

Pharmacological Evaluation of Stem-Bark Extracts of Some Medicinal Plants for Their Antimicrobial and Antioxidant Properties

Maitera, O. N.¹, Shagal, M. H.¹, Fatihat, B.^{1*}, Hadiza, S.¹

¹*Department of Chemistry, Moddibo Adama University Yola, Adamawa State, Nigeria*

Corresponding Author: Fatihat, B., fatihatbashir2016@gmail.com

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This study investigates the phytochemical composition, antimicrobial, and antioxidant activities of ethanolic extracts from ten medicinal plants sourced from Gerei Local Government Area, Adamawa State, Nigeria. Phytochemical screening was conducted using standard qualitative methods, antioxidant activities were assessed via DPPH radical scavenging assay, and antimicrobial activities were evaluated using the disc diffusion method. Phytochemical analysis revealed that alkaloids, steroids, terpenoids, phenols, and flavonoids were prevalent in most plant extracts, while resins, saponins, and other compounds showed variable presence, underscoring the unique phytochemical profiles of each plant. Antimicrobial tests indicated that *Tridax procumbens* exhibited broad-spectrum inhibition against *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*, while *Prosopis africana* was effective against *Candida albicans*, *Pseudomonas aeruginosa*, *Salmonella typhi*, and *Staphylococcus aureus*. In contrast, plants such as *Daniella oliveri*, *Guiera senegalensis*, *Tamarindus indica*, *Detarium microcarpum*, and *Balanites aegyptiaca* showed no antimicrobial activity against the tested microorganisms. Antioxidant assays demonstrated significant dose-dependent activity, with *Daniella oliveri* (93.90%), *Prosopis africana* (93.41%), and *Guiera senegalensis* (90.00%) exhibiting the highest scavenging effects at 50 µL, comparable to ascorbic acid (99.30%). These findings highlight the potent bioactive compounds in these medicinal plants, supporting their traditional use in ethnomedicine due to their significant antimicrobial and antioxidant properties.

Keywords: Antioxidant, Antimicrobial, *Candida albicans*, Medicinal plants, Terpenoids

Introduction

Medicinal plants are used by many tribal people as folk medicine to treat diseases such as diabetes mellitus, rheumatism, abdominal disorders, and inflammation. Some are used for treating insect poisoning. Many compounds have been isolated from medicinal plants, including saponins, flavonoids, terpenoids, essential oils, and phenolic compounds. These compounds are reported to exhibit protective effects due to their chemical properties. In present days, almost all pharmacopoeias in the world prescribe plant drugs of real medicinal value. Countries such as the United Kingdom, Russia, and Germany have separate herbal pharmacopoeias. Yet, in practice, a much higher number of unofficial drugs are used, grounded on the experiences of traditional medicine or new scientific research and experimental results (conventional medicine). Many medicinal plants are applied through self-medication or at the recommendation of a physician or pharmacist. They can be used independently or in combination with synthetic drugs (complementary medicine). For adequate and successful therapy, knowledge of the precise diagnosis of the illness and the pharmacological effect of medicinal plant components is essential. Plant drugs and phytopreparations,

most commonly with defined active components, verified action, and sometimes therapeutic efficiency, are applied as therapeutic means.

Medicinal plants are described as those in which one or more of their organs contain substances that can be used for therapeutic purposes. These may be organized drugs (materials with a cellular structure, e.g., leaf, bark, petal, flower, stem, root) or unorganized drugs (acellular medicinal agents such as gums, balsams, and latex). Such plant materials may be utilized as decoctions in cold or warm water, concoctions, soups, drinks, or infusions, often made by pouring water on specified plant material and allowing the mixture to stand for about fifteen minutes. Human beings have used plants for the treatment of diverse ailments for thousands of years. According to the World Health Organization (2014–2023), most populations still rely on traditional medicines for their psychological and physical health requirements, as they cannot afford Western pharmaceutical products, which also have side effects and limited healthcare facilities. Rural areas of many developing countries, like Nigeria, rely on traditional medicine for primary healthcare needs, finding a place in day-to-day life. These medicines are relatively safer and cheaper than synthetic or modern medicine. People in rural

areas, such as Gerei Local Government Area of Adamawa State, know from personal experience that these traditional remedies are valuable for maintaining human health, though they may not understand the science behind them. Some medicinal plants are highly effective only when used at therapeutic doses. Therefore, the aim of this work is to investigate ten medicinal plant extracts for their antimicrobial and antioxidant properties.

Materials and Methods

Sample Selection, Collection, and Preparation

The selection of plants for studying secondary metabolite constituents or biologically active metabolites may focus on plant materials (*Guiera senegalensis*, *Tamarindus indica*, *Prosopis africana*, *Vitex doniana*, *Balanites aegyptiaca*, *Detarium microcarpum*, *Acacia nilotica*, *Daniella oliveri*, *Piliostigma thonningii*, and *Tridax procumbens*) due to their local use in traditional medicine. In this work, the selection was based on prior studies of these plants.

During collection, it was ensured that the specimens were healthy, as microbial and other infections may alter the metabolites produced. Variations in collection site altitude, plant age, climate, and soil type can influence the concentration and types of secondary metabolites biosynthesized. Stem bark of the ten plants was collected from Gerei Local Government Area of Adamawa State, identified, and authenticated by Dr. Bristone Basiri of the School of Life Sciences, Department of Plant Sciences, Modibbo Adama University, Yola. Details of the plants were recorded and assigned a herbarium number.

The samples were air-dried under shade and pulverized to reduce particle size. This process facilitates the penetration of the carrier solvent into the cellular structure of the plant tissues, thereby enhancing the dissolution of secondary metabolites and increasing extraction yield.

Extraction of Plant Materials

The pulverized plant samples (50 g each) were extracted with 500 mL of ethanol using a Soxhlet apparatus for 6 hours each. The ethanolic extracts obtained were concentrated using a rotary evaporator to yield crude dried extracts. The ethanolic crude extracts were stored at 4°C until further use.

Screening the Extracts for Bioactive Agents (Phytochemical Screening)

Phytochemical screening for the major constituents of the plant extracts was carried out using standard qualitative methods as described below:

Test for Saponins

Exactly 5 mL of the extract was vigorously shaken for 2 minutes with 10 mL of distilled water in a test tube; frothing that persists on warming was taken as evidence for the presence of saponins.

Test for Resins

To 2.5 mL of the plant extracts, 2.5 mL of copper(II) sulphate was added. The solution was shaken vigorously and allowed to separate; a green precipitate indicates the presence of resins.

Test for Flavonoids

Two milliliters (2 mL) of the extracts were heated with 10 mL of ethyl acetate on a water bath and allowed to cool for the layers to separate. A layer of reddish coloration indicates the presence of flavonoids.

Test for Terpenoids

To 0.5 mL of each extract, 2 mL of chloroform and 3 mL of concentrated sulphuric acid were added carefully to form a layer. The presence of terpenoids was indicated by the formation of a reddish-brown coloration at the interface.

Test for Alkaloids

One milliliter (1 mL) of concentrated H₂SO₄ was added to a small quantity of the extract and treated with Wagner's reagent. An orange coloration indicates evidence for the presence of alkaloids.

Test for Essential Oils

A small quantity of the extract was dissolved in 90% alcohol, and a drop of ferric chloride was added. A green coloration indicates the presence of essential oils.

Test for Steroids

Exactly 0.5 mL of the extract was dissolved in 2 mL of chloroform and 2 mL of dilute H₂SO₄. A reddish-brown color at the interface indicates the presence of a steroidal ring.

Test for Phenols

An equal volume of the extract was added to an equal volume of ferric chloride in a test tube; a deep bluish solution indicates the presence of phenols.

Antibacterial Assays

The antibacterial bioassay was performed using the Kirby-Bauer disk diffusion method. Muller-Hinton agar no. CMO337 (Oxoid Ltd, Basingstoke, Hampshire, England) was prepared according to the manufacturer's instructions for culturing bacteria, namely: *Pseudomonas aeruginosa*, *Escherichia coli*, *Salmonella typhi*, and *Staphylococcus aureus*. Normal saline solution was used to dilute fresh 24-hour cultures of bacterial type cultures or clinical isolates to attain a 0.5 McFarland Standard, equivalent to an approximate density of 1×10^8 bacteria. The spread plate method was used to culture 100 μ L of the bacterial suspension introduced into Petri dishes. Eighteen dry sterile discs (6 mm diameter) were soaked in 100 μ L plant extract (made by dissolving 300 mg of each extract in 1000 μ L (1 mL) of DMSO). The discs were air-dried and placed onto the inoculated plates at a distance of 3 mm apart. Discs impregnated with DMSO and air-dried served as negative controls, while a commercially

available disc of chloramphenicol was used as a positive control for bacteria. Incubation was carried out at 37°C for 24 hours. All tests were performed in triplicate. After incubation, bacterial growth inhibition was determined by measuring the diameter of the zone of inhibition in millimeters using a transparent ruler and recorded against the corresponding plant extracts.

Antifungal Assays

To determine the antifungal activities of the plant extracts against the fungal strain (*Candida albicans*), Sabouraud Dextrose Agar no. CM OO4 (Oxoid Ltd, Basingstoke, Hampshire, England) was prepared using the manufacturer's instructions for culturing fungi. Normal saline solution was used to dilute fresh 24-hour cultures of fungal type cultures or clinical isolates to attain a 0.5 McFarland Standard. The spread plate method was used to culture 100 µL of the fungal suspension introduced into Petri dishes. Eighteen dry sterile discs (6 mm diameter) were soaked in 100 µL plant extract (made by dissolving 300 mg of each extract in 1000 µL (1 mL) of DMSO). The discs were air-dried and placed aseptically into the inoculated plates at a distance of 3 mm apart. Discs impregnated with DMSO and air-dried served as negative controls, while commercially available discs of miconazole were used as positive controls. The inocula were incubated at respective conditions: yeast cultures at 37°C for 24 hours and filamentous fungi at 28°C for 48 hours in humid chambers. All tests were performed in triplicate. After incubation, fungal growth inhibition was determined by measuring the diameter of the zone of inhibition in millimeters using a transparent ruler and recorded against the corresponding plant extracts.

Antioxidant Assays

DPPH radical scavenging activity of the plant extracts was determined with some modifications. One milliliter (1 mL) of 0.135 mM DPPH in methanol was prepared and mixed with 1.0 mL of various concentrations (0.2–1.0 µL) of the plant extracts, vitamin C, or BHT. Both vitamin C and BHT were used as standards. The reaction mixture was vortexed thoroughly and left in the dark at room temperature for 30 minutes. The absorbance of the mixture was measured spectrophotometrically at 517 nm. The ability of the plant extract to scavenge DPPH radical was calculated using the equation:

$$\text{DPPH radical scavenging activity} = \frac{\text{Abs control} - \text{Abs sample}}{\text{Abs control}} \times 100$$

where Abs control is the absorbance of DPPH radical + methanol, and Abs sample is the absorbance of DPPH radical + sample extract or standards (Vitamin C and BHT).

Results and Discussion

Percentage Yield of the Extracts for the Ten Medicinal Plants

The crude ethanolic extract of the plant samples gave the percentage yield as shown in Table 1. The percentage yield of crude ethanolic extracts of *Guiera senegalensis* (25.60%), *Tamarindus indica* (31.80%), *Prosopis africana* (40.20%), *Vitex doniana* (39.70%), *Balanites aegyptiaca* (26.40%), *Detarium*

microcarpum (42.00%), *Acacia nilotica* (42.00%), *Daniella oliveri* (39.40%), *Piliostigma thonningii* (37.52%), and *Tridax procumbens* (36.42%). *Detarium microcarpum* and *Acacia nilotica* had the highest crude extract yield of 42.00%, while *Guiera senegalensis* had the lowest yield of 25.60% out of the ten samples. The variation in yields, with *Acacia nilotica* having the highest and *Guiera senegalensis* the lowest, may be attributed to factors such as differences in plant material quality, phytochemical composition, and environmental conditions. Additionally, variations in extraction conditions, plant parts used, and genetic factors can also impact the yield of bioactive compounds from medicinal plants.

Table 1 Percentage yield of ethanolic crude extract of the ten medicinal plants

Plant	Percentage Yield (%)
<i>Guiera senegalensis</i>	25.60
<i>Tamarindus indica</i>	31.80
<i>Prosopis africana</i>	40.20
<i>Vitex doniana</i>	39.70
<i>Balanites aegyptiaca</i>	26.40
<i>Detarium microcarpum</i>	42.00
<i>Acacia nilotica</i>	42.00
<i>Daniella oliveri</i>	39.40
<i>Piliostigma thonningii</i>	37.52
<i>Tridax procumbens</i>	36.42

Phytochemical Screening of the Ten Medicinal Plants

Table 2 shows the results of phytochemical screening of ethanolic extracts of the stem bark of the plants. The results revealed that *Guiera senegalensis*, *Tamarindus indica*, *Prosopis africana*, *Vitex doniana*, *Balanites aegyptiaca*, *Detarium microcarpum*, *Piliostigma thonningii*, *Acacia nilotica*, *Tridax procumbens*, and *Daniella oliveri* contain essential oils. All the plants contain terpenoids except *Balanites aegyptiaca* and *Detarium microcarpum*. Phenols are common in all the plants, especially in those whose stem barks were analyzed. Saponins are present in 5 out of 10 plant samples, while flavonoids are detected in 7 out of the 10 plants. All the plants contain alkaloids except *Vitex doniana*. Steroids are present in 6 out of 10 plants, while resins are present in 5 out of 10 plants. Other researchers have reported that phenolic compounds such as phenolic acids, flavonoids, tannins, quinones, and others exhibit anticarcinogenic and antioxidant activities, whereas saponins are reported to have anti-inflammatory and immune-stimulating properties. Based on these reported medicinal properties of phytochemicals, it is possible to attribute the therapeutic properties of these tested plants to the presence of saponins, terpenoids, flavonoids, alkaloids, essential oils, and phenols.

Antioxidant Activities of the Ten Medicinal Plants

The antioxidant activities of the extracts from ten medicinal plants were investigated using 2,2-diphenyl-1-picrylhydrazyl

Table 2 Phytochemical Analysis of Ethanolic Extracts of the Ten Medicinal Plants

Plant Extract	Res	Sap	Eo	Alk	Ste	Terp	Phe	Flav
<i>G. senegalensis</i>	+	+	+	+	-	+	+	+
<i>T. indica</i>	+	-	+	+	-	+	+	-
<i>P. africana</i>	-	+	+	+	+	+	+	+
<i>V. doniana</i>	-	-	+	-	+	+	+	+
<i>B. aegyptiaca</i>	+	+	+	+	-	+	+	-
<i>D. oliveri</i>	-	-	+	+	+	+	+	+
<i>P. thonningii</i>	+	+	+	+	+	+	+	-
<i>A. nilotica</i>	-	-	+	+	+	+	+	+
<i>T. procumbens</i>	-	-	+	+	+	+	+	+
<i>D. microcarpum</i>	-	+	+	+	-	+	+	-

Key: Res = Resin, Sap = Saponins, Eo = Essential Oil, Alk = Alkaloids, Ste = Steroids, Terp = Terpenoids, Phe = Phenols, Flav = Flavonoids

(DPPH). The free radical scavenging activity of the medicinal plants was measured at varying concentrations (10, 20, 30, 40, and 50 μ L). From the results shown in Table 3, all samples exhibited antioxidant activity, with the ten extracts showing dose-dependent scavenging activity comparable to the standard antioxidant (ascorbic acid). In the DPPH assay, the antioxidant activities of *Guiera senegalensis* ranged from 69.70 to 90.00%, *Tamarindus indica* from 73.50 to 87.70%, *Prosopis africana* from 61.14 to 93.41%, *Balanites aegyptiaca* from 76.00 to 89.50%, *Vitex doniana* from 16.67 to 79.50%, *Acacia nilotica* from 38.82 to 89.10%, *Detarium microcarpum* from 19.37 to 82.50%, *Piliostigma thonningii* from 80.90 to 89.00%, *Tridax procumbens* from 22.34 to 82.63%, and *Daniella oliveri* from 69.21 to 93.90%. The control (ascorbic acid) ranged from 70.70 to 99.30%.

All samples exhibited antioxidant activities with values above 80% at the highest concentration of 50 μ L. The free radical scavenging activity of *Daniella oliveri*, *Prosopis africana*, and *Guiera senegalensis* by the DPPH method exhibited a concentration-dependent response, with the highest concentrations being the most active free radical scavengers (93.90%, 93.41%, and 90.00% inhibition at 50 μ L, respectively). The lowest activity was observed in *Vitex doniana* (79.50% inhibition at 50 μ L). The ascorbic acid standard was the most potent at 99.30%, remarkably active at higher concentrations (50 μ L). Although none surpassed the activity of ascorbic acid, the results suggest significant antioxidant potential. The antioxidant properties of the plants can be attributed to the presence of phenols, flavonoids, tannins, alkaloids, saponins, and terpenoids, which have been associated with high antioxidant activities.

Antimicrobial Activities of the Ten Medicinal Plants

The antimicrobial activities of these plants were investigated using the disc diffusion method against five selected microorganisms. The results in Table 4 show that the selected plants exhibited antibacterial activity with varying inhibition zones. The ethanolic extract of *Tridax procumbens* showed maximum activity against all microorganisms assayed except *Salmonella typhi* and *Candida albicans*. The extract of *Prosopis africana* showed inhibition against all microorganisms except *Escherichia coli*. *Piliostigma thonningii* showed inhibition against *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella typhi*, while *Acacia*

Table 3 Result of Antioxidant Activities using DPPH Method (% Scavenging Property/ μ L)

Plant Extracts	10 μ L	20 μ L	30 μ L	40 μ L	50 μ L
<i>Guiera senegalensis</i>	69.70	72.70	79.00	84.80	90.00
<i>Tamarindus indica</i>	73.50	79.90	87.50	87.60	87.70
<i>Prosopis africana</i>	61.14	91.45	92.13	92.50	93.41
<i>Vitex doniana</i>	16.67	26.70	43.80	49.80	79.50
<i>Balanites aegyptiaca</i>	76.00	86.01	86.80	88.00	89.50
<i>Daniella oliveri</i>	69.21	74.20	75.50	88.10	93.90
<i>Detarium microcarpum</i>	19.37	26.66	30.00	56.67	82.50
<i>Piliostigma thonningii</i>	80.90	82.81	84.80	87.10	89.00
<i>Acacia nilotica</i>	38.82	55.40	66.10	86.45	89.10
<i>Tridax procumbens</i>	22.34	35.50	51.62	70.51	82.63
<i>Ascorbic acid</i>	70.70	83.23	89.33	93.20	99.30

nilotica revealed inhibition against *Escherichia coli* and *Pseudomonas aeruginosa* only. The inhibitory effect of *Vitex doniana* was observed only on *Pseudomonas aeruginosa*. *Daniella oliveri*, *Detarium microcarpum*, and *Balanites aegyptiaca* showed no antimicrobial activity, which may be due to the absence of bioactive components, genetic limitations, or environmental factors. The results of this work may be related to the various active components present in the extracts, which exhibit antibacterial activity either through individual or synergistic actions.

Table 4 Antimicrobial Activities of the Ten Medicinal Plants. Zone of Inhibition (mm)

Plants	<i>E. coli</i>	<i>C. albicans</i>	<i>P. aeruginosa</i>	<i>S. typhi</i>	<i>S. aureus</i>
<i>P. africana</i>	0.0	4.0	6.0	6.0	6.0
<i>D. oliveri</i>	0.0	0.0	0.0	0.0	0.0
<i>D. microcarpum</i>	0.0	0.0	0.0	0.0	0.0
<i>G. senegalensis</i>	0.0	0.0	0.0	0.0	0.0
<i>A. nilotica</i>	2.0	0.0	4.0	0.0	0.0
<i>P. thonningii</i>	2.0	0.0	0.0	2.0	2.0
<i>B. aegyptiaca</i>	0.0	0.0	0.0	0.0	0.0
<i>T. indica</i>	0.0	0.0	0.0	0.0	0.0
<i>T. procumbens</i>	2.0	0.0	4.0	0.0	8.0
<i>V. doniana</i>	0.0	4.0	2.0	4.0	0.0

Conclusion

The study demonstrated that the selected medicinal plants contain a wide range of bioactive compounds, including essential oils, terpenoids, phenols, flavonoids, alkaloids, and saponins, which contribute to their therapeutic potential. The phytochemical analysis confirmed the presence of these compounds, supporting their traditional use in treating various ailments. The antioxidant evaluation using the DPPH assay revealed strong free radical scavenging activity in all plant extracts, with *Daniella oliveri*, *Prosopis africana*, and *Guiera senegalensis* exhibiting the highest antioxidant capacities. This suggests their potential in combating oxidative stress-related diseases. Furthermore, antimicrobial screening indicated that *Tridax procumbens* and *Prosopis africana* had significant inhibitory effects against pathogenic bacteria and fungi, validating their use in traditional medicine for

infections. However, some plants showed limited or no antimicrobial activity, which may be due to variations in bioactive compound concentrations or extraction efficiency. This study provides scientific evidence supporting the ethnomedicinal use of these plants, particularly for their antioxidant and antimicrobial properties.

Conflict of Interest

The authors declare no competing interest.

References

- Abdallah, E. M. (2011). Plants: An alternative source for antimicrobials. *Journal of Applied Pharmaceutical Science*, 1(6), 16–20.
- Adeyemi, F. G., & Onigbanjo, H. O. (2010). Phytochemical and antimicrobial screening of the stem bark extracts of *Pterocarpus erinaceus*. *Nigerian Journal of Basic and Applied Science*, 18(1), 1–5.
- Anita, S., Shakya, V. K., Arya, N., & Saxena, R. C. (2012). Preliminary physico-phytochemical study of the bark of *Acacia nilotica*. *Research Journal of Pharmacy and Biological Chemical Sciences*, 3(2), 84–88.
- Banthorpe, D. V. (1991). Classification of terpenoids and general procedure for their characterization. In *Methods in Plant Biochemistry* (Dey, P. M., & Harborne, J. B., Eds.), Vol. 7. New York: Academic.
- Bergougnot, V., Caissard, J. C., Julien, F., Maguard, J. L., Scalliet, G., Cock, J. M., Hugueney, P., & Baudino, S. (2007). Both the adaxial and abaxial epidermal layer of the rose petal emit volatile scent compounds. *Planta*, 226, 853–866.
- Bii, C., Korir, R. K., Rugutt, J., & Mutai, C. (2010). The potential use of *Prunus africana* for the control, treatment and management of common fungal and bacterial infections. *Journal of Medicinal Plants Research*, 4(11), 995–998.
- Cheng, W., Li, J., You, T., & Hu, C. (2005). Anti-inflammatory and immunomodulatory activities of the extracts from the inflorescence of *Chrysanthemum indicum* Linne. *Journal of Ethnopharmacology*, 101, 334–337.
- Costa, R. M. P. B., Vaz, A. F. M., Oliva, M. L. V., Coelho, L. C. B. B., Correia, M. T. S., & Carneiro-da-Cunha, M. G. (2010). A new mistletoe *Phthirusa pyrifolia* leaf lectin with antimicrobial properties. *Process Biochemistry*, 45, 526–533.
- Cruz, M. C. S., Santos, P. O., Barbosa Jr., A. M., de M'elo, D. L. F. M., Alviano, C. S., Antonioli, A. R., Alviano, D. S., & Trindade, R. C. (2007). Antifungal activity of Brazilian medicinal plants involved in popular treatment of mycoses. *Journal of Ethnopharmacology*, 111, 409–412.
- Dangles, O., Fargeixa, G., & Dufourb, C. (2000). Antioxidant properties of anthocyanins and tannins: A mechanistic investigation with catechin and the 3,4,7-trihydroxyflavylium ion. *Journal of the Chemical Society, Perkin Transactions*, 2, 1653–1663.
- Dubale, S., Kebebe, D., Zeynudin, A., Abdissa, N., & Suleman, S. (2023). Phytochemical screening and antimicrobial activity evaluation of selected medicinal plants in Ethiopia. *Journal of Experimental Pharmacology*, 15, 51–62.
- Emad, M. A., Hsouna, A. B., & Al-Khalifa, K. S. (2012). Antimicrobial, antioxidant and phytochemical investigation of *Balanites aegyptiaca* (L.) Del. edible fruit Sudan. *African Journal of Biotechnology*, 11(52), 11535–11542.
- Farnsworth, N. R., Henry, L. K., Svoboda, G. H., Blomster, R. N., Yates, M. J., & Euler, R. L. (1966). Biological and phytochemical evaluation of plants. I. Biological test procedures and results from 200 accessions. *Lloydia*, 29, 101–122.
- George, F., Zohar, K., Harinder, P. S. M., & Klaus, B. (2002). The biological action of saponins in animal systems. *British Journal of Nutrition*, 88, 587–605.
- Huang, W. Y., Cai, Y. Z., & Zhang, Y. (2010). Natural phenolic compounds from medicinal plants: Potential use for cancer prevention. *Nutrition and Cancer*, 62(1), 1–20.
- Kitonde, K. C., Fidahusein, S. D., Lukhoba, W. C., & Jumba, M. M. (2013). Antimicrobial activity and phytochemical study of *Veronica glabra* (Steetz) Oliv. and Hiern in Kenya. *African Journal of Traditional, Complementary and Alternative Medicines*, 10(1), 000–000.
- Kubmarawa, D., Wase, G. A., & Ayinla, O. G. (2007). Preliminary studies on phytochemical analysis and antimicrobial evaluation of extracts of *Commiphora kerstingii*. *Journal of Chemical Society of Nigeria*, 32(1), 38–40.
- Kubmarawa, D., Akiniyi, J. A., & Okorie, D. A. (2013). Ethnomedicinal survey of traditional medicine of Lala people of Nigeria. *International Journal of Medicinal Plant and Alternative Medicine*, 1(3), 39–57.
- Majhenic, L., Skerget, M., & Knez, Z. (2007). Antioxidant and antimicrobial activity of guarana seed extract. *Food Chemistry*, 104, 1258–1268.
- Manjamalai, A., Jiflin, G. J., & Grace, V. M. (2012). Study on the effect of essential oil of *Wedelia chinensis* (Osbeck) against microbes and inflammation. *Asian Journal of Pharmaceutical and Clinical Research*, 5, 155–163.
- Mann, A., Dattner, A. M., Walters, W., Gonzalez, A., Berg, M., & Müller, D. B. (2023). Phytochemical variability and antimicrobial efficacy in plants: A meta-analysis of ecological and methodological influences. *Frontiers in Microbiology*, 14, 1123456.
- Mariita, R. M., Ogot, C. K. P., Ogue, N. O., & Okemo, P. O. (2010). Antitubercular and phytochemical investigation of methanol extracts of medicinal plants used by the Samburu community in Kenya. *Tropical Journal of Pharmaceutical Research*, 9(4), 379–385.
- Matu, E. N., Kirira, G. P., Kigundu, M. V. E., Moindi, E., & Amugune, B. (2012). Antibacterial activity of organic total extracts of three Kenyan medicinal plants. *African Journal of Pharmacology and Therapeutics*, 1(4), 14–18.
- Nelson, D., & Cox, M. (2005). *Lehninger Principles of Biochemistry* (4th ed.). New York: W.H. Freeman and Company, 1–41.
- Omori, O. E., Calistus, O., Mbugua, K. P., & Okemo, O. P. (2012). Ethnobotanical identification and antimicrobial evaluation of some anti-diarrheal plants used by the Samburu community, Kenya. *Malaysian Journal of Microbiology*, 8(2), 68–74.
- Omwenga, E. O., Okemo, P. O., Mbugua, P. K., & Ogot, C. P. K. (2009). Ethnobotanical survey and antimicrobial evaluation of medicinal plants used by the Samburu community (Kenya) for treatment of diarrhea. *Pharmacognosy Magazine*, 4(18), 169–176.
- Ravi, K. U., Pratibha, D., & Shoeb, A. (2010). Screening of antibacterial activity of six plant essential oils against pathogenic bacterial strains. *Asian Journal of Medicinal Science*, 2(3), 152–158.
- Reenaa, M. (2016). Antimicrobial activity of *Tridax procumbens* against multidrug resistant *Pseudomonas aeruginosa* isolated from burn cases. *Indian Journal of Applied Microbiology*, 19(1), 58–65.

- Rios, J. L., & Recio, M. C. (2005). Medicinal plants and antimicrobial activity. *Journal of Ethnopharmacology*, 100, 80–84.
- Roy, H., Chakraborty, A., Bhanja, S., Nayak, B. S., Mishra, S. R., & Ellaiah, P. (2010). Preliminary phytochemical screening of the bark of *Acacia nilotica*. *Journal of Pharmaceutical Science and Technology*, 2(5), 217–221.
- Runde, M., Kubmarawa, D., & Maina, H. M. (2015). Compositional analysis and antioxidant assessment of essential oil of some aromatic plants obtained from North-Eastern Nigeria. *Research Journal of Chemical Sciences*, 5(10), 7–12.
- Shruti, S., Trivedi, A., Chaudhary, K. B., & Ghadiali, J. K. (2024). Global climate change and its effect on medicinal and aromatic plants. *International Journal of Environment and Climate Change*, 10, 1–12.
- Silva, E. M., Souza, J. N. S., Rogez, H., Rees, J. F., & Larondelle, Y. (2007). Antioxidant activities and polyphenolic contents of fifteen selected plant species from the Amazonian region. *Food Chemistry*, 101, 1012–1018.
- Sofowora, A. (1982). *Medicinal Plants and Traditional Medicine in Africa*. New York: Wiley, 10–13.
- Somanawat, J., Talangsri, N., Deepolngam, S., & Kaewamatawong, R. (2012). Flavonoid and megastigmane glycosides from *Artabotrys hexapetalus* leaves. *Biochemical Systematics and Ecology*, 44, 124–127.
- Sudjaroen, Y., Haubner, R., Wurtele, G., Hull, W. E., Erben, G., & Spiegelhalter, B. (2005). Isolation and structure elucidation of phenolic antioxidants from *Tamarindus indica* L. seeds and pericarp. *Food and Chemical Toxicology*, 43, 1673–1682.
- World Health Organization. (2014–2023). *Traditional Medicine Strategy*. WHO, 1–76.
- Wintola, O. A., & Afolayan, A. J. (2011). Phytochemical constituents and antioxidant activities of the whole leaf extract of *Aloe ferox* Mill. *Pharmacognosy Magazine*, 7, 325–333.