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Assessment of Antibacterial and Antioxidant Properties of Ethanol and Aqueous Extracts of *Euphorbia polycnemoides* Aerial Parts

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Abstract: *The search for effective and safer alternatives to synthetic antimicrobial agents has intensified due to rising concerns over antibiotic resistance. Herbal medicines, rich in bioactive compounds, have emerged as promising candidates due to their antimicrobial and antioxidant properties. This study assessed the antibacterial and antioxidant activities of ethanol and aqueous extracts from the aerial parts of* Euphorbia polycnemoides*. Antibacterial efficacy was evaluated against* Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae, *and* Enterococcus faecalis *using agar well diffusion and minimum inhibitory concentration (MIC) assays. The ethanol extract exhibited strong antibacterial activity, particularly against* S. aureus *(20.0±0.0 mm at 500 mg/mL) and* K. pneumoniae *(19.0±1.0 mm), with MIC values generally lower than those of the aqueous extract. Antioxidant potential was assessed using FRAP, DPPH, nitric oxide, lipid peroxide, and hydrogen peroxide scavenging assays. Both extracts demonstrated dose-dependent radical scavenging activities, with the aqueous extract showing higher performance in DPPH (75.79±0.66% at 100 µg/mL) and lipid peroxide (66.56±0.47%) assays. Phytochemical screening revealed the presence of flavonoids, tannins, alkaloids, phenols, and saponins in both extracts, supporting their bioactivity. Quantitative analysis indicated higher tannin and reducing sugar contents in the aqueous extract, while the ethanol extract had higher phenol, alkaloid, and flavonoid contents These findings suggest that E. polycnemoides aerial part extracts, particularly ethanol-based preparations, hold promising potential as natural antibacterial and antioxidant agents, supporting their possible application in the development of phytotherapeutic drugs.*

Keywords: *E*uphorbia *polycnemoides, antimicrobial agents, antioxidant, phytochemical screening*

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1.0 Introduction

The genus *Euphorbia*, one of the largest within the family Euphorbiaceae, exhibits remarkable diversity in distribution, morphology, and ecological adaptation. The Euphorbiaceae family comprises over 300 genera and approximately 8,000 species, predominantly distributed across tropical regions (Kemboi *et al.*, 2020). Members of this family include herbs, shrubs, trees, and climbers, many of which produce a characteristic milky latex. Among them, *Euphorbia* stands out with over 2,000 species, recognized for their economic and medicinal relevance (Vasas and Hohmann, 2014).

Phytochemically, *Euphorbia* species are rich in bioactive compounds such as essential oils, sesquiterpenes, and macrocyclic diterpenoids. These constituents have demonstrated a wide range of pharmacological activities, including cytotoxic, antitumor, antiviral, anti-inflammatory, and multidrug-resistance-modulating effects, positioning the genus as a valuable resource in drug discovery (Kemboi *et al.*, 2020).

In Nigeria, *Euphorbia polycnemoides* is traditionally employed in the treatment of various ailments. Its crushed leaves, often mixed with palm oil, are applied topically to alleviate rashes from measles, chickenpox, and formerly smallpox. Orally, the plant is used to manage diarrhea and dysentery, while infusions from dried leaves or the entire plant serve as laxatives. The plant is also used in the treatment of respiratory conditions such as cough, sore throat, asthma, and bronchitis (Jain *et al.*, 2017).

Traditional medicine, grounded in ethnobotanical knowledge, continues to serve as a critical source of therapeutic agents. Ethnopharmacological research bridges indigenous healing practices and modern pharmacology, providing scientific validation for the use of phytochemicals in treating diseases (Chihomvu *et al.*, 2024).

Despite its widespread traditional use, there is limited scientific evidence evaluating the antibacterial and antioxidant properties of ethanol and aqueous extracts of the aerial parts of E. polycnemoides. Most previous studies have focused on other Euphorbia species, leaving a knowledge gap for this particular plant species.

Therefore, this study aims to evaluate and compare the antibacterial and antioxidant activities of ethanol and aqueous extracts of the aerial parts of E. polycnemoides.

Understanding the bioactivity of these extracts is significant as it could support the development of natural antibacterial and antioxidant agents, offering safer alternatives to synthetic drugs and contributing to the fight against antibiotic resistance.

2.0 Materials and Methods

2.1 Sample Collection and Identification

Fresh aerial parts of *Euphorbia polycnemoides* were collected from Dukai village in Gande, Silame Local Government Area, Sokoto State, Nigeria. The samples were identified at the Botany Unit, Department of Biological Sciences, Faculty of Science, Usmanu Danfodiyo University, Sokoto, Nigeria, with a voucher number UDUS/ANS/0876.

2.2 Sample Preparation

The collected plant materials were thoroughly washed with deionized water to remove dust and contaminants. Samples were air-dried under shade at ambient temperature and then pulverized using an electric blender to obtain a fine powder. The powder was sieved for uniform particle size and stored in labeled

polyethylene bags under dry conditions until extraction.

2.3 Preparation of Plant Extracts

Two extracts were prepared from the powdered samples, which included aqueous and ethanol extracts.

To prepare the aqueous extract**,** 25 g of the powder sample was soaked in 250 mL of distilled water for 72 hours at room temperature with intermittent shaking. Also, in the preparation of the ethanol extract, 250 g of the powder was soaked in 250 mL of 95% ethanol under the same conditions. After soaking, the mixtures were filtered using Whatman No. 1 filter paper. The filtrates were concentrated to dryness using a water bath and stored for subsequent analysis.

2.4 Phytochemical Screening

2.4.1 Qualitative Analysis

Both extracts were screened for the presence of secondary metabolites following the methods of Silva et al. (1998), Wadood et al. (2013), Shaikh and Patil (2020), and Uba et al. (2021). Tests conducted included alkaloids (Dragendorff's test), tannins (Braymer's test), flavonoids, saponins, cardiac glycosides, phenols (Ferric chloride test) and reducing sugars (Fehling's test).

2.4.2 Quantitative Analysis

Quantitative determination of phenols, flavonoids, tannins, alkaloids, saponins, cardiac glycosides, and reducing sugars was conducted using standard procedures. All results were expressed as mg/100 g of dried extract.

2.5 Antioxidant Activity Assays

All antioxidant tests were performed in duplicate unless otherwise stated.

2.5.1 Ferric Reducing Antioxidant Power (FRAP)

FRAP was determined following Oyaizu (1986). 1 mL of extract was mixed with 2.5 mL phosphate buffer (0.2 M, pH 6.6) and 2.5 mL 1% potassium ferricyanide [$K_3Fe(CN)_6$]. The mixture was incubated at 50 °C for 20 min, followed by the addition of 2.5 mL 10% trichloroacetic acid and centrifugation at 3000 × g for 10 min. The supernatant (2.5 mL) was mixed with 2.5 mL distilled water and 0.5 mL 0.1% $FeCl_3$. Absorbance was measured at 700 nm using ascorbic acid as a standard.

2.5.2 DPPH Radical Scavenging Activity

DPPH assay was carried out according to Blois (1958). 1 mL of 0.1 mM DPPH solution in methanol was added to 3 mL of extract at various concentrations (10–125 µg/mL). After 30 min, absorbance was measured at 517 nm, and percentage inhibition was calculated.

2.5.3 Nitric Oxide Scavenging Activity

Nitric oxide generated from sodium nitroprusside in phosphate-buffered saline (PBS, pH 7.4) reacted to form nitrite ions, detected using Griess reagent (Green et al., 1982; Marcocci et al., 1994). Absorbance was measured at 546 nm.

2.5.4 Hydrogen Peroxide Scavenging Activity

Extract (4 mL) was mixed with 0.6 mL of 4 mM H_2O_2 in 0.1 M phosphate buffer (pH 7.4) and incubated for 10 minutes. Absorbance was measured at 230 nm.

2.5.5 Lipid Peroxidation Inhibition

Lipid peroxidation was determined using the thiobarbituric acid (TBA) assay. 1 mL of supernatant was mixed with 0.5 mL 30% trichloroacetic acid and 0.5 mL 0.8% TBA. Tubes were incubated at 80 °C for 30 min, cooled in ice water, centrifuged at 800 × g for 15 min, and absorbance was measured at 540 nm.

2.6 Antibacterial Assay

2.6.1 Test Organisms

The bacterial strains *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Enterococcus faecalis* were obtained from the Diagnostic Laboratory, Gwagwalada, FCT-Abuja, and maintained on nutrient agar slants at 4 °C.

2.6.2 Media Preparation

Nutrient agar and Mueller-Hinton agar were prepared according to the manufacturer's instructions and sterilized at 121 °C for 15 minutes.

2.6.3 Preparation of Sample Concentrations

Stock solutions of extracts were prepared at 500 mg/mL in dimethyl sulfoxide (DMSO) and diluted twofold to obtain 250, 125, and 62.5 mg/mL concentrations.

2.6.4 Agar Well Diffusion Method

Antibacterial activity was assessed using the agar well diffusion method (Irshad et al., 2012). 1 mL of standardized 18-hour bacterial culture was spread on Mueller-Hinton agar plates. Wells (6 mm diameter) were filled with 0.4 mL of extract. Plates were incubated at 37 °C for 24 hours. Zones of inhibition were measured in mm. DMSO served as the negative control, while chloramphenicol and ampicillin were positive controls.

2.6.5 Minimum Inhibitory Concentration (MIC)

MIC was determined using the broth dilution method (Olutiola et al., 2000). Serial dilutions of extracts (500–62.5 mg/mL) were mixed with nutrient broth and 10 µL of bacterial inoculum, incubated at 37 °C for 24 h, and evaluated for turbidity. The lowest concentration showing no visible growth was recorded as the MIC.

2.6.6 Minimum Bactericidal Concentration (MBC)

MBC was determined from MIC tubes showing no growth by subculturing onto fresh nutrient agar plates (Asowata et al., 2013). The lowest concentration with no bacterial growth after 24 h incubation at 37 °C was recorded as MBC.

3.0 Results and Discussion

3.1 Results

3.1.1 Qualitative analysis

Qualitative screening revealed that both ethanol and aqueous extracts contained all major classes of secondary metabolites, including tannins, phenols, flavonoids, alkaloids, saponins, reducing sugar, and cardiac glycosides.

Quantitative analysis showed that the aqueous extract had high levels of tannins (65.45 mg/100g) and reducing sugars, possibly contributing to stronger antioxidant activities. The ethanol extract had higher contents of phenols (34.43 mg/100g), flavonoids (28.36 mg/100g), and alkaloids (46.99 mg/100g), which may account for its better antibacterial efficacy.

Table 1: Qualitative Phytochemical Screening of *E. polycnemoides* Aerial Part Extracts

Phytochemicals	Ethanol	Aqueous
Tannin	+	+
Phenol	+	+
Reducing sugar	+	+
Alkaloid	+	+
Flavonoid	+	+
Saponins	+	+
Cardiac Glycosides	+	+

Key: + = Positive - = Negative

Table 2: Quantitative Phytochemical Analysis of E. polycnemoides Aerial Part Extracts

Phytochemicals	Ethanol (mg/100g)	Aqueous (mg/100g)
Tannin	60.23±0.23	65.45±0.07
Phenol	34.43±0.25	24.59±0.12
Reducing sugar	34.98±0.25	43.71±0.11
Alkaloid	46.99±1.35	37.16±0.15
Flavonoid	28.36±0.38	20.19±0.08
Saponins	08.75±0.04	10.67±0.08
Cardiac Glycoside	44.02±0.22	35.86±0.31

****Values represent Mean ± SD**

3.1.2 Antioxidant Activity

Both extracts displayed dose-dependent antioxidant activities in all assays. FRAP assay (Table 3): The aqueous extract (0.47 ± 0.006) at 100 µg/mL showed slightly higher reducing power than the ethanol extract (0.40 ± 0.001), though both were lower than ascorbic acid

(0.69±0.003). DPPH scavenging (Table 4): The aqueous extract (75.79±0.66%) was slightly more active than the ethanol extract (70.89±0.28%) at 100 µg/mL, but both were lower than ascorbic acid (86.67±0.47%). Nitric oxide (Table 5), lipid peroxide (Table 6), and hydrogen peroxide scavenging (Table 7): Both extracts showed increasing scavenging activity with concentration. The aqueous extract generally outperformed ethanol, particularly in lipid peroxide and H_2O_2 scavenging, indicating strong radical scavenging potential likely due to hydrophilic antioxidants.

3.1.3 Antimicrobial Activity

The antimicrobial activity of *E. polycnemoides* aerial part extracts (ethanol and aqueous) demonstrated a concentration-dependent inhibition of all tested bacterial strains. According to the Clinical and Laboratory Standards Institute (CLSI, 2020) standards, zones of inhibition ≥18 mm are considered active, 15–17 mm moderate, and ≤ 6 mm inactive. The ethanol extract exhibited the highest antibacterial activity, especially against *Staphylococcus aureus* (20.0±0.0 mm) and *Klebsiella pneumoniae* (19.0±1.0 mm) at 500 mg/mL, classifying them as active. It showed moderate activity against *E. coli* (16.0±1.0 mm) and *E. faecalis* (14.0±0.0 mm). The aqueous extract also showed good activity, but was generally lower than the ethanol extract. At 500 mg/mL, *S. aureus* (19.0±1.0 mm) and *K. pneumoniae* (18.0±0.5 mm) were active, *while E. coli* (15.0±0.0 mm) was moderate and *E. faecalis* (12.0±0.0 mm) showed lower activity. Compared with standard antibiotics (chloramphenicol and ampicillin), both extracts had lower inhibition zones, confirming that while the extracts possess significant antibacterial properties, they are less potent than conventional antibiotics.

Table 3: FRAP Scavenging Activity of *E. polycnemoides* Aerial Parts

C (µg/mL)	Ethanol	Aqueous	Ascorbic acid
20	0.08±0.002	0.11±0.002	0.13±0.002
40	0.13±0.001	0.16±0.001	0.14±0.004
60	0.31±0.004	0.26±0.004	0.38±0.002
80	0.37±0.006	0.35±0.009	0.45±0.006
100	0.40±0.001	0.47±0.006	0.69 ±0.003

****Values represent Mean± standard deviation, Key: FRAP = Ferric Reducing Antioxidant Potential**

Table 4: DPPH Scavenging Activity of *E. polycnemoides* Aerial Parts

C (µg/mL)	Ethanol	Aqueous	Ascorbic acid
20	14.33±0.19	16.91±0.10	24.08±0.09
40	29.58±0.37	33.75±0.28	50.60±0.28
60	52.65±0.75	54.31±0.47	70.42±0.75
80	63.99±0.47	69.63±0.57	77.33±0.37
100	70.89±0.28	75.79±0.66	86.67±0.47

****Values represent Mean± standard deviation, Key: DPPH = 2, 2- Diphenyl-1-picrylhydrazyl.**

Table 5: Nitrogen Oxide Scavenging Activity of *E. polycnemoides* Aerial Parts

Conc. (µg/ml)	Ethanol	Aqueous	Ascorbic acid
20	8.46±0.47	7.80±0.47	14.07±0.93
40	15.38±0.31	15.39±0.93	21.76±0.62
60	37.25±0.16	35.38±0.31	38.35±2.02
80	55.49±0.47	49.12±0.78	62.75±0.47
100	66.81±0.62	60.55±1.71	79.34±0.31

****Values represent Mean± standard deviation**

Table 6: Lipid Peroxide Scavenging Activity of *E. polycnemoides* Aerial Parts

Conc. (µg/ml)	Ethanol	Aqueous	Ascorbic acid
20	6.56±0.47	15.90±0.69	17.54±1.16
40	22.63±1.39	26.23±0.93	39.67±0.47
60	35.24±0.23	32.30±2.08	52.46±1.39
80	47.38±0.69	56.72±0.47	63.61±0.46
100	59.18±0.69	66.56±0.47	72.30±0.23

****Values represent Mean± standard deviation**

Table 7: Hydrogen Peroxide Scavenging Activity of *E. polycnemoides* Aerial Parts

Conc. (µg/mL)	Ethanol	Aqueous	Ascorbic acid
20	10.12±0.40	10.97±0.32	24.95±0.32
40	27.58±0.71	25.95±0.16	39.88±0.23
60	35.18±0.40	40.55±1.18	55.32±0.23
80	54.92±0.64	54.81±0.48	63.03±0.71
100	68.46±0.47	64.93±0.40	83.67±0.31

****Values represent Mean± standard deviation**

Table 8: Antibacterial activity of E polycnemoides showing mean zones of inhibition in millimeters

Test Organism / Extract	500 mg/mL	250 mg/mL	125 mg/mL	62.5 mg/mL
Ethanol Extract				
E. coli	16.00 ± 1.00	12.00 ± 0.00	7.50 ± 1.00	5.00 ± 0.00
S. aureus	20.00 ± 0.00	18.50 ± 1.00	13.00 ± 0.00	11.00 ± 0.00
K. pneumoniae	19.00 ± 1.00	17.00 ± 0.00	9.00 ± 1.00	6.50 ± 0.50
E. faecalis	14.00 ± 0.00	10.00 ± 0.00	7.00 ± 1.00	NA
Aqueous Extract				
E. coli	15.00 ± 0.00	9.50 ± 0.00	6.50 ± 0.00	NA
S. aureus	19.00 ± 1.00	15.00 ± 0.00	11.50 ± 0.00	10.00 ± 1.00
K. pneumoniae	18.00 ± 0.50	14.00 ± 1.00	7.00 ± 0.00	6.00 ± 0.00
E. faecalis	12.00 ± 0.00	7.00 ± 0.00	5.00 ± 1.00	NA

Controls				
E. coli (CH)	24.00 ± 2.00	21.00 ± 1.00	15.00 ± 1.00	10.00 ± 1.00
S. aureus (AMP)	30.00 ± 2.00	28.00 ± 2.00	19.00 ± 1.00	12.00 ± 1.00
K. pneumoniae (CH)	26.00 ± 1.00	25.00 ± 1.50	17.00 ± 0.00	11.50 ± 0.50
E. faecalis (AMP)	22.00 ± 2.00	19.00 ± 1.00	14.00 ± 0.00	9.00 ± 0.00

Values represent Mean± standard deviation from three replicate values.
Keys: CH Chloramphenicol, AMP = Ampicillin NA = No Activity
Clinical and Laboratory Standards Institute Guidelines (CLSI, 2020): ZONE ≥ 18mm = Active, ≤ 6mm = Inactive, ≤ 15mm = Moderate. **The MIC values supported the findings from Table 8.

The ethanol extract had lower MIC value for *E. faecalis*, with complete inhibition at 500mg/mL. The aqueous extract showed growth at all concentrations for *E. coli* and *E. faecalis*, suggesting weaker activity. The ethanol extract exhibited better efficacy at lower concentrations than the aqueous extract, particularly against *S. aureus* and *K. pneumoniae*.

Table 9: Minimum inhibitory concentration (MIC) of *E. polycnemoides* against test organisms

Test Organisms/ Extracts	**Concentrations in mg/ml**			
	500	**250**	**125**	**62.5**
Ethanol				
E. coli	-	-*	+	+
S. aureus	-	-	-*	+
K. pneumoniae	-	-*	+	+
E. feacalis	+	+	+	+
Aqueous				
E. coli	+	+	+	+
S. aureus	-	-	-*	+
K. pneumoniae	-	-*	+	+
E. feacalis	+	+	+	+
Controls				
E. coli (CH)	-	-	-*	+
S. aureus (AMP)	-	-	-	-*
K. pneumoniae (CH)	-	-	-*	+
E. feacalis	-	-	-*	+

****Keys: CH= Chloramphenicol, AMP= Ampicillin, + = Growth, - = No growth, -* = MIC.**

Comparatively, despite showing activity, aqueous extracts had high MIC values and lower inhibition zones, possibly due to the lower solubility of key antibacterial agents. Similar patterns were observed in studies on *E. hirta and E. thymifolia* (Hussain *et al.,* 2014), reinforcing the role of solvent polarity in extract bioactivity.

3.2 Discussion

This study has been carried out of the evaluate the phytochemical screening and *in vitro* antibacterial and antioxidant activities of the both the aqueous and ethanol extracts of *Euphorbia polycnemoides* aerial parts. The qualitative analysis revealed the presence of major secondary metabolites, which include tannins, phenols, flavonoids, alkaloids, saponins, reducing sugars, and cardiac glycosides in both ethanol and aqueous extracts of *E. polycnemoides*, aligning with prior studies on the *Euphorbia* genus. For example, studies on *E. heterophylla, E. hirta,* and *E. prostrata* have also reported similar profiles, indicating that these classes of phytochemicals are characteristic of the genus (Jain *et al.,* 2011; Tran *et al.,* 2020).

Quantitative phytochemical analysis revealed that the aqueous extract of *E. polycnemoides* aerial parts contained a higher concentration of tannins (65.45 mg/100 g) and reducing sugars compared to the ethanol extract. In contrast, the ethanol extract exhibited a greater abundance of phenols (34.43 mg/100 g), flavonoids (28.36 mg/100 g), and alkaloids (46.99 mg/100 g). These results contrast with the observations of Roghini and Vijayalakshmi (2018), who reported higher levels of all tested phytoconstituents in ethanol extracts relative to aqueous extracts, highlighting the potential species-specific or environmental variation in phytochemical accumulation.

Antioxidant Activities

Both extracts exhibited dose-dependent antioxidant activities across all assays. The aqueous extract outperformed ethanol in most cases, particularly in FRAP (0.47±0.006 vs. 0.40±0.001) and DPPH (75.79±0.66% vs. 70.89±0.28%). These results are consistent with studies by Bursal and Koksal (2011), who reported that aqueous extracts tend to have superior ferric reducing and free radical scavenging capacities.

The ethanol extract of *E. polycnemoides* demonstrated comparatively higher nitric oxide scavenging activity (Table 5) and hydrogen peroxide scavenging activity (Table 7) than the aqueous extract. These observations are in agreement with previous studies by Kumar *et al.* (2016) and Farhan *et al.* (2012), respectively, and suggest a greater concentration of hydrophilic antioxidants in the ethanol extract, possibly attributed to the presence of polyphenolic compounds. In contrast, the aqueous extract exhibited moderate scavenging activity, which may be linked to its relatively high phenolic and flavonoid content, both of which are known contributors to radical scavenging activity (Shahidi and Ambigaipalan, 2015).

Antibacterial Activities

The ethanol extract of *E. polycnemoides* exhibited stronger antibacterial activity compared to the aqueous extract, with notable zones of inhibition observed against *S. aureus* (20.0 ± 0.0 mm) and *K. pneumoniae* (19.0 ± 1.0 mm). These results are consistent with the minimum inhibitory concentration (MIC) values, which showed complete inhibition at concentrations ranging from 250 to 125 mg/mL. This enhanced activity aligns with the findings of Obi and Onuolia (2000), who identified ethanol as a more effective solvent for extracting bioactive compounds of medicinal relevance.

However, the differences in antibacterial potency between the ethanolic and aqueous extracts were not substantial for all test organisms, a trend that supports the observations of Agu and Thomas (2012), who reported minimal variation in antibacterial efficacy between ethanolic and aqueous plant extracts.

This study confirms that *E. polycnemoides* aerial parts are rich in diverse bioactive phytochemicals with notable antioxidant and antibacterial activities. Ethanol extracts, being richer in phenolics and alkaloids, are more potent antimicrobials, while aqueous extracts exhibit stronger antioxidant activity due to high tannin and sugar content.

4.0 Conclusion

The findings of this study revealed that both ethanol and aqueous extracts of the aerial parts of *Euphorbia polycnemoides* contained diverse secondary metabolites, including tannins, phenols, flavonoids, alkaloids, saponins, reducing sugars, and cardiac glycosides, which are known contributors to biological activity. Quantitative analysis showed that the aqueous extract had higher concentrations of tannins and reducing sugars, while the ethanol extract contained higher levels of phenols, flavonoids, and alkaloids. Antioxidant assays demonstrated that both extracts exhibited dose-dependent radical scavenging and reducing power, with the aqueous extract generally outperforming the ethanol extract, particularly in DPPH and lipid peroxide scavenging assays. On the other hand, the ethanol extract showed stronger antibacterial activity, producing significant inhibition zones against *Staphylococcus aureus* and *Klebsiella pneumoniae*, and lower MIC values compared to the aqueous extract. These results suggest that solvent type influenced the type and strength of bioactivity observed, with ethanol favoring antibacterial potency and water favoring antioxidant efficiency.

In conclusion, the aerial parts of *Euphorbia polycnemoides* possess significant antibacterial and antioxidant activities, confirming its ethnomedicinal relevance and highlighting its potential as a natural therapeutic agent. Ethanol extracts were particularly effective as antibacterial agents, while aqueous extracts exhibited stronger antioxidant potential, indicating that the plant could be exploited in different formulations depending on the intended therapeutic use.

It is recommended that further studies should be conducted to isolate and characterize the specific bioactive compounds responsible for these activities, as this will provide clearer insights into their mechanisms of action. In vivo studies should also be carried out to validate the safety, efficacy, and pharmacological relevance of the extracts. Additionally, formulation development and dosage standardization should be pursued to support the integration of *Euphorbia polycnemoides* into modern phytotherapeutic drug development and its possible application as a complementary or alternative therapy in combating antibiotic resistance and oxidative stress-related disorders.

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Consent for publication

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Availability of data

Data shall be made available on demand.

Competing interests

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Not applicale

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Aletan U.I. conceived the study, designed the research methodology, and supervised the overall project. Adamu H.K. assisted with literature review, data curation, and preparation of the initial draft of the manuscript Onifade O.O carried out the phytochemical analyses and contributed to data interpretation. Ahams E.E. performed the antibacterial assays and participated in result validation. Yisa A.G. conducted the antioxidant experiments and contributed to statistical analysis.. All authors read, revised, and approved the final manuscript for submission.