



Heavy metal content, phytochemicals quantification, and antioxidant activity of *Terminalia ivorensis* A. Chev (Combretaceae) leaves collected from Lagos, Nigeria

Oluwatosin Oladele JOHNSON*, Gloria Abiodun AYOOLA, Sandra Chinedu EZE, Olubiodun Moses DUROJAIYE, David Kehinde ADEYEMI, Adebowale Olufemi ADELUOLA, Modupe OLOGUNAGBA, Adeshina ADEGOKE

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, University of Lagos, College of Medicine Campus, Idi-araba, Lagos, 100254, Nigeria.

Received 14th August 2025; Accepted 3rd December 2025

Abstract

Investigating heavy metals in medicinal plants like *Terminalia ivorensis* is crucial for safety, as they can accumulate harmful metals from the environment. Used in traditional West African medicine for various ailments, *T. ivorensis* has shown important pharmacological activities. However, studies on heavy metal content and specific phytochemicals quantification in its leaves are limited. This investigation aims to address these gaps and further explore its antioxidant activity. *T. ivorensis* leaves were collected, extracted with 50% ethanol, and analysed for phytochemicals, antioxidants, and heavy metals using standard spectrophotometric, gravimetric, and chemical methods for qualitative and quantitative assessments. Qualitative screening revealed the presence of saponins, phenolics, tannins, flavonoids, cardiac glycosides, terpenoids, steroids, and alkaloids, with no anthraquinones or triterpenoids detected. Quantitative results (mg/100g) showed: alkaloids (32.45 ± 0.343), saponins (30.07 ± 0.015), tannins (36.76 ± 0.107), cardiac glycosides (22.48 ± 0.057), steroids (30.70 ± 0.072), terpenoids (48.60 ± 0.228) and reducing sugars (25.87 ± 0.335 mg GE/100g). High levels of phenolics (220.89 mg GAE/g) and flavonoids (441.63 mg RE/g) were recorded. Antioxidant activity was significant, with DPPH IC₅₀ at 26.54 µg/mL, phosphomolybdate assay at 44.68 ± 0.98 mg AAE/g, and FRAP IC₅₀ at 44.19 µg/mL. Heavy metal analysis detected cadmium (Cd), lead (Pb), calcium (Ca), Zinc (Zn), magnesium (Mg), iron (Fe), Copper (Cu), sodium (Na), potassium (K), and manganese (Mn), all below WHO safety limits.

Keywords: Antioxidant; Heavy metal; Medicinal plant; Phytochemicals; *Terminalia ivorensis*

INTRODUCTION

Investigating the heavy metal content of medicinal plants is crucial for ensuring their safety and efficacy. Medicinal plants possess the capability to accumulate heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg) from contaminated

environments, including soil, water, and air. The ingestion of these metals can lead to significant health risks, including kidney damage, neurological disorders, and carcinogenic effects [1]. Furthermore, the presence of heavy metals can undermine the therapeutic value of these plants and

*Correspondence. E-mail: tosyn.villa@gmail.com

Tel: +234-8033708829.

ISSN 0189-8442

2026. Published by Faculty of Pharmaceutical Sciences, University of Jos, Nigeria. Under Creative Commons Attribution-Non-Commercial 4.0 International License. <https://creativecommons.org/licenses/by-nc/4.0/>

contravene regulatory standards established by health organizations, such as the World Health Organization (WHO). Consequently, regular monitoring and risk assessment are imperative to safeguard public health and uphold the integrity of traditional and herbal medicines [2, 3].

Terminalia ivorensis A. Chev., belonging to the Combretaceae family, is an indigenous plant commonly referred to as Black Afara in English and designated by various local names across Nigeria, such as Afara dudu in Yoruba, Baushe in Hausa, and Awunshin in Igbo. In traditional medicine, *T. ivorensis* is utilized in the West African region for treating conditions such as diuresis, general body pains, haemorrhoids, wounds, and yellow fever [4, 5]. The pulverized leaves of the plant are employed as a poultice to alleviate burns and bruises [6]. In the context of Nigerian ethnomedicine, various parts of this plant are utilized for the treatment of syphilis, with the decoction of its bark serving as a lotion for sores, and the leaves again being used in poultice form for external injuries [7].

Numerous pharmacological activities of *T. ivorensis* have been documented, including antibacterial [8, 9], antifungal [10, 11], antioxidant [8, 12 – 14], antidiabetic [15, 16], anti-trypanocidal [7], anti-inflammatory [13, 17], anti-nociceptive, anti-psychotic, hepatoprotective, and nephroprotective properties [18-20] as well as anti-plasmodial activity [21]. *T. ivorensis* is recognized as a valuable source of phytochemicals contributing to ethno-medicinal practices, with an abundance of compounds such as polyphenols, flavonoids, saponins, steroids, and punicalagin, many of which are associated with diverse biological activities [15, 16, 18]. Our investigation focuses on the crude leaf extract of *T. ivorensis* due to the absence of comprehensive studies in the existing literature. Previous research regarding the heavy metal content of *T. ivorensis* has primarily concentrated on contexts such as soil

phytoremediation, biomass adsorption of heavy metals, and metal uptake under contaminant stress. Reports indicate that *T. ivorensis* can accumulate and remediate metals like Pb, Cu, Cd, and Ni from environmental sources [22-25]. However, reliable data quantifying the concentration of various heavy metals specifically in the leaves of *T. ivorensis* remain scarce. Moreover, there is a noticeable deficiency in the quantification of certain phytochemicals, including alkaloids, reducing sugars, cardiac glycosides, steroids, terpenoids, tannins, and saponins. This study will further investigate the antioxidant activity of *T. ivorensis* using established conventional methodologies.

EXPERIMENTAL METHODS

Plant collection and identification. The leaves of *Terminalia ivorensis* were collected in Akoka, Lagos, Nigeria, on April 5, 2023. Mr. Nodza George, a botanist, identified the specimen at the Botany Department of the University of Lagos, Nigeria, and provided a voucher specimen number LUH 9909. The freshly collected leaves were thoroughly washed with sterile distilled water, dried at room temperature ($25 \pm 2^\circ\text{C}$), and then milled into uniform dry pieces.

Extraction procedure. In the extraction process, two solvent systems were employed. A mixture of ethanol and distilled water in a 50:50 ratio was utilized. A total of 750 g of air-dried plant material was macerated using a cold extraction method with approximately 5000 mL of an ethanol-water mixture for 72 hours with constant stirring. The resulting extract was initially filtered through cotton wool and subsequently through Whatman filter paper number 42 (125 mm). The solvent was then evaporated using a rotary evaporator, and the remaining water was eliminated by freeze-drying to yield a dried extract. The final product, which appeared dark brown in colour, was weighed and stored in a clean sample bottle for further analysis.

Qualitative phytochemical screening. The leaves of *T. ivorensis* was tested for saponins, phenols, tannins, phlobatannins, flavonoids, anthraquinones, cardiac glycosides, terpenoids, triterpenoids, steroids, reducing sugar, and alkaloids using phytochemical reagents according to a procedure described by Trease and Evans (1983) [26].

Quantitative phytochemical analysis:

Determination of total alkaloid content. The total alkaloid content of the crude extract of the plant was determined using the method of Harborne (1973) [27], where the residue was dried and weighed, and expressed in mg/100g.

Determination of total saponin content. The total saponin content was determined using the method described by Orengo *et al.* (2022) [28], and it was expressed in mg per 100g.

Determination of total reducing sugar content. The quantification of reducing sugar content was performed using the 3,5-dinitrosalicylic acid (DNSA) method, as outlined by Krivorotova and Sereikaite (2014) [29]. This method utilized a UV-Visible spectrophotometer, and the results were expressed as milligrams of D-glucose equivalent (GE) per 100 grams of dry extract weight.

Determination of total tannin content. The method of Nair *et al.* (2015) was used [30]. Folin-Denis reagent, a colorimetric reagent that reacts with the tannins, is used to measure its concentration using spectrophotometric analysis.

Determination of cardiac glycoside Content. The cardiac glycoside content in the sample was determined by the method described by Louis *et al.* (2018) using Buljet's reagents [31].

Determination of total steroid content. The spectrophotometric method of determining quantitative steroidal content, as previously described by [32], was employed for the crude plant sample.

Determination of terpenoid content. The terpenoid content was determined by the method described by Malik *et al.* (2017) [33].

Determination of total flavonoid content. The total flavonoid content was determined using a modified method based on Miliuskas *et al.* (2004) [34].

Determination of total phenolic content. Total phenolic content was assessed using a modified Folin-Ciocalteu method as outlined by Ayoola *et al.* (2018) [35].

DPPH (1,1-diphenyl-2-picric-hydrazyl) assay. The radical scavenging activity of the plant extract against DPPH (1,1-diphenyl-2-picrylhydrazyl) radical was assessed using a refined method based on Brand-Williams *et al.* (1995) [36]. Ascorbic acid served as the standard for comparison. To prepare the DPPH solution, 24 mg of DPPH was dissolved in 100 mL of methanol, resulting in a 0.2 mM DPPH solution. The stock extract solution was created by dissolving 40 mg of the plant extract in 40 mL of methanol, yielding a concentration of 1 mg/mL. We proceeded with various dilutions of the stock extract to achieve concentrations of 20, 40, 60, 80, and 100 µg/mL in methanol, each made up to 5 mL with the DPPH solution. The same dilutions were prepared for the standard (ascorbic acid) using the stock solution, also made up to 5 mL with the DPPH solution. The blank control consisted of 2 mL of methanol and 3 mL of the 0.2 mM DPPH solution. All preparations, including the different concentrations of the standard and the plant extract solution, were conducted in triplicate. After incubation in a dark environment for 30 minutes, we measured the absorbance of the extract solution and the ascorbic acid standard at a wavelength of 517 nm using a UV/Visible spectrometer. This approach ensures accurate and reliable results regarding the radical scavenging activity of the plant extract.

The scavenging activity was estimated based on percentage of DPPH radical scavenged as seen in the formula:

DPPH scavenging effect (%) =

$$\frac{(\text{Abs of the blank} - \text{Abs of sample})}{\text{Abs of the blank}} \times 100 \dots \text{Equation 1}$$

Where, Abs= absorbance

Phosphomolybdate assay (Total Antioxidant Capacity). The total antioxidant capacity (TAC) was measured using the phosphomolybdate assay, with a slight modification of the method described by Preito *et al.* (1999) [37]. Ascorbic acid served as the standard. The TAC reagent was prepared by combining 0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate ($\text{H}_{32}\text{Mo}_7\text{N}_{60}\text{O}_{28}$) in 20 mL of distilled water, then diluted to a final volume of 50 mL with additional distilled water. A concentration of 1 mg/mL was used for the extract. Different concentrations of the standard ascorbic acid (10, 20, 50, 100, and 200 $\mu\text{g/mL}$) were prepared from a 1 mg/mL stock solution in methanol. To each of these, 9 mL of the TAC reagent was added. Additionally, 9 mL of the TAC reagent was also added to 1 mL of the extract solution in a test tube. All preparations, including the various concentrations of the standard and the plant extract solution, were conducted in triplicate. The samples were incubated at 90°C for 90 minutes in a water bath, then allowed to cool. After cooling, the absorbance of both the extract solution and the ascorbic acid standard was measured at a wavelength of 695 nm using a UV/Visible spectrometer.

$$\text{TAC} = \frac{(C \times V)}{M} \dots \dots \dots \text{Equation 2}$$

TC is the total phenolic content in mg/g of the extracts.
C is the concentration of ascorbic acid established from the calibration curve in mg/mL
V is the volume of the extract solution in mL
M is the weight of the extract in g.

Ferric reducing power assay (FRAP). To evaluate the ferric reducing power of the extract, various dilutions were prepared to achieve final concentrations of 25, 50, 70, and 100 $\mu\text{g/mL}$. Each concentration was prepared by mixing 1 mL of the diluted extract with 2.5 mL of 0.1 M sodium phosphate buffer (pH 6.6), followed by the addition of 2.5 mL of 1% (w/v) potassium ferrocyanate [$\text{K}_3\text{Fe}(\text{CN})_6$] in a 250 mL conical flask. The mixture was then incubated at 50°C for 20 minutes. Subsequently, 2.5 mL of 10% (w/v) trichloroacetic acid was added, and the mixture was centrifuged at 5000 rpm for 10 minutes to precipitate any proteins. After centrifugation, 5 mL of the upper layer was isolated and combined with 0.5 mL of fresh FeCl_3 (0.1%, w/v). The absorbance of the resulting solution was then measured at 710 nm against a blank. Ascorbic acid served as the control for comparison [38].

The percentage scavenging effect was thus determined as:

$$\text{FRAP Scavenging effect (\%)} = \frac{(A_0 - A_1)}{A_0} \times 100 \dots \dots \dots \text{Equation 3}$$

Where A_0 was the absorbance of the control and A_1 was the absorbance in the presence of the standard sample or extract.

Heavy metal analysis: Acid digestion method. A 2 g portion of the freeze-dried extract sample was weighed and placed into a 250 mL beaker in duplicate. Then, 10 mL of Aqua regia (a mixture of 1-part HNO_3 to 3 parts HCl) was added. The beaker was placed on a heating mantle set to 105°C and heated for 3 hours until the entire sample was fully digested. A 1:1 serial dilution was conducted on the aliquot, and the resulting mixture was adjusted to a final volume of 100 mL with distilled water in a standard flask [39]. The metal concentrations in the resulting solution were determined using a Buck Scientific atomic absorption spectrophotometer (AAS), model 210A.

Standards for each metal were prepared from stock solutions, and lower concentrations were made through serial dilutions. These standards were used to calibrate the spectrometer. The blank was aspirated into the machine first to zero the equipment. After five determinations, the standards were run to calibrate the instrument and establish a linearity curve, followed by the sample. The observed concentrations were recorded in duplicate, and the mean observed concentration was used to calculate the actual concentrations.

Actual concentration (mg/100g) =

$$\frac{\text{Observed concentration} \times \text{markup volume}}{\text{Weight per volume of sample}} \dots \text{Equation 4}$$

RESULTS AND DISCUSSION

Qualitative phytochemistry. Phytochemical analysis of the leaves revealed the presence of saponins, phenolic compounds, tannins, flavonoids, cardiac glycosides, terpenoids, steroids, and alkaloids, while anthraquinones and triterpenoids were absent. This finding is supported by the studies of Johnny *et al.* (2014) and Bongo *et al.* (2017) [15, 16], which utilized the plant leaves as detailed in Table 1.

Quantitative phytochemistry. The quantitative phytochemical content from the current study is presented in Table 2. Beyond the phenolic and flavonoid content, the phytochemical data reported here appears to be satisfactory, to the best of our knowledge. The findings indicate that *T. ivorensis* leaves have a significantly higher phenolic content (220.89 ± 1.34 mg (GAE)/g) compared to the hydroethanolic extract of the barks, which contains 62.34 ± 1.41 mg (GAE)/g, as noted by Konan *et al.* (2022) [13]. This difference may be attributed to the higher activity of the phenylalanine ammonia lyase (PAL) enzyme in the leaves, which is a crucial catalyst in phenolic biosynthesis [40]. In contrast, another study reported that the crude 80% methanol extract of *T. ivorensis* leaves yielded a total phenolic content of 367.19 ± 18.40 mg GAE/g

and a total flavonoid content of 531.10 ± 4.94 mg quercitrin (QUE)/g [14]. It is important to note that the present study employed a 50% ethanol extraction method, which may account for the slight differences observed, as 50% ethanol is often effective at extracting phenolic and flavonoid compounds, although 80% methanol has been recognized for its strong broad-spectrum extraction capabilities [41].

DPPH assay. The percentage inhibition of *T. ivorensis* demonstrates a concentration-dependent relationship; specifically, as the concentration of the extract increases, its ability to scavenge free radicals improves, leading to a higher percentage inhibition (see Figure 1). The IC₅₀ value for *T. ivorensis* was determined to be 26.54 µg/mL, in contrast to the standard, ascorbic acid, which had an IC₅₀ of 1.18 µg/mL. A comparison to previously published data reveals that the 80% crude methanol extract of the plant leaves yielded a DPPH IC₅₀ value of 4.26 ± 0.16 µg/mL [14]. This discrepancy suggests that 80% aqueous methanol typically provides marginally higher antioxidant potency, while 50–80% aqueous ethanol also demonstrates significant activity with fewer toxicity concerns [42].

When examining other studies, the IC₅₀ for the stem bark of *T. ivorensis* using DPPH was reported to be 12.6 µg/mL, whereas ascorbic acid measured 7.75 µg/mL [8]. Moomin *et al.* (2024) found that the DPPH IC₅₀ for *T. ivorensis* bark extracts was significantly lower for ethanol (7.9 ± 0.8 µg/mL) and ethyl acetate (9.4 ± 0.1 µg/mL) compared to petroleum ether (1163.3 ± 6.2 µg/mL) and chloroform extracts (1617.0 ± 186.3 µg/mL) [12]. Additionally, Konan *et al.* (2022) reported IC₅₀ values of 9.67 ± 1.12 µg/mL for vitamin C and 16.23 ± 0.33 µg/mL for *T. ivorensis* bark extract [13]. This variation in results may be attributable to findings indicating that the bark of many plant species exhibits enhanced antioxidant activity compared to leaves due to higher concentrations of antioxidant compounds,

such as tannins, phenolics, and proanthocyanidins. Moreover, the bark may possess different compound profiles that are more effective in oxidative defense [43, 44].

Total antioxidant capacity assay (phosphomolybdate assay). The assay is founded on the reduction of Mo (VI) to Mo (V) by the antioxidants present in the extract, leading to the formation of a green phosphate/Mo(V) complex at acidic pH. The ascorbic acid calibration curve depicted in Figure 2 was utilized to determine the concentration of ascorbic acid, based on the mean absorbance measured at 0.293 ± 0.005 for the plant sample. Using Equation 2, the total antioxidant capacity (TAC) was calculated to be 44.68 ± 0.985 mg ascorbic acid equivalent (AAE)/g of the plant sample. In comparison to the study conducted by Ehigie and Aderogba (2020), which employed 80% methanol for the extraction of crude plant leaves, their reported TAC was 38.54 ± 1.78 mg AAE/g sample [14]. A 50% ethanol-water mixture offers intermediate polarity, enabling the extraction of a broader spectrum of antioxidant compounds, ranging from polar phenolics to moderately nonpolar compounds. Conversely, highly polar solvents like 80% methanol may be more effective at extracting specific polar phenolics but might be less efficient for capturing a diverse array of antioxidants [45]. Moreover, the water content in the 50% ethanol solution facilitates swelling of the cell walls, thereby enhancing the penetration and release of various antioxidants, including those that are not readily soluble in predominantly methanolic solvents.

Ferric reducing power assay (FRAP). This assay enables the evaluation of the reducing power of antioxidant substances, highlighting their potential ability to donate electrons and convert ferric ions to their ferrous form. The IC₅₀ values for the *T. ivorensis* extract and ascorbic acid, indicating 50% inhibition for FRAP, were determined from the plots above (Figure 3a, b) to be 44.19 µg/mL and 38.89

µg/mL, respectively. In comparison to another study, the 80% methanol extract of *T. ivorensis* leaves yielded a FRAP value of 111.62 ± 11.20 mg AAE/g [14]. Additionally, the ethanol extract showed 119 ± 0.7 Trolox equivalents/µg of the dry sample, and the ethyl acetate extract exhibited a FRAP value of 156.3 ± 0.9 of *T. ivorensis* bark, both significantly surpassing those of the petroleum ether extract (3.8 ± 0.5) and chloroform extract (2.1 ± 0.5) as reported by Moomin *et al.* (2024) [12].

Heavy metal content. All analyzed elements, including potentially toxic heavy metals such as cadmium, lead, nickel, and arsenic, were found to be below the permissible limits established by the World Health Organization (WHO) for medicinal and edible plants. The presence of cadmium (Cd), lead (Pb), nickel (Ni), and arsenic (As) in food or medicinal plants raises serious concerns, as even trace amounts can lead to severe health consequences, particularly for children and pregnant women. It is crucial that their levels in consumable products remain significantly below international safety standards. In addition, essential minerals such as calcium (Ca), magnesium (Mg), iron (Fe), sodium (Na), potassium (K), and manganese (Mn) were observed to be within acceptable, non-toxic ranges. These six metals are vital for life, playing key roles in functions ranging from bone strength to nerve transmission and energy production. Maintaining a balanced intake through diet is essential, as both deficiencies and excess can lead to serious health issues.

There is paucity of information on the concentrations of heavy metals in *T. ivorensis*. Table 3 showed the details of the heavy metal content in the plant leaves. However, a study on a related species, *Terminalia avicennioides*, reported estimated intake levels of lead (Pb) at 0.08 mg/kg, nickel (Ni) at 0.23 mg/kg, cadmium (Cd) at not detected (ND), chromium (Cr) at 0.52 mg/kg, copper (Cu) at 7.90 mg/kg, and manganese (Mn) at 56.80 mg/kg [46].

Conclusion. In conclusion, this study highlights *T. ivorensis* leaves as a rich source of bioactive phytochemicals, including phenolics, flavonoids, tannins, and alkaloids, which contribute to its notable antioxidant properties. The 50% ethanol extract demonstrated significant free radical scavenging and reducing power, affirming its

therapeutic potential. Importantly, the heavy metal content in the leaves was found to be below WHO safety limits, ensuring the plant's safety for medicinal use. These findings support the continued use of *T. ivorensis* in traditional medicine while emphasizing the need for ongoing monitoring of its chemical and toxicological profiles.

Table 1: Phytochemical composition of *T. ivorensis* leaves compared to published data

Phytochemical composition	Results	Johnny et al., 2014 [15]	Bongo et al., 2017 [16]
Saponin	+++	+	+++
Phenolic compounds	++	ND	+++
Tannins	+++	++	+++
Flavonoids	+++	++	+++
Anthraquinones	NP	ND	ND
Cardiac glycoside	+++	+++	ND
Terpenoids	+	+	ND
Triterpenoids	NP	ND	ND
Steroids	++	ND	ND
Alkaloids	+	++	+++

+: slightly present, ++: moderately present, +++: heavily present, ND: not done, NP: not present

Table 2: Quantitative phytochemistry content of *T. ivorensis* leaves

Phytochemicals	Total Content
Alkaloid	32.45 ± 0.343 mg/100g
Saponin	30.07 ± 0.015 mg/100g
Reducing sugars	25.87 ± 0.335 mg/(GE)100g
Tannins	36.76 ± 0.107 mg/100g
Cardiac glycoside	22.48 ± 0.057 mg/100g
Steroid	30.70 ± 0.072 mg/100g
Terpenoids	48.60 ± 0.228 mg/100g
Flavonoid	441.63 ± 5.01 mg (RE)/g
Phenolic	220.89 ± 1.34 mg (GAE)/g

Data represents mean ± SD of triplicate determinations, RE: Rutin equivalent, GAE: Gallic acid equivalent, GE: Glucose equivalent

Table 3: Heavy metal concentration of *T. ivorensis*

	M e t a l s											
	Ca	Zn	Fe	Mg	Na	Cu	Cd	Mn	Pb	K	Ni	Ar
Mean observed concentration	0.047	0.022	0.2875	0.0386	0.5105	0.014	0.0001	0.0177	0.0002	0.413	ND	ND
Actual Concentration (mg/100g)	2.35	1.1	14.375	1.93	25.525	0.7	0.005	0.885	0.01	20.65	ND	ND
WHO maximum Permissible	NS	50	20	200	NS	3	0.3	2	10	NS	0.1	1.4
Limit/benchmark in plant (mg/kg)												

NS: Not specified, ND: Not detected

The mean observed concentration represents the measured metal content in the digested and diluted sample solution, determined by atomic absorption spectrometry (AAS) and expressed in (mg/L). The actual concentration, expressed in (mg/100g), denotes the heavy metal content in *T. ivorensis* leaves and was calculated using Equation 4.

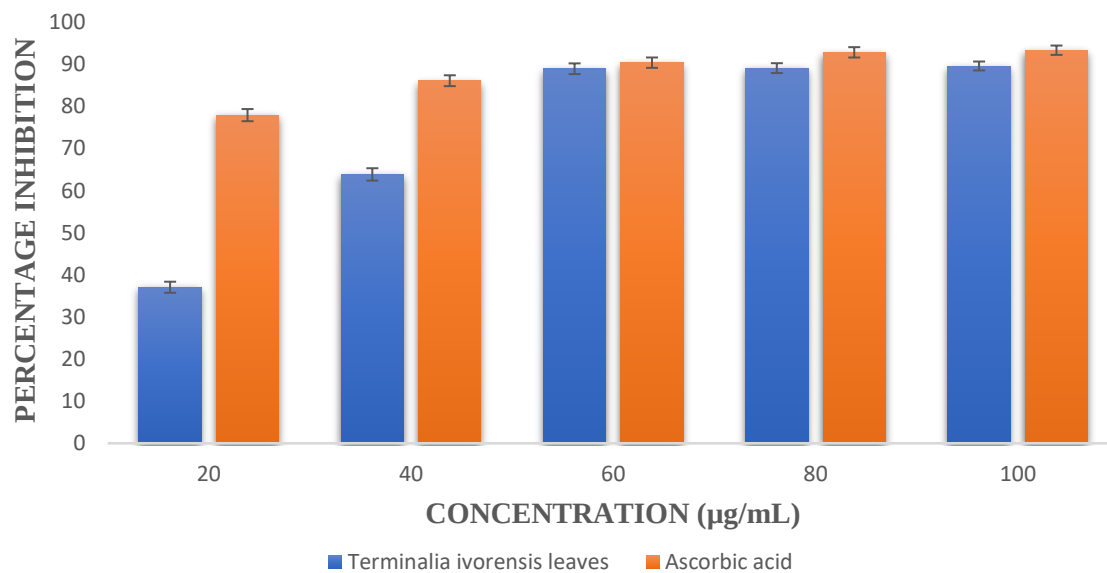


Figure 1: Plot of percentage inhibition against concentration *T. ivorensis* extract and standard (ascorbic acid)

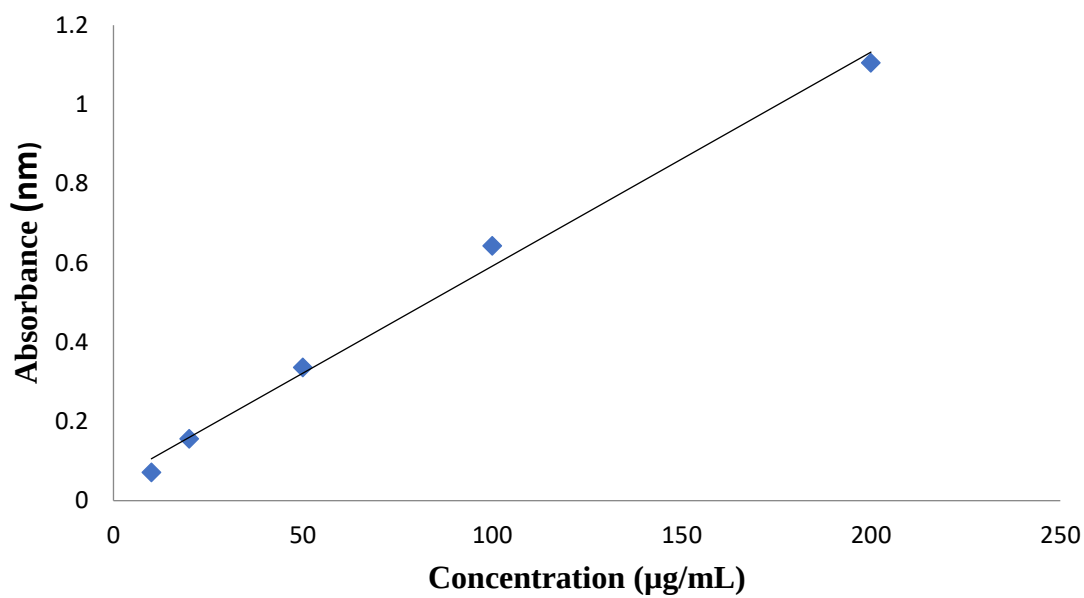


Figure 2: Total antioxidant capacity calibration curve of ascorbic acid

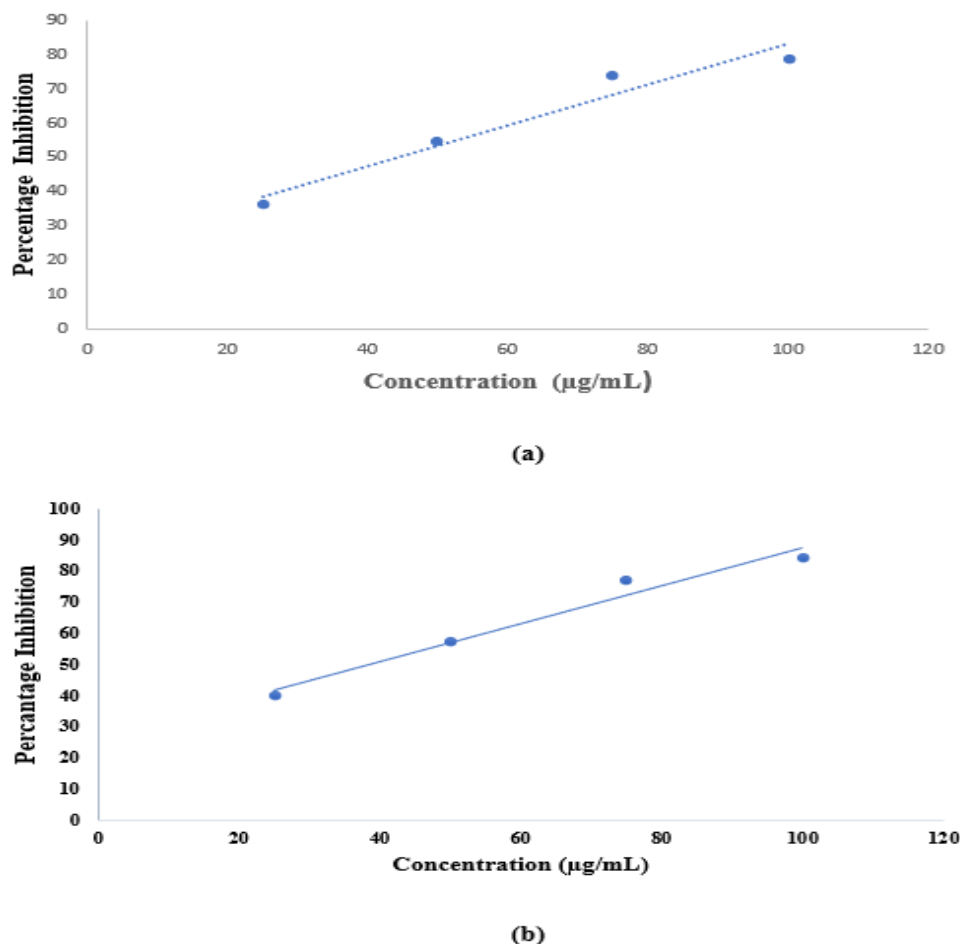


Figure 3: Plot to determine FRAP for *T. ivorensis* (a), and ascorbic acid (b)

Acknowledgement. This research was supported by the Tertiary Education Trust Fund (TETFund), under the supervision of Federal Ministry of Education, Nigeria, with registration number TETF/ES/DR&D-CE/NRF2021/SETHi/HSW/00290/VOL.1

REFERENCES

1. Järup L. Hazards of heavy metal contamination. Br. Med. Bul. 2003;68(1),167-182. <https://doi.org/10.1093/bmb/ldg032>
2. World Health Organization (WHO). Guidelines for assessing quality of herbal medicines with reference to contaminants and residues. 2007.
3. Abou-Arab AAK., Abou Donia MA. Heavy metals in Egyptian spices and medicinal plants and the effect of processing on their levels. J. Agric. and Food Chem. 2000;48(6):2300-2304. <https://doi.org/10.1021/jf990508j>
4. Etukudo, I. Ethnobotany: Conventional and Traditional Uses of Plants. Volume 1. Uyo: The Verdict Press; 2003;191.
5. Akinyemi KO, Oluwa OK, Omomigbehin EO. Antimicrobial activity of crude extracts of three medicinal plants used in south-west Nigerian folk medicine on some food-borne bacterial pathogens. Afr. J. Tradit. Complement. Altern. Med. 2006;3(4):13-22.
6. Coulibaly K, Zirihi GN, Guessennd-Kouadio N, Oussou KR, Dosso M. Antibacterial properties studies of trunk barks of *Terminalia ivorensis*, a commercial and medicinal species on some methicillin-resistant Staphylococci species strains. Afr Health Sci. 2014;14(3):753-756.
7. Agbedahunsi JM, Anao I, Adewunmi CO, Croft SL. Trypanocidal properties of *Terminalia ivorensis*, A. Chev. (Combretaceae). African Journal of Traditional, Complementary and Alternative Medicines. 2006;3(2):51-56. <https://doi.org/10.4314/ajtcam.v3i2.31157>.

8. Kipré GR, Agré DJ, Djyh BN, Ouattara N, Djaman AJ. Evaluation of the antioxidant potential and phytochemical analysis of *Terminalia mantaly* and *Terminalia ivorensis*, two plants of the Ivorian pharmacopoeia. *J. Drug Deliv. and Ther.* 2023;13(1):57-60.
9. Claudine T, Pambu A, Mwanza F, Mbadiko C, Makengo G, Iteku J, Tshilanda D, Mpiana P, Mbemba T. Comparative anti-mycobacterial activity on Lowenstein-Jensen Slants of selected medicinal plants used in the Congolese Pharmacopoeia. *J. Dis. Med. Plants.* 2017;3(5):88-96.
10. Sitapha Q, Adou Koffi MKRA, Kouassi EK, Guédé NZ, Houphouët FY, Jean DN, Allico JD. Comparative study chromatographic fractions activities from *Terminalia ivorensis* and ketoconazole as standard antifungal on in vitro growth of *Trichophyton mentagrophytes* Var. *Interdigitale*. *J. Drug Deliv. and Ther.* 2013;3(5):18-21.
11. Kporou, E. Antifungal activities of *Terminalia ivorensis* A. Chev. bark extracts against *Candida albicans* and *Aspergillus fumigatus*. *J. Ethnopharmacol.* 2013;2:49-52.
12. Moomin A, Knott RM, Russell WR, Moyer MP, Duthie SJ. *Terminalia ivorensis* demonstrates antioxidant properties and alters proliferation, genomic instability, and migration of human colon cancer cells in vitro. *Mutagenesis.* 2024;26:1-14
13. Konan GKNA, KRA AKM, Bolou GEK, Lidji Cjsr, Kple TKM, Monney YU, Kouame CC, N'guessan JD, Djaman AJ. Study of The Anti-Inflammatory Activity and Healing Power of The Hydroethanol Extract of *Terminalia Ivorensis* in Wistar Rats. *International Journal of Scientific Advances (IJSCIA).* 2022;3(4):673-678
14. Ehigie AS, Aderogba MA. Antioxidant activities of *Terminalia ivorensis* leaf extracts and its isolated constituent. *Niger. J. Nat. Prod. Med.* 2020; 24(1):7-11.
15. Johnny I, Okon J. Phytochemical Screening and Anti-hyperglycaemic Activity of Ethanolic Extract of *Terminalia ivorensis* A. Chev. Leaves on Albino Wistar Rats. *Glob. Adv. Res. J. Med. Med. Sci.* 2014;3:186-189.
16. Bongo GN, Ngbolua K-te-N, Ashande CM, Karume KL, Mukiza J, Tshilanda DD, Tshibangu DST, Ngombe NK, Mbemba TF, Mpiana PT. Pharmacological screening of *Gymnanthemum coloratum* (Willd.) H. Rob. & B. Kahn (Compositae) and *Terminalia ivorensis* A. Chev. (Combretaceae) from DR Congo: Spotlight on the antisickling, antibacterial and anti-diabetic activities. *Trop. Plant Res.* 2017;4(3):441-448.
17. Iwu MM, Anyawu BN. Anti-inflammatory and anti-arthritis properties of *Terminalia*. *Fitoterapia.* 1982;52:25-34.
18. Ben-Azu B, Aderibigbe AO, Ajayi AM. Neuroprotective effects of the ethanol stem bark extracts of *Terminalia ivorensis* in ketamine-induced schizophrenia-like behaviors and oxidative damage in mice. *Pharm. Biol.* 2016;54(12):2871-2879. <https://doi.org/10.1080/13880209.2016.1190382>
19. Ansah C, Moomin A, Boadu K. *Terminalia ivorensis* A. Chev. Ethanolic stem bark extract protects against Gentamicin-Induced renal and hepatic damage in rats. *J. Appl. Pharm. Sci.* 2016;6(4):175-82.
20. Moomin A, Mensah KB, Forkuo AD, Adu-Gyamfi PKT, Ansah C. Ethanolic stem bark extract of *Terminalia ivorensis* A. Chev. protects against potassium dichromate-induced nephrotoxicity in rats. *Scientific African.* 2020; 8: e00410.
21. Annan K, Sarpong K, Asare C, Dickson R, Amponsah K, Gyan B, Ofori M, Gbedema S. In vitro anti-plasmodial activity of three herbal remedies for malaria in Ghana: *Adenia cissampeloides* (Planch.) Harms., *Terminalia ivorensis* A. Chev., and *Elaeis guineensis* Jacq. *Pharmacogn. Res.* 2012;4(4):225-229.
22. Olayiwola VA., Azeez JO, Afolabi JO, Ihediuche CI. Bioaccumulation potentials of selected tree species in heavy metal contaminated soil. *Niger. Agric. J.* 2021;52(2):247-257.
23. Babalola JO, Olayiwola FT, Olowoyo JO, Alabi AH, Unuabonah EI, Ofomaja AE, Omorogie MO. Adsorption and desorption kinetics of toxic organic and inorganic ions using an indigenous biomass: *Terminalia ivorensis* seed waste. *Int. J. Ind. Chem.* 2017;8(2):207-220. <https://doi.org/10.1007/s40090-016-0109-5>.
24. Veerababu S, Sreenitha P, Kumar P, Reddy T, Ravindhranath, K. Removal of Lead (II) Ions from Industrial Waste Water using Biomaterials of *Terminalia ivorensis* Plant and its Composite with Fe-Alginate Beads as Adsorbents. *Asian J. Chem.* 2022; 32(12):2977-2984. <https://doi.org/10.14233/ajchem.2020.22799>.
25. Sijuola TO, Olajuyigbe SO. Phytoextraction of Heavy Metals from Diesel Oil Contaminated Soil using *Terminalia ivorensis* A. Chev. Seedlings. *Ibadan J. Agric. Res.* 2016;11:78-86.
26. Trease GE and Evans WC. Textbook of Pharmacognosy, Ballieri Tindall, London, UK, 12th edition. 1983.

27. Harborne, JB. *Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis*. London: Chapman & Hall. 1973.
28. Orengo KO, Mbaria JM, Ndichu M, Jafred K, Okumu MO. Preliminary Phytochemical Composition and In Vitro Anthelmintic Activity of Aqueous and Ethanol Extracts of *Olea africana* against Mixed Gastrointestinal Worms in Dogs. *Evid Based Complement Alternat Med*. 2022;2022:1-8.
29. Krivorotova T, Sereikaite J. Determination of fructan exohydrolase activity in the crude extracts of plants. *Electron. J. Biotechnol*. 2014;17:329-333
30. Nair R, Ghakker N, Sharma A. Spectrophotometric Estimation of Tannins in Raw and Processed Form (*Paan Masala*) Of Areca Nut. *Int. J. Ed. Sci. Res. Rev*. 2015;2(1):51-56.
31. Louis H, Akakuru OU, Linus MN, Innocent J, Amos PI. Qualitative and Quantitative Phytochemical Analyses of *Sclerocarya birrea* and *Sterculia setigera* in Kem and Yola, Adamawa State, Nigeria. *Am. J. Biomed. Res*. 2018;6(1):1-10. DOI: 10.12691/ajbr-6-1-1
32. Baccou JC, Lambert F, Sauvaire Y. Spectrophotometric method for the determination of total steroidal sapogenin. *Analyst*. 1977;102:458-465.
33. Malik SK, Ahmad M, Khan F. Qualitative and Quantitative estimation of terpenoids content in some important plants in Punjab, Pakistan. *Pak. J. Sci*. 2017;69(2):150-154.
34. Miliauskas G, Venskutonis PR, Van Beek TA. Screening of radical scavenging activity of some medicinal and aromatic plant extracts. *Food Chem*. 2004;85(2):231–237.
35. Ayoola GA, Adeyemi DK, Johnson OO, Eze OS. Phytochemical screening, antioxidant, antiulcer and toxicity studies of the leaves and stems of *Desmodium adscendens*. *Trop. J. Pharm. Res*. 2018; 17(7):1301-1307.
36. Brand-Williams W, Cuvelier ME, Berset C. Use of a free radical method to evaluate antioxidant activity. *Lebenson Wiss and Technol* 1995;28(1):25-30.
37. Prieto P, Pineda M, Aguilar M. Spectrophotometric Quantitation of Antioxidant Capacity through the Formation of a Phosphomolybdenum Complex: Specific Application to the Determination of Vitamin E. *Anal Biochem*; 1999;269(2):337-341.
38. Gülçin I, Elmastaş M, Aboul-Enein HY. Antioxidant activity of clove oil – A powerful antioxidant source. *Arabian J. Chem*. 2012;5(4):489-499.
39. AOAC. *Official Methods of Analysis of AOAC International*, 20th Edition. Association of Official Analytical Chemists, Gaithersburg, MD, USA. 2015.
40. Dixon RA, Paiva NL. Stress-Induced Phenylpropanoid Metabolism. *The Plant Cell*. 1995;7(7):1085–1097.
41. Nguyen, Q, Thoai H, Lam T, Le, T. Effects of Different Extraction Solvent Systems on Total Phenolic, Total Flavonoid, Total Anthocyanin Contents and Antioxidant Activities of Roselle (*Hibiscus sabdariffa* L.) Extracts. *Asian J. Chem*. 2019;31:2517-2521. 10.14233/ajchem.2019.22147.
42. Gonfa T, Temesgen A, Kiros T, Muthusaravanan S, Erba UO, Teklu T. Phytochemical Investigation and in vitro Antimicrobial and Antioxidant Activities Evaluation of *Erianthemum aethiopicum* Wiens and Polhill. *J Exp Pharmacol*. 2024;13(16):71-80. doi: 10.2147/JEP.S452098.
43. Tanase C, Coşarcă S, Muntean DL. A Critical Review of Phenolic Compounds Extracted from the Bark of Woody Vascular Plants and Their Potential Biological Activity. *Molecules*. 2019;24(6):1182. doi: 10.3390/molecules24061182.
44. Russo D, Miglionico R, Carmosino M, Bisaccia F, Andrade PB, Valentão P, Milella L, Armentano MF. A Comparative Study on Phytochemical Profiles and Biological Activities of *Sclerocarya birrea* (A.Rich.) Hochst Leaf and Bark Extracts. *Int J Mol Sci*. 2018;19(1):186. doi: 10.3390/ijms19010186.
45. Wakeel A, Jan SA, Ullah I, Shinwari ZK, Xu M. Solvent polarity mediates phytochemical yield and antioxidant capacity of *Isatis tinctoria*. *Peer J*. 2019;7:e7857. doi: 10.7717/peerj.7857.
46. Olusola JA, Akintan OB, Erhenhi HA, Osanyinlusi OO. Heavy Metals and Health Risks Associated with Consumption of Herbal Plants Sold in a Major Urban Market in Southwest, Nigeria. *J Health Pollut*. 2021;11(31):210915. doi: 10.5696/2156-9614-11.31.210915.