Nutritional, Antinutritional and Phytochemical Contents of *Cleome viscosa*, *Chromolaena odorata* and *Lamium purpureum* Dried Roots

Gafar, M. K.*[1], Olatunji, L. K.[2], Ahmad, J.[1], Mukarram, A.[1], Musa, A.[1] and Tanko, A. A.[1]

[1]*Department of Chemistry, Faculty of Science, Federal University Gusau, P.M.B. 1001, Zaria Road, Gusau, Zamfara State, Nigeria*
[2]*Department of Pharmacology and Therapeutics, College of Health Sciences, Abdullahi Fodiyo University of Science and Technology, Aleiro, P.M.B. 1144, Birnin Kebbi, Kebbi State, Nigeria*

***Corresponding author:** mkgafar@fugusau.edu.ng **Phone number:** +2348027415703

ABSTRACT

Background: *The economic and food insecurities around the globe have caused many households in developing nations to seek alternative food and medicine sources among nature-abundant wild edible plants, which are often termed weeds, with a view to improving the quality of life.*
Objective: *In this study, the roots of wild edible plants, Cleome viscosa, Chromolaena odorata, and Lamium purpureum, with tremendous literature on every part of the plants except the roots, were examined for their nutritional, anti-nutritional, and phytochemical contents.*
Methodology: *The dried powdered root materials were subjected to proximate and mineral analyses, anti-nutritional analysis for determination of phytates, oxalates and tannins, and phytochemical analysis.*
Results: *The results showed that the roots are rich in carbohydrates and crude fibre, with C. odorata having the highest percentage of 57.00 % carbohydrate and C. viscosa with 35.00 % crude fibre, respectively. Whereas L. purpureum has the highest calorific energy value of 320.03 kcal/100g. The three roots showed high ash contents of not less than 5 %, which indicated rich mineral contents for K, Fe, and Mn. The Fe contents in C. odorata and L. purpureum can contribute 80.13 - 180.29 % and 45.66 - 102.74 %, respectively, to the Recommended Dietary Allowance (RDA) per day. The phytates, oxalates, and tannin contents are lower than the reported lethal doses. The roots also recorded the presence of alkaloids, saponins, and flavonoids in various quantities.*
Conclusion: *These data indicated that the roots of the three plants could serve as sources of nutraceuticals.*

Keywords: *Cleome viscosa*; *Chromolaena odorata*; *Lamium purpureum*; Nutraceuticals; Anti-nutritional

Doi: https://dx.doi.org/10.4314/njns.v47i2.8

INTRODUCTION

Nutraceutical plants are termed as plant foods that provide medical or health benefits, which include preventing and treating diseases [1]. These plants include conventional food plants that are normally cultivated and non-conventional plants that are termed as wild plants. The wild edible plants are always being perceived as weeds with little or no nutritional value among most people around the world. However, recent global economic meltdowns have caused a significant increase in households (undocumented) turning to these plants as sources of food as well as medicines. Since the plants are picked from wild, uncultivated areas, they are more accessible than conventional food plants to most of this population in the rural and semi-urban communities. Unlike conventional food plants, data on the nutritional as well as health benefits of wild edible plants are limited. In

this study, three wild edible plants; *Cleome viscosa* (Asian spiderflower), *Chromolaena odorata* (Siam weed), and *Lamium purpureum* (Purple dead-nettle) are considered (see Figure 1). These plants are known as medicinal plants with tremendous pharmacological activities, including anthelmintic, antimalarial, anti-inflammatory, antimicrobial, antidiarrheal, antiviral, and antioxidant. These activities could be attributed to the phytochemicals they contain [2,3,4].

The stem, leaf, root, and seed of the *Cleome viscosa* plant have been reported to contain valuable nutrients such as fibre, carbohydrate, protein, and nutritional mineral elements [5,6]. The information on the anti-nutritional factors of this plant is limited. The leaves of the *Chromolaena odorata* plant were also reported to contain a significant amount of protein content of about 24 %, and some nutritional elements including calcium, potassium, iron, manganese, zinc, and magnesium [7]. However, the plant was found to be toxic when eaten raw by some domestic animals, and that could be attributed to the alkaloids and high content of anti-nutritional factors in the plant [8]. Although there is limited information on the proximate content of the *Lamium purpureum* plant, it was reported to contain fibre and protein with a significant amount of ash content of 9.80 % [9]. This study aimed at the determination of the nutritional, anti-nutritional and phytochemical contents of the roots of the three plants; *C. viscosa*, *C. odorata* and *L. purpureum* due to the limited data on their roots with a view to adding these data to the profile of the plants.

MATERIALS AND METHODS

Materials

The fresh plants of *C. viscosa*, *C. odorata* and *L. purpureum* were collected from Gwiwa low-cost area in Wamakko LGA, Sokoto State, Nigeria, at a location with the GPS coordinates of 13.010341°N, 5.217194°E using Earth 3D Map on the 22nd January 2022 (Plate 1). The plants were authenticated by Aliyu Sharhabilu Aminu, a senior technologist at the Herbarium of the Department of Biological Sciences, Federal University Gusau, Zamfara State. They were assigned voucher numbers: FUG/BIO/HEB/2022/0079, FUG/BIO/HEB/2022/0076, and FUG/BIO/HEB/2022/0075, respectively.

Sample Preparation

The roots were separated from the plants, washed, cut into pieces, and air-dried for 3 days. The dried roots were pulverized and stored in airtight containers at room temperature for further analysis.

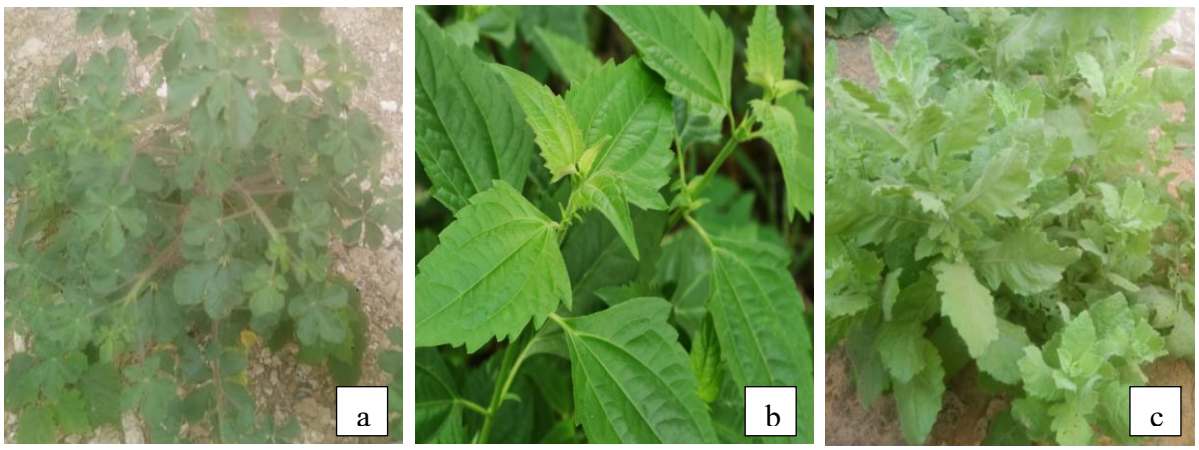

Plate 1: *Cleome viscosa* (a); *Chromolaena odorata* (B); *Lamium purpureum* (C) Plants

Proximate Composition and Mineral Composition Analysis

The proximate content; moisture, ash, crude fibres, crude lipids, crude proteins and carbohydrates of the powdered root samples of the three plants were determined using methods by [10] and their estimated calorific values (in kcal/100g) were calculated by multiplying the percentages of crude protein, crude lipid and carbohydrate with the recommended factors of 3.99 (16.7 kJ), 9.01 (37.7 kJ) and 3.99 (16.7 kJ), respectively [11]. The triple acid digestion method was used for the digestion of the powdered samples as described by [10,12]. The digested solutions were subjected to Atomic Absorption Spectroscopy and Flame Photometry analysis for the determination of the micro mineral elements: Cu, Fe, Mn and Zn, and the macro mineral elements: Ca, Na and K, respectively, as described by [10].

Phytochemical Analysis

Extraction

About 20 g of each powdered root sample was measured separately into a 250 cm^3 conical flask, and 150 cm^3 ethanol was added to each flask, covered with aluminium foil and allowed to soak for 24 hours, which was then filtered. The crude extracts were then subjected to screening.

Screening

The presence of phytochemicals was detected by Wagner's [13] and Hager's [14] tests for alkaloids, Alkaline test for flavonoids [15], Sulphuric acid test for terpenoids [16], Salkowski's test for phytosterols and Liebermann's and Keller-kilani test for glycosides [17], Emulsion test for saponins [16] and Ferric chloride test for tannins [15] and phenols [17], respectively.

Quantification

Alkaloids

The powdered root samples (2.50 g) were weighed into a 250 cm^3 beaker separately, and 200 cm^3 of 10% acetic acid in ethanol was added to each beaker and allowed to stand for 4 hours. The mixture was filtered and concentrated to one-quarter of its original volume over a water bath. Concentrated ammonium hydroxide was added dropwise until precipitation was complete. The mixture was allowed to settle for 3 hours, and the supernatant solution was decanted and discarded. The precipitates formed were washed with 20 cm^3 of 0.1 M ammonium hydroxide and collected with filter paper. The precipitates were dried in the oven and weighed. The % alkaloids = weight of the precipitates (alkaloids)/weight of the root sample x 100 [13,18].

Flavonoids

Each powdered root samples (2.50 g) were weighed separately into a 250 cm^3 beaker, and 50 cm^3 of 80 % aqueous methanol was added, covered, and allowed to stand for 24 hours at room temperature. The supernatant was collected, and the residue was re-extracted 3 times with the same volume of ethanol and added to the supernatant solution. The solution was then filtered, and the filtrate was transferred into a crucible and evaporated to dryness over a water bath. The % flavonoids = weight of the residue (flavonoids)/weight of the root sample x 100 [18].

Saponins

Five grams (5 g) of powdered root samples were weighed separately into a 250 cm^3 conical flask, and 100 cm^3 of 20 % aqueous ethanol was added to each flask. The mixture was heated at a temperature of 55°C in a water bath for 4 hours with occasional stirring. The mixture was filtered, and the residue was re-extracted with a fresh 100 cm^3 of 20 % aqueous ethanol with the same process. The two filtrates were combined and concentrated over a water bath to about 40 cm^3 of solution and transferred into a separating funnel. 20 cm^3 of diethyl ether was added to the solution, shaken vigorously, and allowed to separate into two layers. The aqueous layer was recovered while the diethyl ether layer was discarded. Another 20 cm^3 of diethyl ether was added to the aqueous layer, and the separation process was repeated twice while discarding the diethyl ether layer. To the combined aqueous layer, 60 cm^3 of n-butanol was added, and the resulting solution was washed with 10 cm^3 of 5 % sodium chloride (twice). The sodium chloride layer was discarded, and the solution was heated in a water bath for 30 minutes. The solution was then transferred into a crucible and dried in an oven to a constant weight. The % saponins = weight of the residue (saponins)/weight of the root sample x 100 [18].

Anti-Nutritional Analysis

Oxalates

To 1 g of the powdered root samples, separately measured into a 250 cm^3 flask, 75 cm^3 of 1.5 M H_2SO_4 was added. The solution was carefully shaken on a mechanical shaker for 1 hour and filtered. 25 cm^3 of the filtrate was titrated against 1.0 M $KMnO_4$ solution till a faint pink colour that persisted for 30 seconds appeared. 1 cm^3 of 0.1 M $KMnO_4$ = 0.00450 g oxalic acid [19].

Phytates

The powdered sample (4 g) was soaked in 100 cm^3 of 2 % HCl for 3 hours and filtered. To 25 cm^3 of the filtrate, 5 cm^3 of 0.3 % NH_4SCN and 53.5 cm^3 of water were added, mixed together, and titrated against standard $FeCl_3$ solution (containing 0.00195 g Fe/cm^3) until a brownish-yellow colour, which persisted for 5 minutes, appeared. Phytin – phosphorus (cm^3 Fe = 1.19 mg phytin phosphorus) was determined, and phytate content was calculated by multiplying the value of phytin–phosphorus by 3.55 [19,20].

Tannins

The sample (0.1 g) was weighed into a 100 cm^3 volumetric flask, 50 cm^3 of distilled water was added, and shaken for 1 hour on a mechanical shaker. This was filtered into a 50 cm^3 volumetric flask and made up to the mark with water. 5 cm^3 of the filtrate was pipetted into a test tube and mixed with 3 cm^3 of 0.1 M $FeCl_3$ in 0.1 M HCl and

3 cm^3 of 0.008 M potassium ferrocyanide. The absorbance was measured using a spectrophotometer at 520 nm wavelength, within 10 min. A blank sample was prepared; the colour was developed as for the sample and absorbance was read at the same wavelength. A standard was prepared using tannic acid. Tannin concentration = (Abs of the test sample/Abs of standard) x conc. of standard [19,21].

RESULTS

The results of the proximate, mineral, anti-nutritional and phytochemical analyses of *C. viscosa*, *C. odorata* and *L. purpureum* roots are presented in Figures 1 – 3 and Table 1 – 3.

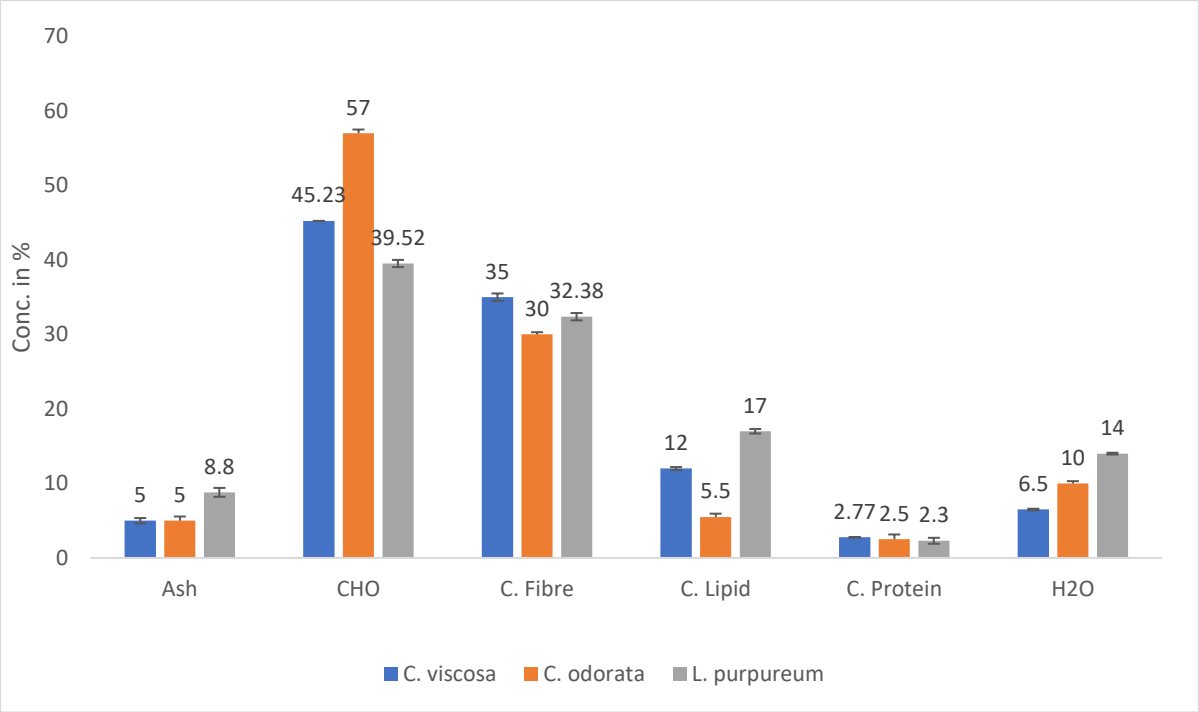

Figure 1: Nutritional Contents of *C. viscosa*, *C. odorata* and *L. purpureum* Dried Roots
Key: CHO = Carbohydrate, H_2O = Moisture C = Crude

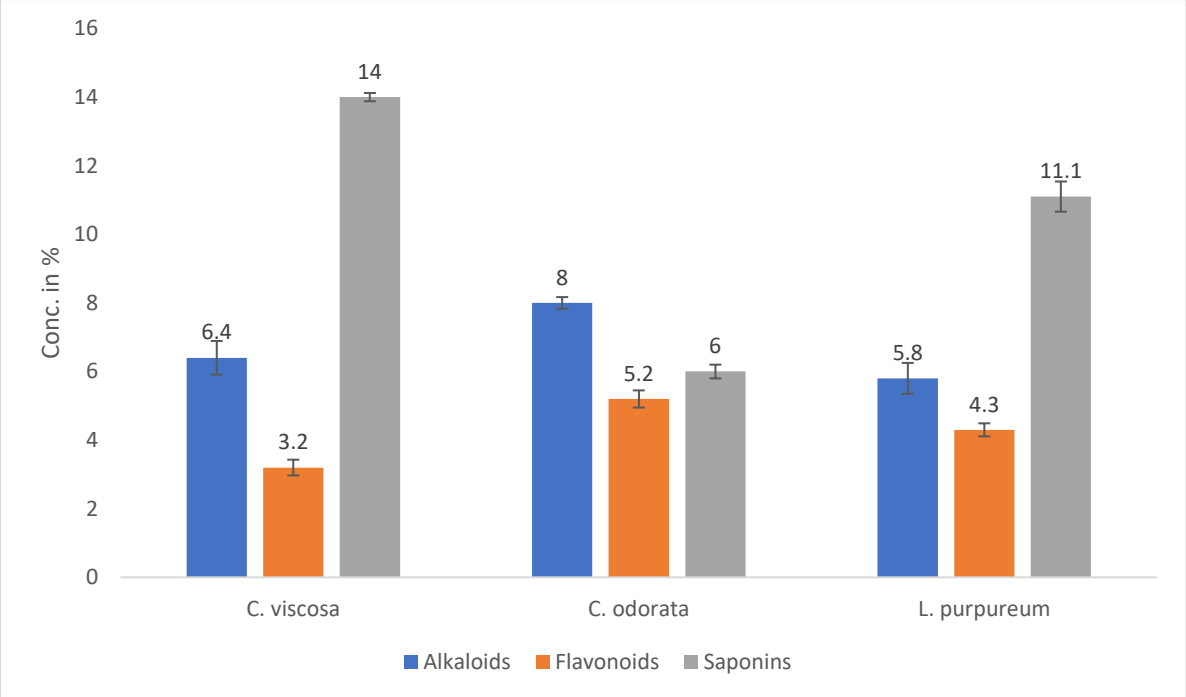

Figure 2: Phytochemical Contents of *C. viscosa*, *C. odorata* and *L. purpureum* Dried Roots

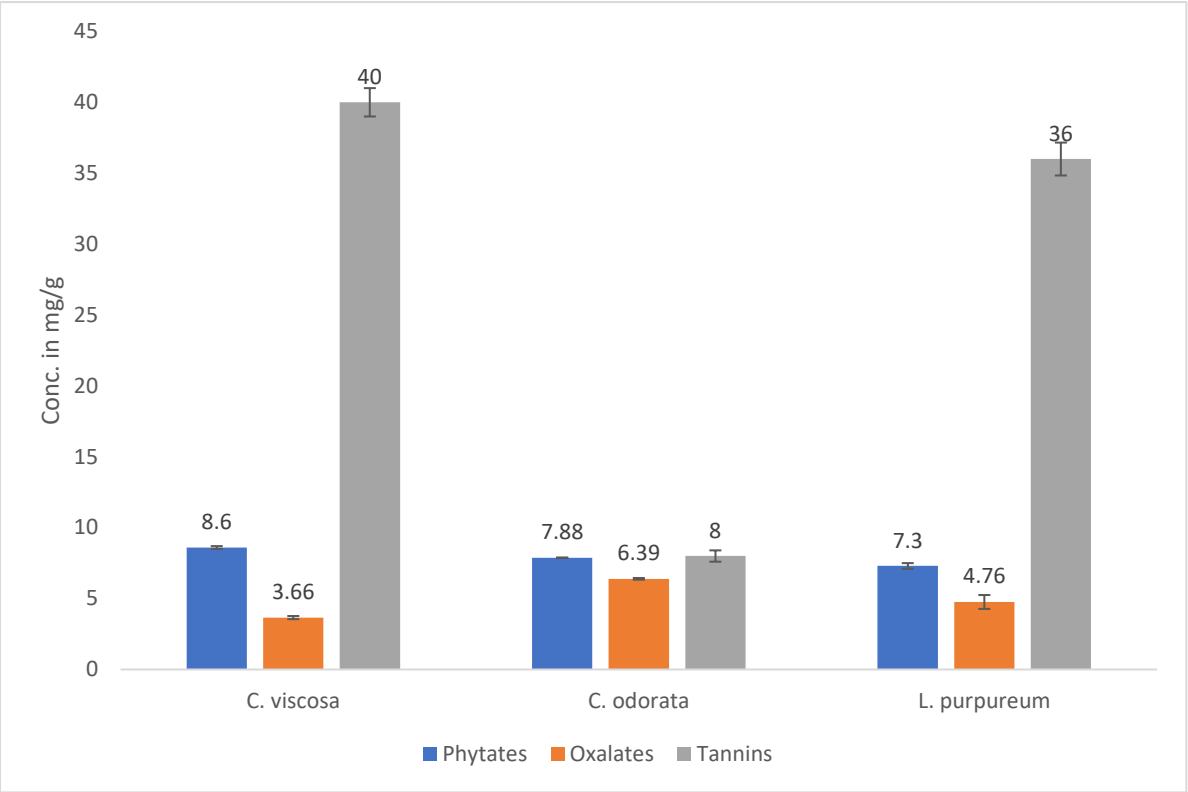

Figure 3: Antinutritional Contents of *C. viscosa*, *C. odorata* and *L. purpureum* Dried Roots

Table 1: Estimated Calorific Value

S/N	Unit	*C. viscosa*	*C. odorata*	*L. purpureum*
	kcal/100g	299.64	286.96	320.03

Table 2: Mineral Contents of the *C. viscosa*, *C. odorata*, and *L. purpureum* Roots in Mg/L and Their Percentage Contributions to the Recommended Dietary Allowance (RDA) per Day for Adults

S/N	Minerals	*C. viscosa* (mg/L)	*C. odorata* (mg/L)	*L. Purpureum* (mg/L)	RDA/Day For Adult*	*C. viscosa* % cont. to RDA/day	*C. odorata* % cont. to RDA/day	*L. purpureum* % cont. to RDA/day
1.	Ca	0.74	0.52	0.68	1200-1000 mg	0.06-0.07	0.04-0.05	0.06-0.07
2.	K	1.32	0.98	1.12	4.7 mg	28.09	20.85	23.83
3.	Na	1.95	1.89	2.35	1500-1200 mg	0.13 - 0.16	0.13 - 0.16	0.16 - 0.20
4.	Cu	0.044	0.076	0.048	0.9 mg	4.89	8.44	5.33
5.	Fe	2.592	14.423	8.219	18-8 mg	14.40 -32.40	80.13 -180.29	45.66 - 102.74
6.	Mn	0.190	0.846	0.265	2.3-1.8 mg	8.26-10.56	36.78-47.00	11.52-14.72
7.	Zn	0.0513	0.0756	0.0936	11-8 mg	0.47-0.64	0.69-0.95	0.85-1.17
8.	[K]/[Na] Ratio	0.68	0.52	0.48				

** The recommended dietary allowance (RDA) for adults* ***[25]***

Table 3: Phytochemical Screening of *C. viscosa*, *C. odorata* and *L. purpureum* Roots Ethanol Extracts

S/N	Phytochemicals	*C. viscosa*	*C. odorata*	*L. purpureum*
1	Alkaloids	++	++	++
2	Flavonoids	+	+	+
3	Terpenoids	+	+	+
4	Phytosterols	+	-	-
5	Glycosides	++	++	++
6	Saponins	+	+	+
7	Tannins	-	+	-
8	Phenols	+	+	-

Keys: + = present - = absent

DISCUSSION

The nutritional contents of the roots of the three plants *C. viscosa*, *C. odorata* and *L. purpureum,* as presented in Figure 1, showed that the carbohydrate and fibre contents are within the range of 30 to 57 %, which are similar to those reported by [5,9,22]. The figures are significant and expected for fibrous roots, which is characteristic of the roots of the three plants. Interestingly, the roots of *C. viscosa* and *L. purpureum* recorded 12 and 17 % crude lipids, respectively, whereas the root of *C. odorata* recorded a lower value of 5 %. All these values are higher than the values reported from the leaf, seed, root, and whole parts of the three plants [5,9,23], except for a study by [22] that showed the *C. odorata* plant with higher percentages of 50, 10, and 40 of crude lipid in leaf, stem, and root, respectively. These high values could be due to adverse environmental conditions such as nutrient deficiency, temperature extremes, drought, salinity, or stress-induced lipid signaling [24]. The significant percentages of carbohydrates and lipids recorded by the three roots, *C. viscosa*, *C. odorata,* and *L. purpureum,* contributed to their high calorific values of 299.64, 286.96, and 320.03 kcal/100g, respectively, as presented in Table 1. These values indicated that the roots can serve as an important source of dietary calories.

The mineral contents of the roots, as presented in Table 2, indicated that they are rich in K, Fe, and Mn, with concentrations of 1.32, 2.59, and 0.19 mg/L for *C. viscosa*, 0.98, 14.42, and 0.85 mg/L for *C. odorata*, and 1.12, 8.22, and 0.27 mg/L for *L. purpureum*, respectively. These values can contribute significantly to the recommended dietary allowance (RDA) for adults [25]. The Fe contents in *C. odorata* and *L. purpureum* can contribute 80.13 - 180.29 % and 45.66 - 102.74 %, respectively, to RDA/day, which are higher than the 14.40–32.40% contributed by *C. viscosa* root. The K content in the three roots can contribute 28.09, 20.85, and 23.83 % for *C. viscosa*, *C. odorata,* and *L. purpureum*, respectively, to RDA/day. Whereas for the Mn content, the *C. odorata* root can contribute the highest values of 36.78 - 47.00 % when compared to the other two roots, *C. viscosa* and *L. purpureum*. These significant contributory percentages recorded for Fe, K, and Mn contents indicated that the roots can be used to combat mineral deficiency diseases and symptoms such as anemia, hypokalemia, impaired growth, bone demineralization, hair depigmentation, abnormal glucose tolerance, etc. [19]. Furthermore, the [K]/[Na] ratio, which is critical for cardiovascular health and blood pressure regulation, for the three roots is below the recommended ratio of 3 – 4 [19].

The three roots indicated the presence of important phytochemicals including alkaloids, flavonoids, terpenoids, phenols, glycosides, and saponins, as presented in Table 3. These phytochemicals have been reported to be present in various parts of the plants, including the seed, stem, and leaves [5,9,22,23]. Furthermore, the percentages of alkaloids, flavonoids, and saponins presented in Figure 2, which are within the range of 3.20 to 14 %, are significantly higher than those reported by [5,23] from leaves, stems, and seeds. This is expected due to some roots of plants being known to hold higher percentages and diverse phytochemicals produced by the plant than other parts of the plant [26]. The anti-nutritional contents of the three roots examined for phytates, oxalates, and tannins, as presented in Figure 3, showed that tannin content is higher in the *C. viscosa* and *L. purpureum* root samples with values of 40 and 36 mg/g, respectively. Whereas the values of phytates, oxalates, and tannins content in *C. odorata* are lower than 10 mg/g. The anti-nutritional contents of phytates, oxalates, and tannins in the three roots are far below the lethal dosage of the values reported by [27]. This serves as an indication that the roots are safe for consumption based on their phytates, oxalates, and tannins contents.

CONCLUSION

The nutritional contents of the roots of the wild edible plants, *C. viscosa*, *C. odorata* and *L. purpureum* revealed that the roots contained significant carbohydrates and crude fibre contents that translate to high calorific values. The presence of important phytochemicals, which include alkaloids, flavonoids, terpenoids, glycosides and saponins, in the roots may be linked to their effective ethnomedicinal properties for treatments of illness, infections and diseases. The low contents of phytates, oxalates and tannins mean that the roots may be safe for consumption based on these anti-nutritional agents. From this study, the roots of *C. viscosa*, *C. odorata* and *L. purpureum* plants could be considered as sources of nutraceuticals. More research needs to be conducted on the isolation and identification of phytochemicals from the roots, as well as the determination of more anti-nutritional agents.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

AUTHORS' DECLARATION

The authors hereby declare that the work presented in this article is original and that any liability

for claims relating to the content of this article will be borne by them.

FUNDING DECLARATION

No funding was received for this research from any funding agency.

REFERENCES

1. Evans, W. C. (2009). *Trease and Evans' pharmacognosy*. 16th edition, Elsevier Health Sciences. Toronto.
2. Vijayaraghavan, K., Rajkumar, J., Bukhari, S. N. A., Al-Sayed, B., & Seyed, M. A. (2017). *Chromolaena odorata*: A neglected weed with a wide spectrum of pharmacological activities. *Molecular Medicine Reports*, *15*(3), 1007-1016.
3. Mali, R. G. (2010). Cleome viscosa (wild mustard): A review on ethnobotany, phytochemistry, and pharmacology. *Pharmaceutical Biology*, *48*(1), 105-112.
4. Salehi, B., Armstrong, L., Rescigno, A., Yeskaliyeva, B., Seitimova, G., Beyatli, A., ... & Sharifi-Rad, J. (2019). Lamium plants—A comprehensive review on health benefits and biological activities. *Molecules*, *24*(10), 1913.
5. Ezeabara, C. A., & Nwafulugo, S. N. (2015). Comparison of phytochemical and proximate compositions of parts of *Cleome ciliata* Schum. & Thonn. and *Cleome viscosa* L. *World Journal of Biomedicine and Pharmaceutical Sciences*, *1*(1), 1-5.
6. Singh, H., Mishra, A., & Mishra, A. K. (2017). Pharmacognostical and physicochemical analysis of *Cleome viscosa* L. seeds. *Pharmacognosy Journal*, *9*(3), 372-377.
7. Nwinuka, N., Nwiloh, B., & Eresama, J. (2009). Nutritional and potential medicinal value of Chromolaena odorata leaves. *International Journal of Tropical Agriculture and Food Systems*, *3*(2). https://doi.org/10.4314/ijotafs.v3i2.50044
8. Tiamiyu, A. M., & Okunlade, O. A. (2020). Benefits and detriments of Siam weed (Chromolaena odorata): A review. *Biochemistry and Biotechnology Research*, *8*, 21-28.
9. Kirilov, A., Georgieva, N., & Stoycheva, I. (2016). Determination of composition and palatability of certain weeds. *International Journal of Agricultural Science and Food Technology*, *2*, 41-43.
10. Gafar, M. K., A. U. Itodo, F. A. Atiku, A. M., Hassan, & I. J, Peni (2011). Proximate and Mineral composition of the leaves of Hairy Indigo (*Indigofera astragalina*). *Pakistan Journal of Nutrition*, *10*(2), 168-175.
11. Aberoumand, A. (2009). Nutritional evaluation of edible *Portulaca oleracia* as plant food. *Food Analytical Methods*, *2*(3), 204-207.
12. Sahrawat, K. L., Kuaar, G. L., & Rao, J. K. (2002). Evaluation of tarcid and dry ashing procedure for detecting Potassium, Calcium, Magnesium, Iron, Zinc, Manganese, and Copper in plant materials. *Communication in Soil Science and Plant Analysis*, *33*(1–2), 95–102.
13. Harbone, J. B. (1973). *Phytochemical methods. A guide to Modern Techniques of Plants analysis*. John Wiley and Sons, Inc., New York, pp. 1 – 26.
14. Al-Marzook, F. A., & Omran, R. (2017). Cytotoxic activity of alkaloid extracts of different plants against breast cancer cell line. *Asian Journal of Pharmaceutical and Clinical Research*, *10*(7), 168-171. https://doi.org/10.22159/ajpcr.2017.v10i7.18863
15. Sruthi, S. N., Anchana, D. C., & Pushpa, N. (2021). Phytochemical Analysis of *Tabernaemontana divaricata* Stem Extract. *International Journal of Recent Scientific Research, 12* (04), 41581- 41586. DOI: http://dx.doi.org/10.24327/ijrsr.2021.1204.5919
16. Ezeonu, C. S., & Ejikeme, C. M. (2016). Qualitative and quantitative determination of phytochemical contents of indigenous Nigerian softwoods. *New Journal of Science*, *2016*(1), Article ID 5601327, 9. http://dx.doi.org/10.1155/2016/5601327
17. Shah, R. K., & Yadav, R. N. S. (2015). Qualitative phytochemical analysis and estimation of total phenols and flavonoids in leaf extract of *Sarcochlamys pulcherrima*. *Global Journal of Bio-science and Biotechnology, 4*(1), 81-84.
18. Ejikeme, C., Ezeonu, C. S., & Eboatu, A. N. (2014). Determination of Physical and Phytochemical Constituents of some Tropical Timbers Indigenous to Niger Delta area of Nigeria. *European Scientific Journal*, *10*(18), 247-270.
19. Gafar, M. K., Hassan, L. G., Dangoggo, S. M., & Itodo, A. U. (2010). Investigating the foliage of *Indigofera astragolina* for their nutritive and antinutritive composition. *Journal of Chemical and Pharmaceutical Research*, *2*(5), 259-269.
20. Ola, F. L., & Oboh, G. (2000). Food value of two Nigerian edible mushrooms (*Termomycetes stratus* and *Termomycetes roburtus*). *The Journal of Technoscience, 4*, 1-3.
21. El-Olemy, M. M., Al-Muhtadi, F. J., & Afifi, A. A. (1994). *Experimental phytochemistry. A Laboratory Manual*. King Saud University Press, pp. 8 – 9.
22. Etejere, E. O., Olayinka, B. U., & Aderemi, R. O. (2017). Phytochemical analysis of aqueous

extract and proximate composition of *Chromolaena odorata* (L.) RM King and H. Robinson. *Centrepoint Journal*, *23*(2), 173-182.
23. Uraku, A. J., & Uraku, O. H. (2018). Quantitative assessment of phytochemicals and nutritional potential of leaves and seeds of Cleome viscosa from Abakaliki, Nigeria. *Journal of Bioscience and Biotechnology Discovery*, *3*(1), 25-29.
24. Singer, S. D., Zou, J., & Weselake, R. J. (2016). Abiotic factors influence plant storage lipid accumulation and composition. *Plant Science*, *243*, 1-9
25. Ward, E. (2014). Addressing nutritional gaps with multivitamin and mineral supplements. *Nutrition journal*, *13*(1), 72.
26. Zhang, Y., Worthy, S. J., Xu, S., He, Y., Wang, X., Song, X., ... & Yang, J. (2024). Phytochemical diversity and their adaptations to abiotic and biotic pressures in fine roots across a climatic gradient. *Science of the Total Environment*, *927*, 172051.
27. Salam, S., Inoussa, C., Patrice, B., Firmin, S., Fréderic, B. S. and Mipro, H. (2025). Nutritional Value and Antinutritional Factors of *Balanites aegyptiaca* Seed Oils and Cakes for Animal Feed: A Review. *Food Science & Nutrition*, *13*(6), e70478. https://doi.org/10. 1002/fsn3.70478