



# Assessment of Antimicrobial Activities of Some Selected Medicinal Plants Used in the Treatment of Skin and Wound Infections in Bauchi Town, Bauchi State Nigeria

Zailani S.B<sup>a</sup>, Shuiabu Y. U.<sup>a</sup>, Adamu M.B.<sup>a\*</sup>, Mudathir, Q.<sup>a</sup>, Zakari N.D.<sup>a</sup>, Lawal A.S<sup>a</sup> and Muhammad L.<sup>a</sup>

<sup>a</sup> Department of Medical Microbiology, Faculty of Basic Clinical sciences, College of Medical Sciences, Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria.

## Authors' contributions

This work was carried out in collaboration among all authors. Author ZSB supervised the research work. Author AMB Researched literature. Author SYS Reviewed and edited the manuscript. Authors MQ, ZND, LAS and ML were involved in gaining ethical approval, participant recruitment and data analysis. All authors contributed to the final version of the manuscript.

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## ABSTRACT

**Aims:** This study aimed to capture the medicinal plants used locally to treat skin and wound infection, and to investigate the antimicrobial activity of the ethanol, ethyl acetate, and aqueous extracts of *Azadiracta indica*, *Mitracarpus hirtus*, *Calotropis procera*, and *Commiphora africana* against bacterial and fungal pathogens causing skin and wound infections.

\*Corresponding author: E-mail: [mabappah@atbu.edu.ng](mailto:mabappah@atbu.edu.ng); [maryambappah045@gmail.com](mailto:maryambappah045@gmail.com);

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**Study Design:** This was a cross-sectional analytical study, conducted in Bauchi town from January to April 2024 at the Department of Medical Microbiology, Abubakar Tafawa Balewa University.

**Methodology:** A semi-structured questionnaire was used to gather information on the use of medicinal plants in treating skin and wound diseases. Twelve leaves extracts from *Azadirachta indica*, *Mitracarpus hirtus*, *Calotropis procera*, and *Commiphora africana* were screened for their antimicrobial activity against four bacterial and one fungal pathogen; *Staphylococcus aureus*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Escherichia coli* and *Trichophyton rubrum* using Agar Disc Diffusion Assay. Minimum Inhibitory Concentrations (MIC) was performed using micro broth dilution assay.

**Results:** A total of 94 respondents used 28 medicinal plants for skin and wound disease management, including leaf paste, infusion, root powder, dried powdered leaves, and oral decoction. The most common plants used were *Azadirachta indica*, *Mitracarpus hirtus*, *Calotropis procera*, and *Commiphora africana*, used to treat eczema, ringworm, skin rashes, and burnt wounds. All of the plant extracts were effective in inhibiting bacterial and fungal growth at variable concentrations, with *Mitracarpus hirtus* being the most effective. *Mitracarpus hirtus* showed the greatest zone of inhibition (ZOI >20 mm) against *Staphylococcus aureus* and *Trichophyton rubrum*, followed by *Calotropis procera*, which had moderate activity on the test isolates with a mean ZOI >11mm. *Azadirachta indica* and *Commiphora africana* exhibited mild to poor action on the majority of the isolates. For each plant extract, the MIC values differed according to the bacterial species. *Mitracarpus hirtus* had the lowest MIC against *Staphylococcus aureus* at 0.325 mg/mL, as did *Calotropis procera* against *Klebsiella pneumoniae*.

**Conclusion:** The study discovered that many medicinal plants had promising antibacterial activities against the tested isolates, but more research is required to identify and purify active components for safe use.

**Keywords:** Antimicrobial activity; skin; wounds; medicinal plant; Bauchi.

## 1. INTRODUCTION

Plants that have therapeutic qualities or have positive pharmacological effects on the human or animal body are referred to as medicinal plants [1]. Medicinal herbs are utilized extensively in traditional societies worldwide and are gaining popularity as natural supplements or substitutes for Orthodox medicine. More than half of all pharmaceuticals used in clinical settings worldwide are made from natural products or their derivatives, with higher plants accounting for at least 25% of the total [2]. Over the ages, medicinal plants have developed into vital components of African civilization, and they are now widely acknowledged as symbols of the continent's rich scientific and cultural legacy [3], and are believed to be the cornerstone of traditional African medicine and other treatments drawn from many global civilizations for a variety of ailments. Almost 80% of people on earth, primarily in developing countries like Africa, still use traditional or herbal medicine to cure illnesses [4].

The skin plays a vital role in protecting the body from the external environment. Damage to skin integrity caused by incisions, burns, scalds, and skin lesions (diabetic foot, venous ulcers,

pressure sores, etc.) is considered a wound. Wound healing is a complicated process, and the effective management of wounds is a major challenge [5]. Natural herbal remedies have now become fundamental for the management of skin disorders due to the side effects of modern medicine and lower price for herbal products [6,7]. The use of medicinal plants for treating various ailments has been a common practice for centuries. In the case of skin and wound infections, Medicinal plants may safely treat such ailments and promote healing [8].

There is a renewed interest in the creation of plant-derived pharmaceuticals. These plant-derived compounds can be found in a variety of plant parts, including roots, leaves, shoots, and bark. Many plants are used as crude extracts, infusions, or plasters for treating common illnesses with little scientific evidence of benefit [9]. Nigeria has various medicinal herbs, and collaborative investigation has demonstrated their usefulness. Plants with antibacterial properties include Guava (*Psidium guajava*), Ginger (*Zingiber officinale*), Neem (*Azadirachta indica*), and Moringa. Studies on Nigerian plants have revealed that they include alkaloids, polyphenols, terpenes, glycosides, and other compounds with potential therapeutic applications

[10]. Herbal medications are used to cure diseases by all segments of the population in Bauchi State. Traditional practitioners sell the herbs in open locations, stores, and at markets. Others drive around with the herbs in their trucks and advertise through loud speakers [11].

Despite the widespread acceptance of the use of plants for treatment by the people of Bauchi state, and the wide availability of medicinal plants, there is still a need to discover, document, and establish vast pharmacopeias to use as medicinal plant guidelines. It is also critical to comprehend local ethnobotanical knowledge and its possible impact on healthcare. The use of medicinal plants in Bauchi town is often based on traditional knowledge and experience, and has been passed down through generations. However, it is important to note that the effectiveness and safety of these remedies may vary, and some may interact with modern medications or have side effects. Therefore, for Safety and efficacy scientific investigation such as In vitro tests can provide initial evidence for the safety and efficacy of plant extracts, informing decisions leading to the development of new antimicrobial agents. *In-vitro* tests may also, provide a controlled environment, minimizing variables and allowing for accurate results.

This study therefore, seeks to address the need for thorough recording of traditional medicinal plants in the treatment of skin and wound infection in the study area and to evaluate the *in-vitro* antimicrobial activity of the selected plants used traditionally.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The study was conducted in Bauchi town, the capital of Bauchi state. The state is one of Nigeria's northeastern states, spanning two distinct vegetation zones: Sudan savannah and Sahel savannah. Bauchi state covers 549,260 km<sup>2</sup> and accounts for 5.3% of Nigeria's total land mass. It is located between latitudes 9° 3' and 12° 3' north of the equator. Longitudinally, the state is located between 8° 50' and 11° east of the Greenwich Meridian [12]. Bauchi State's estimated population in 2015 was 6,275,523 based on the 2006 census, when the population was 4,653,066 and the growth rate was 3.6% [13].

### 2.2 Ethnobotanical Survey

An extensive survey was conducted between January and April of 2024, involving individuals possessing valuable knowledge of local plant uses, herb sellers and alternative medicine practitioners. The questionnaire covered essential demographic information; age, gender and place of residence, the local name of the plant used and related ailments, Assumed Pharmacological Importance, and of administration mode. Participants included both male and female aged 18 to 65, with or without formal education. The plants were recognized using their native names and verified by a botanist using a guide by [14] for their botanical names.

### 2.3 Plant Collection and Identification

Fresh leaves of four plants that were frequently mentioned in the survey were collected after the interview from different parts of Bauchi town. The plants were *Azadirachta indica* (Neem), *Mitracarpus hirtus* (Tropical Girdle pod), *Calotropis procera* (Rooster tree) and *Commiphora africana* (African Myrrh). The plants were identified by a botanist in the department of Biological sciences, Abubakar Tafawa Balewa University, Bauchi. The voucher specimens (ATBU herbarium 2571, 2572, 2573 & 2574) were prepared and deposited at the departmental herbarium.

### 2.4 Sample Preparation

Collected plant materials were air dried and pulverized to a fine powder using an electric blender. Powder of selected plants (400 g) were macerated in 1.5 liter of ethanol, Ethyl acetate and distilled water, this was carried-out in a water bath at 40°C for 4 h to allow liquid adsorption before transferring to an incubator shaker at 40°C for another 24 h. The extract was filtered through a nylon filter and subsequently centrifuged at 3500 rpm (KUBOTA 5100, Japan) for 5 min. The supernatant was filtered under vacuum through a filter paper (Whatman 125 mm GF/C, England). The concentrated extracts was transferred into glass Petri dishes and freeze dried for 3 days [15].

### 2.5 Bacterial Strains

Five Bacterial and one fungal isolates from patients presenting with skin and wound infection attending Bauchi State Specialist Hospital and Abubakar Tafawa balewa University Teaching Hospital, Bauchi were obtained and further

confirmed via standard microbiological techniques. The confirmed organisms were *Staphylococcus aureus*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Escherichia Coli*, and *Trichophyton rubrum*.

## 2.6 Sample preparation and Agar Disc Diffusion Assay

The microbial growth inhibition potential of the plant extracts was determined by using the agar disc diffusion method. Varying concentrations of the crude extracts (200mg/mL, 100mg/mL, 50mg/mL 25mg/mL,) were prepared by weighing 0.20g, 0.10g, 0.50g and 0.025 respectively using an electric metler balance with model No. H30 and then each dissolved in 1mL of diluents called dimethyl sulphoxide (DMSO) under aseptic condition. The sterilized discs were then put into the bottles each containing discs so that each would absorb equal volume [16]. Cultures of different bacterial isolates were grown in nutrient media, Sabouraud Dextrose Agar (Oxoid) was employed in growing fungal isolates. All cultures were cultivated in a shaking incubator at 37°C for 24h overnight prior to use. Bacterial and fungal cultures were adjusted to 0.5 McFarland's standard  $1.5 \times 10^8$  CFU/mL of each organism used in experiments, and were swabbed evenly onto plates containing Mueller Hinton agar and Saboroud Dextrose Agar respectively. The filter paper discs impregnated with the above concentrations of extracts were placed on the surface of the inoculated plates with the aid of sterilized pair of forceps. An amount of 100 $\mu$ L DMSO/disc was served as negative control; ciprofloxacin (5 $\mu$ g) and clotrimazole (10 $\mu$ g) (Source: Oxoid) were placed at the center of the plates to serve as positive controls for bacteria and fungi respectively. A pre – diffusion time of 30 seconds was allowed for the extracts to diffuse from the discs into the agar medium before incubation. The plates were inverted and incubated at 37°C for 24 hours. The degree of sensitivity of the organisms to the extracts was determined by measuring diameter of visible zones of inhibition to the nearest millimeter with respect to each isolate and extract concentration [17].

## 2.7 Minimum Inhibitory Concentration (MIC) Assay

The stock concentration of the plant extracts 10 mg/mL was added in to Mueller Hinton broth

(MHB; Merck, Germany) for bacterial isolates, Sabouraud dextrose broth for *Trichophyton rubrum* and serially diluted two fold in 96 well microtitre plate (Nunc; 300 $\mu$ L total volume per well) to a final volume of 100 $\mu$ L until 0.325mg/mL. Bacterial and fungal suspension (100 $\mu$ L) were adjusted to 0.5 McFarland standards, and added to test solutions and antibiotics controls to a final volume of 200 $\mu$ L well. The negative control comprises only Mueller Hinton broth (MHB; Merck, Germany) and test organism. All tests were performed in triplicate. The MIC was recorded as the lowest concentration that produced no visible growth after 24h incubation at 37°C (NA; Merck, Germany) [18].

## 2.8 Data Analysis

Data analysis was done immediately after the completion of data collection. Data was entered manually from the questionnaires into an excel sheet. The Microsoft Excel software was used to generate frequencies, percentages and averages.

## 3. RESULTS

### 3.1 Ethnobotanical Survey

An ethnobotanical survey conducted in Bauchi town revealed a total number of twenty-eight (28) plants species belonging sixteen (16) families used in the treatment of skin and wound infections. Respondents from various parts of the town disclosed the types of plants they utilized on a particular skin or wound infection. Participants surveyed included both Male 67 (71.2%) and female 27(28.1%) across the ages of 18 to over 50 years old. The vast majority of the surveyed participants fall under the category of herbalist; this is followed by alternative medicine practitioners and then others having varied occupations. The investigation was conducted throughout Bauchi town as such; the study interviewees were from almost all the districts visited (Table 1). The study subjects disclosed that, the ways in which the mentioned plants are being used in treatment include; (Table 2). It was compiled from the survey conducted, that the most frequent plant used in the management of skin and wound infection were *Azadirachta indica*, *Mitracarpus hirtus*, *Calotropis procera* and *Commiphora africa*, and were used to treat eczema, ringworm, skin rashes, burnt wounds etc.

**Table 1. Demographic information of the study participants (n=94)**

| Variables                 | Category                           | Number | Percentage (%) |
|---------------------------|------------------------------------|--------|----------------|
| <b>Age (years)</b>        | 18-30                              | 17     | 18.0           |
|                           | 31-50                              | 32     | 34.1           |
|                           | 50 and above                       | 45     | 47.8           |
| <b>Gender</b>             | Male                               | 67     | 71.2           |
|                           | Female                             | 27     | 28.7           |
| <b>Place of residence</b> | Makama                             | 22     | 23.4           |
|                           | Majidadi                           | 15     | 15.9           |
|                           | Birshi/Miri                        | 21     | 22.3           |
|                           | Turwun                             | 25     | 26.5           |
|                           | Durum                              | 7      | 7.4            |
|                           | Zungur                             | 4      | 4.2            |
| <b>Occupation</b>         | Alternative Medicine practitioners | 15     | 15.9           |
|                           | Herbalist                          | 27     | 28.7           |
|                           | Others                             | 52     | 55.3           |

**Table 2. Ethnobotanical survey of medicinal plants**

| Botanical name                    | Local name   | English name        | Plant part        | Pharmacological Importance        | Administration Mode                                                    |
|-----------------------------------|--------------|---------------------|-------------------|-----------------------------------|------------------------------------------------------------------------|
| <i>Bombax brevicuspe</i>          | Kurya        | Silk-cotton         | Leaves            | Bruises                           | Topically applied as Ointments                                         |
| <i>Zanthoxylum zanthoxyloides</i> | Fasa-kwairi  | Prickly ash         | Bark and root     | Cuts, Abrasions                   | Decoctions and ointments                                               |
| <i>Brachiaria distichophylla</i>  | Gariji       | Brachiaria          | Leaves            | Wound                             | Leaves powder applied topically                                        |
| <i>Cassia occidentalis</i>        | Bauzanfari   | Coffee senna        | Seed/leaves       | Ringworm                          | Infusions applied topically                                            |
| <i>Cymbopogon citrus</i>          | Kififi       | Lemon grass         | Leaves            | Athletes foot, eczema, wound      | Topically applied as Ointments                                         |
| <i>Parkia bigbolosa</i>           | Dorawa       | Locust bean         | Bark              | Skin and wound                    | Powder applied topically                                               |
| <i>Entada Africana</i>            | Tawatsa      | Monkey ladder       | Leaves            | Wound                             | Powder Applied topically                                               |
| <i>Solanum rigrum</i>             | Gautar kaddi | African Nightshade  | Fruit             | Skin eruptions                    | Leaf paste applied topically                                           |
| <i>Curcuma longa</i>              | Kurkur       | Tumeric             | Root              | Eczema                            | Root paste and powder                                                  |
| <i>Azadirachta indica</i>         | Dogon yaro   | Neem                | Root, leaves, oil | Eczema, ringworm                  | Decoctions taken orally, leaf paste or oil is applied to infected area |
| <i>Mitracarpus hirtus,</i>        | Gogamasu     | Tropical girdle pod | Leaves            | Ringworm, eczema                  | Leaves powder or paste is Applied topically.                           |
| <i>Calotropis procera</i>         | Tunfafiya    | Rooster tree        | Leaves            | Skin                              | Leaf paste applied topically                                           |
| <i>Commiphora Africana</i>        | Dashi        | African myrrh       | Leaves            | Burnt wound                       | Leaves powder applied topically                                        |
| <i>Ageratum conyzoides</i>        | Gangarde     | Billy goat weed     | Whole plant       | Wound                             | Applied topically                                                      |
| <i>Tamarindus indica</i>          | Tsamiya      | Tamarind            | Leaves            | Burnt wound                       | Burnt leaves powder applied to infected area.                          |
| <i>Centauriea perrottetii</i>     | Tarzargade   | Artemisia           | Whole plant       | Skin infection                    | Decoctions taken orally                                                |
| <i>Ziziphus spina-christi</i>     | Kurna        | Christ' thorn       | Leaves            | Skin                              | Ointments                                                              |
| <i>Acacia nilotica</i>            | Bagaruwa     | Acasia seed         | Bark, branches    | sores, rashes, boils, and scabies | Infusions applied topically, powder                                    |

| Botanical name                  | Local name   | English name   | Plant part  | Pharmacological Importance | Administration Mode                                  |
|---------------------------------|--------------|----------------|-------------|----------------------------|------------------------------------------------------|
|                                 |              |                | and Pods    |                            | sprinkled in infected area                           |
| <i>Psidium guajava</i>          | Gwaiba       | Guava          | Leaves      | Skin burns                 | Infusions taken orally, leaf paste applied topically |
| <i>Prosopis Africana</i>        | Kiryá        | Iron wood tree | Leaves      | Sores, bruises             | Infusions applied topically                          |
| <i>Terminalia avicennioides</i> | Baushe       | Black Afzelia  | Leaves      | Laceration                 | Powder applied topically                             |
| <i>Aloe barbadensis miller</i>  | Alobera      | Aleo vera      | Gel         | Burns, eczema              | Gel applied topically                                |
| <i>Vernonia amygdalina</i>      | Shuwaka      | Bitter leaf    | Leaves      | Ringworm, eczema           | Leaf paste applied topically                         |
| <i>Bowellia dalzielii</i>       | Árarrábíí    | Bowellia       | Bark        | Sores, wounds and burns    | Infusions taken orally, powder applied topically     |
| <i>Lawsonia inermis</i>         | Lalle        | Henna          | Leaves      | Athletes foot and wound    | Leaf paste applied topically                         |
| <i>Zizipus abyssinica</i>       | Magarya      | Large jujebe   | Leaves/bark | Rashes                     | Powder applied topically                             |
| <i>Cajanus cajans</i>           | Waken turawa | Pigeon pea     | Leaves      | Skin infections            | Leaf paste                                           |
| <i>Combretum aculeatum</i>      | Farar geza   | Red buswillow  | Leaves      | Skin infections            | Decoctions taken orally                              |

Table 3. The list of plant family and number of the species

| Family        | Species                                                                                                                                                                                | Percentages (%) |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Asteraceae    | <i>Ageratum conyzoides</i> , <i>Vernonia amygdalina</i> , <i>Centauria perrottetii</i>                                                                                                 | 10.7            |
| Bombacaceae   | <i>Bombax brevicuspe</i>                                                                                                                                                               | 3.5             |
| Poaceae       | <i>Brachiaria distichophylla</i> , <i>Cymbopogon citrus</i>                                                                                                                            | 7.1             |
| Solanaceae,   | <i>Solanum rigrum</i>                                                                                                                                                                  | 3.5             |
| Maliaceae     | <i>Azadirachta indica</i>                                                                                                                                                              | 3.3             |
| Rutaceae      | <i>Zanthoxylum zanthoxyloides</i>                                                                                                                                                      | 3.5             |
| Asphodalaceae | <i>Aloe barbadensis miller</i>                                                                                                                                                         | 3.5             |
| Myrtaceae     | <i>Psidium guajava</i>                                                                                                                                                                 | 3.5             |
| Lythraceae    | <i>Lawsonia inermis</i>                                                                                                                                                                | 3.5             |
| Rhamnaceae    | <i>Ziziphus spina-christ</i> , <i>Zizipus abyssinica</i>                                                                                                                               | 7.1             |
| Combreteceae  | <i>Combretum aculeatum</i> , <i>Terminalia avicennioides</i>                                                                                                                           | 7.1             |
| Burseraceae   | <i>Commiphora Africana</i> , <i>Bowellia dalzielii</i>                                                                                                                                 | 7.1             |
| Fabaceae      | <i>Cajanus cajans</i> , <i>Prosopis Africana</i> , <i>Acacia nilotica</i> , <i>Parkia biglobosa</i> , <i>Entada Africana</i> , <i>Teramarindus indica</i> , <i>Cassia occidentalis</i> | 25.0            |
| Rubiaceae     | <i>Mitracarpus hirtus</i> ,                                                                                                                                                            | 3.5             |
| Apocynaceae   | <i>Calotropis procera</i>                                                                                                                                                              | 3.5             |
| Zingiberaceae | <i>Curcuma longa</i>                                                                                                                                                                   | 3.5             |

### 3.2 Antimicrobial Activities and Minimum Inhibitory Concentration of the Plants Extracts

The study evaluated the antimicrobial activity of plants extracts against various bacterial and fungal pathogens. The greatest zone of inhibition (ZOI) was recorded from the ethanol extracts of *Mitracarpus hirtus* against *Staphylococcus aureus* and *Trichophyton rubrum* with ZOI>20mm. *Azadirachta indica* showed significant activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa* with ZOI>16mm, while *Calotropis procera* show notable activity against *Klebsiella*

*pneumoniae*, *Staphylococcus aureus*, *Proteus mirabilis* and *Pseudomonas aeruginosa* with ZOI>16mm. *Commiphora africana* showed moderate activity against *Staphylococcus aureus*, *Proteus mirabilis* with ZOI>16mm. The result of Minimum inhibitory concentration performed showed that the growths of the bacterial isolates were inhibited at concentration ranging from 0.326mg/mL to 5mg/mL. The aqueous extract of *Calotropis procera* had the lowest activity against *Staphylococcus aureus*, with a MIC value of 0.325mg/mL, while the ethanol extract of *Mitracarpus hirtus* had the lowest activity, with a MIC value of 0.625mg/mL (Table 6).

**Table 4. Antimicrobial activity of the extracts of *Azadirachta indica* and *Calotropis procera***

| S/N | Extracts                         | Organisms            | Diameter of Zones of Inhibition for different extracts (mm) |          |          |         |         | DMSO |
|-----|----------------------------------|----------------------|-------------------------------------------------------------|----------|----------|---------|---------|------|
|     |                                  |                      | Positive Control                                            | 200mg/mL | 100mg/mL | 50mg/mL | 25mg/mL |      |
| 1.  | <b><i>Azadirachta indica</i></b> |                      |                                                             |          |          |         |         |      |
|     | Ethanol extract                  | <i>S. aureus</i>     | ++++                                                        | ++       | ++       | ++      | +       | -    |
|     |                                  | <i>P. mirabilis</i>  | +++                                                         | -        | -        | -       | -       | -    |
|     |                                  | <i>P. aeruginosa</i> | ++++                                                        | -        | -        | -       | -       | -    |
|     |                                  | <i>k. pneumoniae</i> | ++++                                                        | -        | -        | -       | -       | -    |
|     |                                  | <i>E. coli</i>       | ++++                                                        | -        | -        | -       | -       | -    |
|     | Ethyl acetate extract            | <i>S. aureus</i>     | ++++                                                        | +++      | +++      | ++      | ++      | -    |
|     |                                  | <i>P. mirabilis</i>  | ++++                                                        | +        | -        | -       | -       | -    |
|     |                                  | <i>P. aeruginosa</i> | +++                                                         | -        | -        | -       | -       | -    |
|     |                                  | <i>k. pneumoniae</i> | ++++                                                        | ++       | +        | -       | -       | -    |
|     |                                  | <i>E. coli</i>       | ++++                                                        | ++       | ++       | +       | +       | -    |
|     | Aqueous extract                  | <i>S. aureus</i>     | ++++                                                        | ++       | +        | +       | +       | -    |
|     |                                  | <i>P. mirabilis</i>  | ++++                                                        | -        | -        | -       | -       | -    |
|     |                                  | <i>P. aeruginosa</i> | ++++                                                        | +++      | +        | -       | -       | -    |
|     |                                  | <i>k. pneumoniae</i> | ++++                                                        | +        | +        | +       | -       | -    |
|     |                                  | <i>E. coli</i>       | ++++                                                        | ++       | ++       | +       | -       | -    |
| 2.  | <b><i>Calotropis procera</i></b> |                      |                                                             |          |          |         |         |      |
|     | Ethanol extract                  | <i>S. aureus</i>     | ++++                                                        | ++       | ++       | +       | +       | -    |
|     |                                  | <i>P. mirabilis</i>  | ++++                                                        | ++       | ++       | ++      | +       | -    |
|     |                                  | <i>P. aeruginosa</i> | +++                                                         | ++       | ++       | ++      | +       | -    |
|     |                                  | <i>k. pneumoniae</i> | ++++                                                        | ++       | ++       | +       | +       | -    |
|     |                                  | <i>E. coli</i>       | ++++                                                        | ++       | ++       | +       | +       | -    |
|     | Ethyl acetate extract            | <i>S. aureus</i>     | ++++                                                        | +++      | ++       | ++      | -       | -    |
|     |                                  | <i>P. mirabilis</i>  | ++++                                                        | +++      | ++       | ++      | +       | -    |
|     |                                  | <i>P. aeruginosa</i> | ++++                                                        | +++      | +++      | ++      | +       | -    |
|     |                                  | <i>k. pneumoniae</i> | ++++                                                        | +++      | ++       | ++      | +       | -    |
|     |                                  | <i>E. coli</i>       | ++++                                                        | ++       | ++       | +       | +       | -    |
|     | Aqueous extract                  | <i>S. aureus</i>     | +++                                                         | ++       | +        | +       | -       | -    |
|     |                                  | <i>P. mirabilis</i>  | +++                                                         | ++       | +        | +       | +       | -    |
|     |                                  | <i>P. aeruginosa</i> | ++++                                                        | +++      | +        | +       | -       | -    |
|     |                                  | <i>k. pneumoniae</i> | ++++                                                        | +++      | ++       | ++      | -       | -    |
|     |                                  | <i>E. coli</i>       | +++                                                         | ++       | ++       | +       | -       | -    |

**Table 5. Antimicrobial Activity of the extracts of *Commiphora africana* and *Mitracarpus hirtus***

| S/N              | Extracts                                      | Organisms               | Diameter of Zones of Inhibition for different extracts (mm) |          |          |         |         |      |
|------------------|-----------------------------------------------|-------------------------|-------------------------------------------------------------|----------|----------|---------|---------|------|
|                  |                                               |                         | Positive Control                                            | 200mg/mL | 100mg/mL | 50mg/mL | 25mg/mL | DMSO |
| 3.               | <i>Commiphora Africana</i><br>Ethanol extract | <i>S. aureus</i>        | ++++                                                        | ++       | +        | +       | -       | -    |
|                  |                                               | <i>P. mirabilis</i>     | +++                                                         | -        | -        | -       | -       | -    |
|                  |                                               | <i>P. aeruginosa</i>    | +++                                                         | -        | -        | -       | -       | -    |
|                  |                                               | <i>E. coli</i>          | +++                                                         | -        | -        | -       | -       | -    |
|                  |                                               | <i>T. rubrum</i>        | ++                                                          | +        | +        | -       | -       | -    |
|                  | Ethyl Acetate extract                         | <i>S. aureus</i>        | ++++                                                        | +++      | ++       | ++      | +       | -    |
|                  |                                               | <i>P. mirabilis</i>     | ++++                                                        | +++      | ++       | ++      | -       | -    |
|                  |                                               | <i>P. aeruginosa</i>    | +++                                                         | ++       | ++       | +       | +       | -    |
|                  |                                               | <i>E. coli</i>          | +++                                                         | +        | +        | -       | -       | -    |
|                  |                                               | <i>T. rubrum</i>        | ++                                                          | ++       | ++       | +       | +       | -    |
|                  | Aqueous extract                               | <i>S. aureus</i>        | ++++                                                        | +        | -        | -       | -       | -    |
|                  |                                               | <i>P. mirabilis</i>     | ++++                                                        | -        | -        | -       | -       | -    |
|                  |                                               | <i>P. aeruginosa</i>    | ++                                                          | -        | -        | -       | -       | -    |
|                  |                                               | <i>E. coli</i>          | ++++                                                        | ++       | ++       | -       | -       | -    |
| <i>T. rubrum</i> |                                               | ++                      | -                                                           | -        | -        | -       | -       |      |
| 4.               | <i>Mitracarpus hirtus</i><br>Ethanol extract  | <i>S. aureus</i>        | ++++                                                        | ++++     | +++      | ++      | ++      | -    |
|                  |                                               | <i>P. mirabilis</i>     | ++++                                                        | +++      | ++       | ++      | +       | -    |
|                  |                                               | <i>P. aeruginosa</i>    | +++                                                         | +++      | ++       | +       | +       | -    |
|                  |                                               | <i>E. coli</i>          | ++++                                                        | +++      | ++       | ++      | +       | -    |
|                  |                                               | <i>Trichophyton spp</i> | ++                                                          | ++++     | ++       | ++      | +       | -    |
|                  | Ethyl acetate extract                         | <i>S. aureus</i>        | +++                                                         | ++       | +        | -       | -       | -    |
|                  |                                               | <i>P. mirabilis</i>     | ++++                                                        | ++       | +        | +       | -       | -    |
|                  |                                               | <i>P. aeruginosa</i>    | +++                                                         | +        | +        | -       | -       | -    |
|                  |                                               | <i>E. coli</i>          | ++++                                                        | +++      | ++       | ++      | ++      | -    |
|                  |                                               | <i>T. rubrum</i>        | +++                                                         | +++      | ++       | ++      | +       | -    |
|                  | Aqueous extract                               | <i>S. aureus</i>        | ++++                                                        | ++       | +        | -       | -       | -    |
|                  |                                               | <i>P. mirabilis</i>     | ++++                                                        | +        | +        | -       | -       | -    |
|                  |                                               | <i>P. aeruginosa</i>    | +++                                                         | +        | -        | -       | -       | -    |
|                  |                                               | <i>E. coli</i>          | +++                                                         | ++       | +        | +       | +       | -    |
| <i>T. rubrum</i> |                                               | ++                      | -                                                           | -        | -        | -       | -       |      |

Keys:(-) inactive

(+) Inhibition diameter between 7-10mm

(++) Inhibition diameter between 11-15mm

(+++) Inhibition diameter between 16-20mm

(++++) Inhibition diameter higher than 20mm



Table 6. Minimum inhibitory concentration

| Organisms                     | <i>Azadirachta indica</i><br>mg/mL |               |         | <i>Mitracarpus hirtus</i><br>mg/mL |               |         | <i>Calotropis procera</i><br>mg/mL |               |         | <i>Commiphora africana</i><br>mg/mL |               |         |
|-------------------------------|------------------------------------|---------------|---------|------------------------------------|---------------|---------|------------------------------------|---------------|---------|-------------------------------------|---------------|---------|
|                               | Ethanol                            | Ethyl acetate | Aqueous | Ethanol                            | Ethyl acetate | Aqueous | Ethanol                            | Ethyl acetate | Aqueous | Ethanol                             | Ethyl acetate | Aqueous |
| <i>Staphylococcus aureus</i>  | 1.25                               | 0.625         | 1.25    | 0.325                              | 2.5           | 2.5     | 1.25                               | 1.25          | 1.25    | 1.25                                | 0.625         | 2.5     |
| <i>Escherichia Coli</i>       | 2.5                                | 2.5           | 5       | 1.25                               | 0.625         | 1.25    | 1.25                               | 0.625         | 1.25    | 2.5                                 | 2.5           | 1.25    |
| <i>P. mirabilis</i>           | 5                                  | 5             | 2.5     | 1.25                               | 1.25          | 2.5     | 0.625                              | 0.625         | 0.625   | 2.5                                 | 1.25          | 5       |
| <i>Pseudomonas aeruginosa</i> | 5                                  | 2.5           | 5       | 1.25                               | 2.5           | 5       | 0.625                              | 0.625         | 1.25    | 5                                   | 1.25          | 5       |
| <i>Klebsiella pneumoniae</i>  | 5                                  | 2.5           | 5       | -                                  | -             | -       | 1.25                               | 0.625         | 0.325   | -                                   | -             | -       |
| <i>Trichophyton rubrum</i>    | -                                  | -             | -       | 1.25                               | 0.625         | 5       | -                                  | -             | -       | 1.25                                | 0.625         | 5       |

#### 4. DISCUSSION

This study has strived to assess the knowledge and practice of indigenous people of Bauchi town on medicinal plants used traditionally to treat skin and wound infections. Bauchi town, located in Northeastern part of Nigeria, has a tropical savanna climate and a flat to gently sloping topography, which significantly influences the use of medicinal plants in treating skin and wound infections [19]. High temperatures and low humidity during the dry season (November to April) lead to dry skin conditions, increased risk of wound infections, and prolonged healing times [20]. The wet season (May to October) brings heavy rainfall that can harbor bacteria virus and fungi, leading to skin infection or even exacerbate skin conditions such as leptospirosis which can cause skin lesions and rashes [21]. The ethnobotanical survey carried-out in Bauchi town (Table 2), disclosed that quiet a number of people utilized medicinal plants. In the survey, systematic random sampling was used in the selection of participants, and a total of ninety-four respondents interviewed all provided useful information on the medicinal plants utilized to treat skin and wound infection. The surveyed participants comprise of both male and female, however, male gender make up two-third f the respondents. This may not be unconnected with the fact that Male had more knowledge of using traditional medicines, and are found in the occupation of alternative medicines than females as reported by [22,23,24].

The age group 50 and above constituted a greater percentage of the study subject. Knowledge on traditional medicines is passed down from generation to generations with older people learning more from their parents and grandparents more than the younger individuals. Likewise, older people may feel a strong sense of responsibility to preserve cultural traditions and knowledge. This is in consistent with the findings of [25,26,27], that reported older people possessing more knowledge on traditional medicines. However, is in contrast with the findings of [28,29,30], who reported younger people aged 18-35 years use herbal medicines to treat and prevent skin illness more frequently than older groups. This study indicates that majority of the respondents are herbalist, followed by Alternative medicines practitioners and then peoples from other professions. Bauchi town is known for its rich cultural heritage and diverse population and this may constitute to the widespread use of medicinal plants across

different demographics. Furthermore, some individuals may be unaware of modern treatment options or prefer traditional methods due to cultural beliefs. In addition, medicinal plants are often readily available and affordable, making them a more accessible option for people from different socioeconomic background.

In terms of the medicinal plants utilize to treat skin and wound infection, a total of twenty-eight (28) plants belonging to sixteen (16) families were mentioned. One-fourth of the depicted plants in this study belonged to the family Fabaceae, also known as the legume family which plays a significant role in treating skin and wound infections. Several species within this family have been traditionally used in folk medicine for their antimicrobial, anti-inflammatory, and wound-healing properties [31]. Fabaceae species like *Acacia nilotica*, *Albizia lebeck*, and *Dalbergia sissoo* have shown significant antibacterial activity against various bacterial strains, making them effective in treating bacterial skin infections [32]. Legumes like *Vicia faba*, *Pisum sativum*, and *Cicer arietinum* have been traditionally used to treat wounds, cuts, and abrasions. They promote collagen synthesis, improve tissue strength, and enhance the healing process [33]. The leaves (67.8%) recorded the most typically used plant portion, followed by the bark (17.8%) and root (10.7%). The most common way of using medicinal plants involves the use of leaf paste, whereby fresh leaves are harvested, rinsed with clean water, and then turned into paste with the aid of a mortar and pestle prior to application to the affected skin part. It also involves the preparation of infusions and decoctions by steeping herbs in cold water to make teas or boiling them to make concentrated liquid from the plants. These infusions and decoctions are applied topically or taken orally. The use of root, bark, leaves, or whole powder and then sprinkled onto wounds are some of the cited ways medicinal plants treat skin and wound infections in Bauchi town.

*In-vitro* tests provide a preliminary screening of plant extracts for antimicrobial activity, helping to identify potential candidates for further research [34]. The results of the *in-vitro* antimicrobial activity of the plants extracts against bacterial and fungal pathogens; *Staphylococcus aureus*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Escherichia Coli*, and *Trichophyton rubrum*, displayed varying effects of the extracts against the isolates (Table 3).

*Azadirachta indica* showed significant activity on *Staphylococcus aureus* with Zone of Inhibition (ZOI) > than 16mm, it produces moderate activity on *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* and *Escherichia Coli* with ZOI extending slightly above 10mm and displayed least activity on *Proteus mirabilis* with the only one recorded ZOI of >10mm. *Calotropis procera* showed notable activity against the tested isolates with ZOI ranging from 11mm-20mm at various concentrations. In addition to this, aqueous extract of *Calotropis procera* produces highest activity on *Klebsiella pneumoniae* with ZOI >20mm. *Commiphora africana* displayed moderate activity on the test isolates, highest ZOI of >16mm was recorded on *Staphylococcus aureus* and *Proteus mirabilis*. The ethanol extract of *Mitracarpus hirtus* exhibited the highest activity against *Staphylococcus aureus* and *Trichophyton rubrum*, with ZOI value >20mm at 400mg/mL. Moreover, the plants exhibited moderate activity on the other isolates with ZOI >11mm.

The MIC assay was used to determine the efficiency of the extracts in inhibiting the growth of the tested bacteria. Plant extracts with great activity against a certain organism usually produce low MIC value, whereas extracts with low activity yield high MIC value [35]. The Ethyl acetate extract of *Azadirachta indica* recorded the lowest activity against *Staphylococcus aureus* with MIC value of 0.625mg/mL, while the ethanol extract of *Mitracarpus hirtus* showed the lowest activity against *Staphylococcus aureus*, with an MIC value 0.325mg/mL. The Aqueous extract of *Calotropis procera* showed notable activity against *Klebsiella pneumoniae*, with an MIC value of 0.325mg/mL. The ethyl acetate extract of *Commiphora africana* displayed significant activity against *Staphylococcus aureus* and an MIC value of 0.625mg/mL. Against fungal isolates, the Ethyl acetate extract of *Mitracarpus hirtus* and *Commiphora africana* showed significant activity against *Trichophyton rubrum*, with an MIC value of 0.625 mg/mL, more so, the ethanol extracts of *Mitracarpus hirtus* showed notable against the fungal isolates with MIC value of 1.25mg/mL.

Our findings are in agreements with other studies conducted globally on the above chosen medicinal plants for their *in-vitro* antimicrobial activities. *Azadirachta indica* showed moderate activity on *Staphylococcus aureus* and *Pseudomonas aeruginosa* (12mm) at the same concentration of 400mg/mL [36]. The aqueous extract of *Mitracarpus* specie showed a minimum inhibitory concentration (MIC) of 0.01 mg/mL

against *Staphylococcus aureus* and *Escherichia coli* [37]. Amini et al. [38] reported *Staphylococcus aureus* and *Trichophyton rubrum* to be susceptible to the extracts of *Calotropis procera* with ZOI of 16-18mm, and 19.60±0.2mm ZOI was recorded against *Pseudomonas aeruginosa* as documented by [39]. *In-vitro* antimicrobial activity of *Commiphora africana* has been reported by Omer et al. [40] and Idris et al. [41] and has shown notable activity against *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Trichophyton rubrum* with ZOI >20mm.

The presence of numerous bioactive chemical components in the extracts may explain the active plants' antibacterial properties. According to Savoia [42], plant extracts may contain Efflux Pump inhibitors in their composition. According to Shankar et al. [43], suppressing normal cell communication through quorum sensing (QS) is a promising way of action for plant-based bioactive compounds against multidrug resistant infections. Studies have reported the antimicrobial effects of the above investigated medicinal plants; *Mitracarpus hirtus* extracts have shown significant antibacterial and antifungal activity against various microorganisms, including *Staphylococcus aureus*, *Escherichia Coli*, and *Candida albicans*, which are common causes of skin and wound infections [44]. The plant's extracts have been reported to enhance wound contraction, increase collagen synthesis, and promote tissue regeneration, leading to faster wound closure and improved skin integrity [45]. *Calotropis procera* contains compounds like calotropin, calactin, and uscharin, which have been shown to exhibit antibacterial, antifungal, and antiviral activities against various microorganisms, making it effective against skin and wound infections [46]. *Commiphora africana* contains compounds like furanoeudesma-1,3-diene, which have been shown to exhibit antibacterial and antifungal activities against various microorganisms, making it effective against skin and wound infections [47]. Active compounds from *Azadirachta indica* such as nimbidin and nimbin has long been known to have therapeutic effects, and helped to inhibit the growth of bacteria like *Staphylococcus aureus* and *Streptococcus pyogenes*, as well as fungi like *Candida albicans* [48,7].

Understanding the role of these microorganisms in skin and wound infections is crucial for proper diagnosis, treatment, and prevention [49]. The microorganism investigated in this research has

been identified as some of the troublesome agents of skin and wound infection. For instances, *Trichophyton rubrum* is a fungus that causes superficial skin infections, particularly: athlete's foot (*Tinea pedis*), jock itch (*Tinea cruris*), ringworm (*Tinea corporis*), infects the keratinized layers of the skin, nails, and hair leading to inflammation, itching, and scaling [50]. *Staphylococcus aureus* is a common cause of skin and wound infections, including abscesses, cellulitis, and can produce toxins that damage skin tissue and impede wound healing [51]. *Escherichia coli* is typically found in the gastrointestinal tract, but can cause skin and wound infections, especially in people with compromised immune systems and can lead to cellulitis, abscesses, and wound necrosis [52]. *Pseudomonas aeruginosa* is frequently found in chronic wounds, such as diabetic foot ulcers and burn wounds produces biofilms that make it resistant to antibiotics and impede wound healing [53]. In addition, *Proteus mirabilis* is a gram-negative bacterium commonly found in the gastrointestinal tract but can cause a range of infections, including Urinary tract infections (UTIs), Wound, Burn and Surgical site infections [54]. These microorganisms can cause skin and wound infections through various mechanisms, including: direct invasion of skin tissue [49], Production of toxins and enzymes that damage skin and impede wound healing [55], biofilm formation, which protects them from antibiotics [56], and the host's immune system and colonization of wounds, leading to chronic infection and delayed healing [57].

## 5. CONCLUSION

The study showed the utilization of medicinal plants in the management of skin and wound infection in Bauchi town. The use of medicinal plants in treating various illnesses is a deeply rooted cultural practice that dates back centuries in the study area. Preliminary *in-vitro* antimicrobial activity demonstrates the potential of *Azadirachta indica*, *Mitracarpus hirtus*, *Calotropis procera* and *Commiphora africana* as a natural antimicrobial agent, which could be used to develop new treatments for various infections and diseases. While Ethnobotanical survey had revealed so many medicinal plants to have been traditionally used to treat skin and wound infections, the effectiveness and safety should be further evaluated through scientific studies to ensure efficacy and safety for modern medical use.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

## CONSENT AND ETHICAL APPROVAL

Approval to conduct this study was granted by Bauchi state Ministry of Health. The Ethical clearance has a health research ethical review committee approval number NERC/040/11/19B/2021/0105. Prior participation, all participants were informed about the aims and objectives of the study, their freedom of participation, and the anonymity of their participation. Only those individuals that gave informed consent to partake in the study were recruited. The data obtained was handled with the utmost confidentiality.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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