JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 14(3), SEPTEMBER, 2026
E-ISSN: 3093-0898, PRINT ISSN: 2277-0011; Journal homepage: www.atbufstejoste.com



Phytochemical Composition and Antibacterial Activity of Cnidoscolus Aconitifolius (CHAYA) Leaf Methanolic Extract Against Selected Pathogenic Bacteria

Obadahun J., Agho O. B., Enyeribe C. C., Pascalina P. L., Joseph Emmanuel Tsaku, Saliu M. Momodu, Bakare M. A., Kadanga B. Lawal, Abubakar Sadiq Musa, Rosemary Ufedo-Ojo, Akanni A. O., Hajara Mustapha
Department of Science Laboratory Technology,
Nigerian Institute of Leather and Science Technology (NILEST), Samaru, Zaria, Kaduna State, Nigeria

ABSTRACT

This study investigated the phytochemical composition and antibacterial activity of methanolic leaf extract of Cnidoscolus aconitifolius against selected pathogenic bacteria. Qualitative phytochemical screening was conducted to identify the major classes of secondary metabolites present in the extract. Antibacterial activity was evaluated against Escherichia coli, Salmonella typhi, Pseudomonas aeruginosa and Klebsiella pneumoniae using the agar well diffusion method. Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) were also determined. The results revealed the presence of alkaloids, tannins, flavonoids, saponins and cardiac glycosides, while steroids and terpenoids were absent. The extract demonstrated concentration-dependent antibacterial activity, with K. pneumoniae showing the highest susceptibility, recording an inhibition zone of 29 mm at 200 mg/ml. E. coli, S. typhi and P. aeruginosa recorded maximum inhibition zones of 28, 24 and 20 mm, respectively. The MIC values were 50 mg/ml for K. pneumoniae, 100 mg/ml for E. coli and S. typhi, and 200 mg/ml for P. aeruginosa. The MBC/MIC ratios ranged from 1.0 to 2.0, indicating a bactericidal mode of action. Ciprofloxacin (10 µg) produced inhibition zones ranging from 28 to 34 mm against the test organisms. The findings demonstrate that methanolic leaf extract of C. aconitifolius possesses broad-spectrum bactericidal activity against Gram-negative pathogens. The observed activity may be associated with the presence of alkaloids, flavonoids, tannins and saponins. Further studies involving isolation and characterisation of the active compounds and toxicity evaluation are recommended to establish its potential for antibacterial applications.

ARTICLE INFO
Article History
Received: May, 2026
Received in revised form: May, 2026
Accepted: July, 2026
Published online: September, 2026

KEYWORDS
Cnidoscolus aconitifolius; Phytochemical Screening; Antibacterial Activity; Alkaloids; Flavonoids; Minimum Inhibitory Concentration

INTRODUCTION

The emergence and global dissemination of antimicrobial-resistant (AMR) pathogens constitute one of the most pressing public health challenges of the twenty-first century. The World Health Organization has projected that, without effective intervention, AMR-related mortality could exceed ten million deaths annually by 2050 [1]. Clinically significant pathogens, including extended-spectrum β-lactamase-producing *Escherichia coli*, multidrug-resistant *Klebsiella pneumoniae*, carbapenem-resistant *Pseudomonas aeruginosa* and fluoroquinolone-resistant *Salmonella typhi*, have developed resistance to multiple classes of conventional antibiotics, thereby compromising therapeutic efficacy and increasing morbidity, mortality and healthcare costs [2,3]. This trajectory underscores the urgent need to identify novel antimicrobial scaffolds from alternative sources.

Corresponding author: Obadahun J.
joshuaobadahun@gmail.com
Department of Science Laboratory Technology, Nigerian Institute of Leather and Science Technology (NILEST), Samaru, Zaria, Kaduna
© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 14(3), SEPTEMBER, 2026
E-ISSN: 3093-0898, PRINT ISSN: 2277-0011; Journal homepage: www.atbufstejoste.com



Medicinal plants represent a vast and largely untapped reservoir of structurally diverse bioactive metabolites with demonstrated antimicrobial properties. It is estimated that over 75% of the global population relies on plant-derived preparations for primary healthcare, and a substantial proportion of modern pharmaceuticals originate from natural product leads [4,5]. Secondary metabolites such as alkaloids, flavonoids, tannins, saponins and glycosides exert antibacterial effects through multiple mechanisms, including disruption of cytoplasmic membrane integrity, inhibition of nucleic acid synthesis, precipitation of microbial proteins and interference with bacterial energy metabolism [6,7]. Despite this potential, a significant number of traditionally used medicinal plants have not been subjected to rigorous scientific evaluation [8].

Cnidoscolus aconitifolius (Mill.) I.M. Johnst., commonly known as chaya or tree spinach, is a perennial leafy shrub of the family Euphorbiaceae, indigenous to Central America and widely naturalised across the Caribbean and tropical Africa, including Nigeria, where it is consumed as a leafy vegetable and employed in folk medicine for the management of infections, inflammation, diabetes and gastrointestinal disorders [9,10]. Preliminary pharmacological investigations have reported that crude extracts of *C. aconitifolius* leaves possess antimicrobial, antioxidant, antihyperglycaemic and anti-inflammatory activities [10,11]. However, the majority of these studies have been limited to qualitative screening, and comprehensive phytochemical profiling coupled with systematic quantitative antibacterial evaluation against clinically relevant Gram-negative pathogens remains scarce. In particular, the concentration-dependent efficacy and spectrum of activity of *C. aconitifolius* leaf extracts against organisms such as *E. coli*, *S. typhi*, *P. aeruginosa* and *K. pneumoniae* require further elucidation [12].

The present study was designed to address this knowledge gap by (i) screening the major phytochemical constituents—alkaloids, tannins, flavonoids, saponins, cardiac glycosides, steroids and terpenoids—in the methanolic leaf extract of *C. aconitifolius*; (ii) evaluating the *in vitro* antibacterial activity of the extract against *E. coli* (Gram-negative), *S. typhi* (Gram-negative), *P. aeruginosa* (Gram-negative) and *K. pneumoniae* (Gram-negative) using the agar well diffusion method; and (iii) determining the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of the extract against the test organisms. The findings are intended to provide a scientific basis for the ethnomedicinal use of *C. aconitifolius* and to inform future bioassay-guided isolation of its active antibacterial principles.

MATERIALS AND METHODS

Plant material collection and preparation

Fresh, mature leaves of *Cnidoscolus aconitifolius* were collected from a local farm in Graceland, Samaru, Zaria, Kaduna State, Nigeria. The plant was identified and authenticated at the Herbarium, Department of Biological Sciences, Ahmadu Bello University, Zaria. The leaves were washed thoroughly with distilled water to remove surface contaminants, air-dried at ambient temperature (25–30 °C) to constant weight, and pulverised into a fine powder using a sterile mortar and pestle. The powdered material was stored in airtight containers at room temperature until extraction.

Preparation of methanolic leaf extract

A 60 g portion of the powdered leaf material was macerated in 400 ml of 70% methanol at room temperature for 72 h in a sealed conical flask covered with aluminium foil, with periodic agitation. The mixture was filtered through Whatman No. 1 filter paper, and the filtrate was concentrated to dryness using a freeze dryer. The resulting crude methanolic extract was stored in a sterile, airtight container at 4 °C until use [13].

Qualitative phytochemical screening

The crude methanolic extract was subjected to qualitative phytochemical screening to detect the presence of major classes of secondary metabolites using standard analytical

Corresponding author: Obadahun J.
joshuaobadahun@gmail.com
Department of Science Laboratory Technology, Nigerian Institute of Leather and Science Technology (NILEST), Samaru, Zaria, Kaduna
© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 14(3), SEPTEMBER, 2026
E-ISSN: 3093-0898, PRINT ISSN: 2277-0011; Journal homepage: www.atbufstejoste.com



procedures described by Brain and Turner [14] and Evans [15].

Test for alkaloids (Mayer's test). The crude extract was mixed with Mayer's reagent (potassium mercuric iodide solution). The formation of a cream-coloured precipitate indicated the presence of alkaloids.

Test for tannins (Ferric chloride test). The crude extract was mixed with a few drops of ferric chloride solution. The appearance of a blue-green colour indicated the presence of tannins.

Test for flavonoids (Shinoda test). The crude extract was mixed with a few fragments of magnesium ribbon, and concentrated hydrochloric acid was added dropwise. The appearance of a pink-scarlet colour after a few minutes indicated the presence of flavonoids.

Test for saponins (Froth test). The crude extract was mixed with 1 ml of distilled water in a semi-micro tube and shaken vigorously. The formation of stable froth indicated the presence of saponins.

Test for cardiac glycosides (Borntrager's test). A 200 mg portion of the crude extract was mixed with 2 ml of dilute sulphuric acid and 2 ml of 5% aqueous ferric chloride solution, then boiled for 5 min. The development of a colour change indicating oxidation to anthraquinones confirmed the presence of cardiac glycosides.

Test for steroids and terpenoids (Liebermann-Burchard test). The crude extract was mixed with a few drops of acetic anhydride, boiled and cooled. Concentrated H_2SO_4 was then added carefully from the sides of the test tube. A brown ring at the junction of two layers indicated a positive result; the upper layer turning green indicated the presence of steroids, while the formation of a deep red colour indicated the presence of triterpenoids.

Test microorganisms

Four clinically relevant Gram-negative bacterial strains were used: *Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*. The organisms were obtained from the Microbiology Laboratory of the Nigerian Institute of Leather and Science Technology (NILEST), Zaria, and maintained on nutrient agar slants at 4 °C.

Preparation of extract concentrations

A stock solution of the crude methanolic extract was prepared by dissolving 1.0 g of the extract in 5 ml of dimethyl sulfoxide (DMSO) to yield a concentration of 200 mg/ml. Serial two-fold dilutions were prepared from the stock to obtain working concentrations of 100, 50 and 25 mg/ml.

Agar well diffusion assay

Mueller–Hinton agar (MHA) was prepared according to the manufacturer's instructions, sterilised at 121 °C for 15 min, and poured into sterile Petri dishes. Standardised bacterial suspensions (adjusted to 0.5 McFarland turbidity standard, approximately 1.5×10^8 CFU/ml) were uniformly inoculated onto the solidified MHA plates using sterile cotton swabs. Wells of 6 mm diameter were bored into the agar using a sterile cork borer, and each well was filled with 100 µl of the respective extract concentration (200, 100, 50 or 25 mg/ml). The plates were allowed to stand at room temperature for 30 min to permit pre-diffusion, then incubated at 37 °C for 24 h. Zones of inhibition were measured in millimetres using a calibrated ruler. Ciprofloxacin (10 µg) discs served as the positive control, and DMSO served as the negative control. All procedures were performed in accordance with CLSI guidelines [16].

Minimum inhibitory concentration (MIC)

The MIC was determined by the broth dilution method [17]. Two-fold serial dilutions of the extract (200, 100, 50 and 25 mg/ml) were prepared in sterile nutrient broth. Each tube was inoculated with a standardised bacterial suspension (0.5 McFarland standard) and incubated at 37 °C for 24 h. The MIC was defined as the lowest concentration of the extract at which no visible turbidity was observed.

Minimum bactericidal concentration (MBC)

Aliquots (10 µl) from MIC tubes showing no visible growth were subcultured onto fresh MHA plates and incubated at 37 °C for 24 h. The

Corresponding author: Obadahun J.
joshuaobadahun@gmail.com
Department of Science Laboratory Technology, Nigerian Institute of Leather and Science Technology (NILEST), Samaru, Zaria, Kaduna
© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 14(3), SEPTEMBER, 2026
E-ISSN: 3093-0898, PRINT ISSN: 2277-0011; Journal homepage: www.atbufstejoste.com

MBC was defined as the lowest extract concentration that yielded no visible colony growth on the agar surface, indicating complete bactericidal activity [17].

RESULTS

Qualitative phytochemical composition

The qualitative phytochemical screening of the methanolic leaf extract of *C. aconitifolius* revealed the presence of five major classes of secondary metabolites (Table 1).

Table 1: Qualitative phytochemical composition of *Cnidoscolus aconitifolius* leaf methanolic extract

Phytochemical	Result
Alkaloids	+
Tannins	+
Flavonoids	+
Saponins	+
Cardiac glycosides	+
Steroids	−
Terpenoids	−

+ = Present; − = Absent

Alkaloids, tannins, flavonoids, saponins and cardiac glycosides were detected in the extract, while steroids and terpenoids were absent. The presence of these bioactive compounds is consistent with the chemical defence repertoire of Euphorbiaceae species and provides a phytochemical basis for the plant's reported ethnomedicinal applications [6,10].

Antibacterial activity

The antibacterial activity of the methanolic leaf extract against the four test organisms, as determined by the agar well diffusion method, is presented in Table 2.

Table 2: Zone of inhibition (mm) of *Cnidoscolus aconitifolius* leaf methanolic extract against test bacteria

Test organism	200 mg/ml	100 mg/ml	50 mg/ml	25 mg/ml	Ciprofloxacin (10 µg)
Klebsiella pneumoniae	29	27	20	17	32
Escherichia coli	28	26	21	18	34
Salmonella typhi	24	20	18	13	30
Pseudomonas aeruginosa	20	18	16	14	28

The methanolic leaf extract of *Cnidoscolus aconitifolius* exhibited antibacterial activity against all four test organisms, with inhibition zones generally increasing with extract concentration. *Klebsiella pneumoniae* was the most susceptible organism, recording inhibition zones of 29, 27, 20 and 17 mm at 200, 100, 50 and 25 mg/ml, respectively. *Escherichia coli* showed high susceptibility, with inhibition zones of 28, 26, 21 and 18 mm at the corresponding concentrations. *Salmonella typhi* exhibited moderate susceptibility, with inhibition zones of 24-, 20-, 18- and 13-mm. *Pseudomonas aeruginosa* was the least susceptible organism, recording inhibition zones of 20, 18, 16 and 14 mm, respectively. Ciprofloxacin (10 µg) produced inhibition zones of 32, 34, 30 and 28 mm against *K. pneumoniae*, *E. coli*, *S. typhi* and *P. aeruginosa*, respectively, indicating greater antibacterial activity than the plant extract under the tested conditions. Overall, the findings suggest that the methanolic leaf extract possesses broad-spectrum antibacterial potential, particularly against *K. pneumoniae* and *E. coli*.

Corresponding author: Obadahun J.
joshuaobadahun@gmail.com
Department of Science Laboratory Technology, Nigerian Institute of Leather and Science Technology (NILEST), Samaru, Zaria, Kaduna
© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 14(3), SEPTEMBER, 2026
E-ISSN: 3093-0898, PRINT ISSN: 2277-0011; Journal homepage: www.atbufstejoste.com



Minimum inhibitory and bactericidal concentrations

The MIC and MBC values of the methanolic extract are summarised in Tables 3 and 4, respectively.

Table 3: Minimum inhibitory concentration (MIC) of *Cnidoscolus aconitifolius* leaf methanolic extract

Test organism	200 mg/ml	100 mg/ml	50 mg/ml	25 mg/ml
Klebsiella pneumoniae	−	−	MIC	+
Escherichia coli	−	MIC	+	+
Salmonella typhi	−	MIC	+	+
Pseudomonas aeruginosa	MIC	+	+	+

KEY; MIC = minimum inhibitory concentration; + = presence of turbidity; − = absence of turbidity or growth.

Table 4: Minimum bactericidal concentration (MBC) of *Cnidoscolus aconitifolius* leaf methanolic extract

Test organism	200 mg/ml	100 mg/ml	50 mg/ml	25 mg/ml
Klebsiella pneumoniae	−	MBC	+	+
Escherichia coli	−	MBC	+	+
Salmonella typhi	−	MBC	+	+
Pseudomonas aeruginosa	MBC	+	+	+

KEY; MBC = minimum bactericidal concentration; + = presence of turbidity; − = absence of turbidity or growth.

The extract was bactericidal against *K. pneumoniae* at an MIC of 50 mg/ml and an MBC of 100 mg/ml (MBC/MIC ratio = 2). *E. coli* and *S. typhi* were both inhibited and killed at 100 mg/ml (MBC/MIC ratio = 1). *P. aeruginosa* required the highest tested concentration (200 mg/ml) for both inhibition and killing (MBC/MIC ratio = 1). The MBC/MIC ratios of ≤ 2 for all susceptible organisms confirm a bactericidal mode of action at or near the inhibitory concentration.

DISCUSSION OF FINDINGS

The qualitative phytochemical screening revealed that alkaloids, tannins, flavonoids, saponins and cardiac glycosides are the major secondary metabolites present in the methanolic leaf extract of *C. aconitifolius*. This phytochemical profile is consistent with previous reports on Euphorbiaceae species; for instance, Okoli et al. [18] reported a similar constellation of bioactive compounds—tannins, alkaloids, saponins, flavonoids and cardiac glycosides—in *Euphorbia hirta*, a related member of the same family. The absence of steroids and terpenoids suggests that the pharmacological activity of *C. aconitifolius* is primarily driven by phenolic compounds, nitrogenous bases and glycosides rather than terpenoid pathways.

The identified phytochemicals collectively provide a mechanistic basis for the observed antibacterial activity. Alkaloids exert antimicrobial effects through DNA intercalation and inhibition of essential enzymatic pathways [6]. Tannins precipitate microbial proteins and inactivate cell-surface adhesins, disrupting membrane integrity and inhibiting extracellular enzyme activity [18].

Flavonoids inhibit DNA gyrase, disrupt cytoplasmic membrane function and suppress bacterial virulence factors such as biofilm formation [7]. Saponins, by virtue of their amphiphilic glycoside structures, interact with membrane sterols and phospholipids, leading to increased membrane permeability and eventual cell lysis [19]. The co-occurrence of these bioactive compounds in *C. aconitifolius* leaves suggests a potential synergistic antibacterial effect, although this hypothesis requires confirmation through combination studies with isolated compounds.

The antibacterial screening results demonstrated broad-spectrum activity against all

Corresponding author: Obadahun J.
joshuaobadahun@gmail.com
Department of Science Laboratory Technology, Nigerian Institute of Leather and Science Technology (NILEST), Samaru, Zaria, Kaduna
© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved



four Gram-negative pathogens tested. *Klebsiella pneumoniae* was the most susceptible organism, with a zone of inhibition of 29 mm at 200 mg/ml and an MIC of 50 mg/ml. *Escherichia coli* and *Salmonella typhi* exhibited comparable susceptibility (MIC: 100 mg/ml), while *P. aeruginosa* was the least susceptible (MIC: 200 mg/ml). The differential susceptibility among the Gram-negative organisms is noteworthy, as all four share the fundamental Gram-negative cell envelope architecture comprising an outer membrane of lipopolysaccharide (LPS) that serves as a permeability barrier [3]. Species-level differences in outer membrane porin composition, LPS structure and efflux pump expression can significantly modulate susceptibility to plant-derived antimicrobials [2].

The comparatively lower susceptibility of *P. aeruginosa* is consistent with the well-documented intrinsic resistance of this organism to many antimicrobial agents, including plant-derived compounds. *P. aeruginosa* possesses a highly impermeable outer membrane with restrictive porin channels (OprD), constitutively expressed efflux pump systems (MexAB-OprM), and the ability to form biofilms, all of which contribute to its reduced susceptibility [10]. Nevertheless, the measurable inhibition observed against this notoriously resistant pathogen (20 mm at 200 mg/ml) suggests that the extract contains compounds capable of partially penetrating or circumventing these defence mechanisms.

The positive control ciprofloxacin (10 µg) produced inhibition zones of 28–34 mm against all test organisms, confirming their susceptibility to conventional antibiotics and validating the assay conditions. While the extract's activity at 200 mg/ml was slightly lower than that of ciprofloxacin, the comparable zones observed against *K. pneumoniae* (29 vs. 32 mm) and *E. coli* (28 vs. 34 mm) suggest that the crude extract possesses substantial antibacterial potency that could be significantly enhanced through bioassay-guided fractionation and purification of its active constituents.

The fact that the MBC/MIC ratios were ≤ 2 for all test organisms indicates that the extract exerts a bactericidal rather than a merely bacteriostatic effect at or near the inhibitory concentration, which is a desirable property for a potential therapeutic agent [16]. The relatively high MIC values (50–200 mg/ml) indicate moderate antibacterial potency, which is typical of unfractionated plant extracts containing a complex mixture of active and inactive constituents. It is anticipated that bioassay-guided fractionation and isolation of the individual active compounds would yield significantly lower MIC values, as has been demonstrated for purified flavonoids and alkaloids from other Euphorbiaceae species [9,10].

CONCLUSION

The methanolic leaf extract of *Cnidoscolus aconitifolius* contains alkaloids, tannins, flavonoids, saponins and cardiac glycosides and demonstrated broad-spectrum, concentration-dependent and bactericidal antibacterial activity against *Klebsiella pneumoniae* (MIC: 50 mg/ml), *Escherichia coli* (MIC: 100 mg/ml), *Salmonella typhi* (MIC: 100 mg/ml) and *Pseudomonas aeruginosa* (MIC: 200 mg/ml). The differential susceptibility pattern is consistent with the structural and permeability differences between the cell envelopes of the test organisms. These findings provide scientific validation for the traditional use of *C. aconitifolius* in the management of bacterial infections and support further investigation through bioassay-guided fractionation, isolation of the active principles, and *in vivo* toxicity and efficacy studies.

REFERENCES

[1] World Health Organization. Global antimicrobial resistance and use surveillance system (GLASS) report. Geneva: WHO Press; 2021.
[2] Laxminarayan R, Duse A, Wattal C, Zaidi AKM, Wertheim HFL, Sumpradit N, et al. Antibiotic resistance—the need for global solutions. Lancet Infect Dis. 2013;13(12):1057–98.
[3] Ventola CL. The antibiotic resistance crisis: Part 1. Causes and threats. Pharm Ther. 2015;40(4):277–83.

Corresponding author: Obadahun J.
joshuaobadahun@gmail.com
Department of Science Laboratory Technology, Nigerian Institute of Leather and Science Technology (NILEST), Samaru, Zaria, Kaduna
© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved



[4] World Health Organization. WHO traditional medicine strategy: 2014–2023. Geneva: WHO Press; 2013.
[5] Akinjogunla OJ, Egharevba RK, Egharevba HO. Antibacterial activity of local medicinal plants against some selected human pathogenic bacteria. Afr J Biotechnol. 2011;10(63):13812–6.
[6] Edeoga HO, Okwu DE, Mbaebie BO. Phytochemical constituents of some Nigerian medicinal plants. Afr J Biotechnol. 2005;4(7):685–88.
[7] Okwu DE, Ukanwa T. Antimicrobial activity, phytochemical screening and nutrient content of *Euphorbia hirta*. Int J Biol Chem Sci. 2010;4(4):1104–10.
[8] Odugbemi T. Outlines and pictures of medicinal plants from Nigeria. Lagos: University of Lagos Press; 2006.
[9] Ross-Ibarra J, Molina-Cruz A. The ethnobotany of chaya (*Cnidoscolus aconitifolius* ssp. *aconitifolius* Breckon): A nutritious Maya vegetable. Econ Bot. 2002;56(4):350–65.
[10] Akinmoladun FO, Akinrinlola BL, Farombi EO. Nutritional, phytochemical, and antioxidant properties of *Cnidoscolus aconitifolius* leaf extract. J Med Plants Res. 2020;14(4):89–95.
[11] Gomez-Bellot MJ, Gil-Izquierdo A, Seiquer I, Núñez-Delicado E. Chaya (*Cnidoscolus aconitifolius*) as a nutritional and functional leafy vegetable: A review. Food Rev Int. 2019;35(1):1–17.
[12] Oguntona T, Oguntona EB, Adeyemi IA. Nutrient composition and antimicrobial properties of selected underutilized leafy vegetables in Nigeria. Afr J Food Sci. 2021;15(3):89–97.
[13] Abdel-Wahab SM, Gismalla MDA. Phytochemical analysis and antimicrobial activity of some medicinal plants. J Med Plants Res. 2017;11(5):78–85.
[14] Brain KR, Turner TD. The practical evaluation of phytopharmaceuticals. Bristol: Wright-Scientechnica; 1975.
[15] Evans WC. Trease and Evans' pharmacognosy. 14th ed. London: W.B. Saunders; 1996.
[16] Clinical and Laboratory Standards Institute. Performance standards for antimicrobial susceptibility testing. M100, 30th ed. Wayne: CLSI; 2020.
[17] Oyeleke SB, Manga SB. Essentials of microbiology. Minna: Tobest Publishers; 2008.
[18] Okoli CO, Akah PA, Okoli AS, Nwafor SV. Phytochemical and antimicrobial properties of *Euphorbia hirta* leaf extract. J Nat Prod. 2009;2:1–7.
[19] Shittu LA, Bankole MA, Ahmed TK. Antimicrobial activity and phytochemical screening of selected Nigerian medicinal plants. J Ethnopharmacol. 2014;156:1–8.

Corresponding author: Obadahun J.
joshuaobadahun@gmail.com
Department of Science Laboratory Technology, Nigerian Institute of Leather and Science Technology (NILEST), Samaru, Zaria, Kaduna
© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved