I.P. Oyekunle, K.O. Iwuozor, and E.C. Emenike, *Green Synthesis of Copper Nanoparticles and Investigation of Its Anti-Microbial Properties*. Advanced Journal of Chemistry-Section B, 2022. **4**(1): p. 39-52.

[40]. Rahmani, M. and M. Sukari. *New Lignum and other Chemical Components from haplophyllum villosum and H. Leaviusculum and their antioxidant activity*. in *Proceedings of the 16th Malaysian Chemical Congress, Malaysia*. 2010.

[41]. Emmanuel, E. and S. Deborah, *Phytochemical and anti-nutritional studies on some commonly consumed fruits in lokoja, kogi state of Nigeria.* General Medicine Open, 2018. **2**(3): p. 1-5.
[42]. Francis, G., Z. Kerem, H.P. Makkar, and K. Becker, *The biological action of saponins in animal systems: a review.* British journal of Nutrition, 2002. **88**(6): p. 587-605.
[43]. Awoyinka, O., A. Ileola, C. Imeoria, T. Tijani, F. Oladele, and M. Asaolu, *Comparison of phytochemicals and anti-nutritional factors in some selected wild and edible bean in Nigeria.* Food and Nutrition Sciences, 2016. **7**(2): p. 102-111.
[44]. Shittu, O.K. and A. Abubakar, *Evaluation of Phytochemicals, Proximate, Minerals and Anti-nutritional composition of Yam peel, Maize chaff and Bean coat.* 2014.