

# The Journal of Phytopharmacology

(Pharmacognosy and phytomedicine Research)

## Review Article

ISSN 2320-480X

JPHYTO 2021; 10(1): 26-34

January- February

Received: 30-11-2020

Accepted: 15-01-2021

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doi: 10.31254/phyto.2021.10107

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## Nigerian Medicinal Plants with Potential Antibacterial Property: A Review

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### ABSTRACT

Medicinal plants have been used in traditional medicine for the treatment of infectious diseases. Several scientific studies were conducted on different medicinal plants to investigate their antibacterial potentials. This review article aimed to summarize and document the antibacterial screening conducted on some Nigerian medicinal plants against various bacterial isolates in an attempt to stimulate further research to discover novel antibacterial agents. We provide specific information about the parts of the plants evaluated, the type of extracts and/fractions, and the tested bacterial strains. The findings documented in this review shows that these medicinal plants possess antibacterial potential based on their reported traditional uses. Also, the information documented in this article could serve as a basis for further microbiological and pharmacological research to discover new antibacterial agents.

**Keywords:** Antibacterial agents; Antibacterial activity; Medicinal plants; Nigerian traditional medicine.

### INTRODUCTION

Microbial infections such as acute lower respiratory tract infections, diarrhoeal diseases and tuberculosis are part of the top ten reasons of mortality and morbidity globally [1]. These infectious diseases cause about 50% of all mortalities in developing countries due to inadequate environmental sanitation, poor hygiene and overcrowding that have all been related to the spread of bacterial infections [2]. There has been increase in bacterial resistance to antibiotics that causes increased therapeutic failure in treating bacterial infections [3]. In addition, there is increased need of antimicrobial agents that are efficacious, available and safe [4].

Medicinal plants contain abundant molecules that can serve as alternative source of antimicrobial agents [4]. In Nigeria and other African countries, herbal medicines have been used for the treatment of bacterial infections. Therefore, antibacterial drugs can be sourced through the appropriate utilization of traditional medicines, evaluation for bioactive compounds from plant extracts [5] and search for plant extracts and fractions with more antibacterial properties. Many medicinal plants used in traditional medicine for the treatments of infectious diseases in Nigeria and other African countries have been scientifically investigated. Therefore, we conducted a review of the literature to summarize and provide information related to antibacterial potentials of some of the medicinal plants in an attempt to enhance further research for the development of novel antibacterial agents.

### *Bidens pilosa*

The plant *Bidens pilosa* belongs to the family Asteraceae which is widely available in the subtropical and tropical countries [6]. It has been used in traditional medicine as anti-inflammatory, antiseptic, liver-protective, antihypertensive, anti-diabetic agent [7] and anti-infective agents [8].

Ajanaku *et al.*, (2018) [6] reported the antibacterial action of the methanol, ethyl-acetate and hexane leaf extract of *B. pilosa* against *B. subtilis*, *E. coli*, *K. pneumonia* and *P. aeruginosa*. In the same study, the hexane/methanol fraction showed activity against drug susceptible and resistant *Mycobacterium tuberculosis*. Owoyemi *et al.*, (2017) reported the antibacterial activity of the ethanol, aqueous and chloroform leaf extract of *B. pilosa* against *S. aureus*, *S. pyogenes*, *B. subtilis*, *P. aeruginosa*, *E. coli*, and *K. Pneumoniae* [8].

The dichloromethane and hexaneleaves extract of *B. pilosa* demonstrated effective antibacterial activity against *Salmonella typhimurium*, *Shigella boydii*, *Vibrio parahaemolyticus*, *E. coli* and *K. pneumonia* [9]. Rabe and van Staden, (1997) reported the antibacterial activity of the methanol leaves extract of the plant against *S. aureus*, *S. epidermis* and *B. Subtilis* [10]. The aqueous leaf extract of *B. pilosa* demonstrated remarkable antibacterial activity against *S. aureus*, *E. coli*, *P. aeruginosa*, *Shigella spp*, *S. arizonae*, *S. choleraesuis*, *S. enteriditis*, *S. typhi*, *S. paratyphi* and *S. Typimurium* [11].

Nakibuule *et al.*, (2019) reported the antibacterial activity of the flavonoids leaves fraction of *B. pilosa* against methicillin resistant *S. Aureus* (MRSA), *P. aeruginosa*, methicillin resistant *S. epidermidis* and *S. Pneumoniae* [12]. In another study by Ukwubile *et al.*, (2014), the methanol leaves extract of *B. Pilosa* demonstrated effective antibacterial activity against *Bacillus subtilis*, *S. typhi*, *S. aureus*, *E. coli*, and *K. Pneumoniae* [13].

#### ***Mallotus oppositifolius***

The plant *Mallotus oppositifolius* is a shrub that belongs to the family Euphorbiaceae which is widely available in tropical African forests and savannas [14]. The leaves of *M. oppositifolius* have been used for the management of infectious diseases [15].

Gbedema *et al.*, (2010) reported the antibacterial activity of the methanol leaves extract of *M. oppositifolius* against *S. aureus*, *B. subtilis*, *P. aeruginosa*, *E. coli* and *S. typhi* [15]. In addition, the extract significantly potentiated the antibacterial activity of amoxicillin against *S. aureus* and *B. subtilis*. The ethanol (root and leaves) extracts of *M. Oppositifolius* produced inhibitory effect against *B. subtilis*, *S. aureus*, *M. luteus*, *K. pneumoniae* and *E. coli* [2].

#### ***Morinda lucida***

*Morinda lucida* belongs to the family Rubiaceae [16]. It is a tree of medium-size about 18-25 m tall which is widely distributed in the tropical West Africa. It is commonly known as the Nfia (Igbo) in Nigeria [17].

Prevost Kouame *et al.*, (2018) reported the antibacterial activity of the essential oil of *M. lucida* against *S. aureus*, *E. coli* and *P. Aeruginosa* [18]. The ethanol and aqueous leaf extract of *M. lucida* demonstrated effective inhibitory effects against *P. Aeruginosa*, *S. aureus*, *S. typhi*, *K. pneumoniae*, *E. coli*, *B. subtilis* and *Flavobacterium sp* [19, 20].

Udeani *et al.*, (2019) reported the inhibitory effect of the methanol leaves extract of *M. lucida* against *S. aureus*. In the same study, the extract reduced the MRSA-induced spleen damage and demonstrated immune boosting effect which are associated with its *in vivo* antibacterial activity [21].

#### ***Cochlospermum tinctorium***

*Cochlospermum tinctorium* is a sub-shrub of approximately 80 cm in length that possesses woody subterranean root and stock which produces its shoots every year. The plant is widely distributed throughout the West African countries including Nigeria [22]. It is locally known as *Oja Ikoko* or *Sewutu* in Yoruba, *Obazi* or *Abanzi* in Igbo and *Rawaya* or *Kyamba* in Hausa languages of Nigeria [22]. The plant has been used in traditional medicine for the management of bronchial infections [22], gonorrhoea, syphilis, leprosy [23], measles [24], pneumonia [25] and other infectious diseases [26].

Tijjani *et al.*, (2009) reported the antibacterial activity of the methanol root extract of *C. tinctorium* against *S. aureus*, *C. ulcerans*, *K. pneumonia*, *E.coli*, *Proteus mirabilis*, *L. Monocytogene* and *Shigelia dysenteriae* [27, 28]. Also, the hydromethanolic leaf extract of the plant at 200 mg/ml elicited concentration-dependent inhibitory effect against *S. typhi*, *B. subtilis*, *P. aeruginosa*, *S. aureus*, and *E. coli* [29]. Muhammad *et al.*, (2020) reported the antibacterial activities of the methanol root extract of *C. tinctorium* and its fractions (n-hexane, ethyl acetate and

aqueous) against *P. aeruginosa*, *E. coli*, *P. specie*, *S. aureus* and *K. Pneumoniae* [30].

#### ***Olax subscorpioidea***

The plant *Olax subscorpioidea* is a shrub that belongs to the family Olacaceae. It is widely available in Nigeria other tropical African countries [31]. The plant is locally called in Hausa as *Gwaanon kummii* or *Gwaanon raafii*, in Igbo as *Igbulu*, *Atu-ogili* or *Osaja*, in Edo as *Ukpakon* and in Igala as *Ocheja* [32]. The plant has been used in traditional medicine against gonorrhoea [33], infectious diseases [34], syphilis [35], typhoid [36], and venereal diseases [37].

The aqueous, methanol and ethanol stem bark extract of *O. subscorpioidea* exerted antibacterial activity against *S. aureus*, *E. coli*, *P. aeruginosa*, *P. vulgaris* and *Salmonella* [31, 38]. Fankam *et al.*, (2011) reported the inhibitory effect of the methanol fruit extract of *O. subscorpioidea* against *E. coli*, *E. aerogenes*, *K. pneumoniae* and *P. Stuarti* [39]. Similarly, the ethanol leaves extract of *O. subscorpioidea* produced remarkable inhibitory activity against *E. coli*, *S. aureus*, *P. aeruginosa*, *K. pneumoniae* and *P. Mirabilis* [35].

#### ***Anacardium occidentale***

*Anacardium occidentale* belongs to the family of Anacardiaceae. An infusion of the stem bark and leaves of the plant is used as a remedy for tooth ache and sore gums while the astringent bark is given for severe diarrhoea and thrush [40].

Ayepola and Ishola, (2009) reported the antibacterial activity of leaf (aqueous and methanol) and methanol stem bark extracts of *Anacardium occidentale* against *Klebsiella pneumonia*, *Bacillus subtilis* [41]. The leaf and bark extracts of *Anacardium occidentale* showed antibacterial activity of *Anacardium occidentale* against *E. coli*, *Proteus vulgaris*, *P.aeruginosa*, *S. aureus*, *Enterococcus faecalis* and *Salmonella typhi* [42, 43].

#### ***Allium sativum***

*Allium sativum* (garlic) belongs to the family Liliaceae and genus Allium. It is a hardy perennial herb with narrow leaves. It is a bulb-like root consisting of several bulbis (cloves) and the bulb is milk-fish in color. It has a strong smelling, powerful arid penetrating odor. The plant is widely available in India, China, Asia, Southern Europe, North America and Northern part of Nigeria [44].

Yahaya *et al*, (2017) reported the antibacterial activity of ethanol and aqueous extracts of *Allium sativum* against *S. Aureus* and *E. coli* in a concentration dependent manner [45]. In another study by Airaodion *et al*, (2020), the bulb of *A. sativum* demonstrated antibacterial activity against *Coliform bacillus*, *Staphylococcal epidermis*, *E. coli*, and *Salmonella typhi* [46].

#### ***Citrus sinensis***

The plant *Citrus sinensis* (orange) belongs to the family Rutaceae. It is a small evergreen tree ranging 7.5 to 15m in high. The plant is grown commercially worldwide in tropics, semi tropical and some warm temperate regions and has become the most widely planted tree fruit in the world today [47].

Based on the study conducted by Abalaka *et al*, (2016), the aqueous, ethanolic and ethyl-acetate extracts of *Citrus sinensis* elicited antibacterial effects against *E. coli*, *K. pneumoniae* and *P. Aeruginosa*

[48]. Nata'ala *et al.*, (2018) reported the antibacterial activity of the aqueous and ethanol stem bark extract of *C. sinensis* against *K. pneumonia*, *S. aureus*, *Proteus mirabilis* and *P. Aeruginosa* [49]. In another study by Baba *et al.*, (2018), the juice, ethanol and aqueous peel extracts of *Citrus sinensis* showed effective antibacterial activity against *S. aureus*, *E. coli* and *P. Aeruginosa* [50].

### ***Carica papaya***

The plant *Carica papaya* belongs to the family Caricaceae. It is commonly called pawpaw (English), Ibebe (Yoruba-Nigeria) or Okroegbe (Igbo-Nigeria). The latex from the leaves of the plant has been used in traditional medicine as antihelminth and for the treatment of bacterial infections [51].

The antibacterial activity of aqueous extracts (root and leaf) of *Carica papaya* root was reported by Anibijuwon and Udeze, (2009) against *E. coli*, *P. aeruginosa*, *K. pneumonia*, *S. aureus* and *P. Mirabilis* [52]. In another study by Wemambu *et al.*, (2018), the ethanol and cold water extracts of *Carica papaya* root exerted antibacterial effect against *S. aureus*, *Klebsiella specie*, *E. coli*, *Pseudomonas specie* and *Salmonella specie* [53].

Doughari *et al.*, (2007) reported the antibacterial activity of the root (water, methanol and acetone) extracts of *Carica papaya* against *S. aureus*, *Streptococcus pyogenase*, *Streptococcus pneumonia*, *Bacillus cereus*, *E. coli*, *P. aeruginosa*, *P. mirabilis*, *S. typhi* and *Shigella flexniri* [54]. Similarly, Fasoyinu and team members in 2019, reported the antibacterial activity of fermented peel and pulp extract of *Carica papaya* against *Salmonella typhi*, *P. mirabilis*, *E. coli* and *S. Aureus* [55].

### ***Calotropis procera***

*Calotropis procera* (Sodom apple) is a member of the plant family Asclepiadaceae. It is a shrub of about 6m high which is widely distributed in West Africa and other parts of the tropics [56]. The plant is erect, tall, large, much branched and perennial with milky latex throughout. In Nigerian traditional medicine, *C. procera* is either used alone or in combination with other herbs to treat fever, rheumatism, indigestion, cold, eczema and diarrhoea. In addition, preparations from latex with honey are used as anti-rabies and also in the treatment of toothache and cough [57].

Kareem *et al.*, (2008), reported the antibacterial activities of the aqueous, chloroform and ethanolic extracts of *C. procera* against *E. coli*, *S. aureus*, *S. albus*, *S. pyogenes*, *S. Pneumoniae* [58]. In another research by Kawo *et al.*, (2009), the leaf and latex ethanol extracts of *C. procera* elicited antibacterial activities against *E. coli*, *S. aureus* and the species of *Salmonella* and *Pseudomonas* [59].

The aqueous and organic leaf and latex extracts of *C. procera* showed effective activity against *E. coli*, *S. Typhi* and *B. Subtilis* [60]. Mainasara *et al.*, (2012) reported the antibacterial activity of the root and leaf (ethanol, water and methanol) extracts of *C. procera* against *P. aeruginosa*, *S typhi*, *E. coli*, *S. aureus*, and *S. Pyogenes* [61].

### ***Piliostigma thonningii***

*Piliostigma thonningii* is a flowering plant that belongs to the family Fabaceae and subfamily Cercidoideae [62]. The leaves of the plant possess antibacterial, antimicrobial and antioxidant activities [63].

Nguta *et al.*, (2013) screened *P. thonningii* leaves extract for its antibacterial activity. Out of 8 crude extracts of *P. thonningii*, 7 extracts

had antibacterial activity at concentration of 250 µg/ml and one crude extract was not effective against all the test bacteria [64]. In another study by Njeru *et al.*, 2015, the methanolic fractions of *P. thonningii* revealed the anti-tuberculous activity with minimum inhibitory concentration (MIC) of 12.5 µg/ml, the highest antibacterial activity with zones of inhibition of 20.3 mm and MIC of 31.25 µg/ml (*Staphylococcus aureus*), 18.3 mm and MIC of 62.5 µg/ml against MRSA, 14 mm and MIC of 125 µg/ml (*Escherichia coli*), 13.3 mm and MIC of 31.25 µg/ml (*Shigella sonnei*). They inhibited both Gram-positive and Gram-negative bacteria giving remarkable zones of inhibition but the activity against Gram positive was the highest [65].

The hexane, ethyl-acetate, methanol and aqueous extracts of the plant were used to investigate their antibacterial activity against MRSA. Out of the 4 extracts that were tested for antibacterial activity only hexane extract gave the highest inhibition against all the MRSA isolates. Crude extract and fractions showed antibacterial activity with overall MICs against MRSA in the range of 1.0 and 2.0 mg/ml [66].

### ***Tapinanthus dodoneifolius***

*Tapinanthus* is a genus of mistletoe in the family Loranthaceae, endemic to Africa [67]. The plant is hemi-parasitic in nature growing on many trees e.g. mahogany and has ascribed medicinal uses [68]. In Ayurvedic medicine, *Tapinanthus dodoneifolius* is used for the treatment of various diseases such as sciatica, chronic fever, rheumatism, internal worm infections, asthma, inflammation, dyspepsia, dermatitis, bronchitis, cough, constipation, greyness of hair and baldness [69].

The *in vitro* assay of the extracts revealed a wide spectrum of antibacterial activities against *S. typhi*, *S. aureus* and *B. subtilis* [70]. The ethanolic and aqueous extracts inhibited the growth of *Klebsiella aerogenes*, *Proteus spp* and *Escherichia coli* [68].

The antibacterial activity of four different extracts of *Tapinanthus dodoneifolius* prepared with four kinds of solvent (1% HCl, 5% acetic acid, acetone and ethanol) were tested against *S. aureus*, *E. coli*, *P. Aeruginosa* and *Klebsiella aerogenes*. The ethanolic extract of the plant showed antibacterial potential against *S. aureus*, *P. aeruginosa* and *K. aerogenes*. On the other hand, the 1% HCl and acetone extracts of *Tapinanthus dodoneifolius* only showed antibacterial activity against *S. aureus* and *P. aeruginosa*. The antibacterial activity ranges from 8.6 µg/ml weight of ethanol extract on *K. aerogenes* to 150µg/ml weight of HCl extract on *S. Aureus*. The *E. coli* was only sensitive to acetic acid extract (22.5µg/ml). The *S. aureus* and *P. aeruginosa* were sensitive to all the extracts, with MIC ranging from 70µg/ml to 150µg/ml and 17.5µg/ml to 75µg/ml respectively [71].

### ***Ananas comosus***

The pineapple (*Ananas comosus*) is a tropical plant with an edible fruit and the most economically significant plant in the family Bromeliaceae. It was found to contain a special class of protein called bromelain [72]. The bromelain belongs to the group of protein digesting enzymes obtained commercially from the fruit and stem of pineapple plant [72]. Bromelain is a mixture of Thiopepdidases, such as asanain and comosain, phosphatases, glucosidases, peroxidases, cellulases, glycoproteins, proteinase inhibitors, such as cystatin [73]. It has also demonstrated antimicrobial effect and can resolve infectious skin diseases [74]. Bromelain has been known for its clinical applications particularly in the field of modulating the tumour growth and blood

coagulation [75]. Bromelain enhances absorption of drugs, especially antibiotics [76].

The antibacterial activity of pineapple extract was carried out by agar well diffusion technique against the bacterial pathogens and the extract was found to be effective against both gram-positive and gram-negative pathogenic bacteria tested. However, the pineapple extract was more effective against *E. coli* at 1000 µg/ml compared with *P. aeruginosa*, *K. pneumoniae* and *S. Aureus* [77].

### **Zanthoxylum zanthoxyloides**

*Zanthoxylum* is a genus of about 250 species of deciduous and evergreen trees, shrubs and climbers in the family Rutaceae [78]. *Zanthoxylum zanthoxyloides* also known as *Fagara zanthoxyloides*, is an indigenous plant used widely as chewing stick for tooth cleaning in West Africa [79].

Antimicrobial activity of the methanol-water and phosphate buffer saline (PBS) extracts, at a concentration of 25mg/ml was tested against four bacterial isolates [80]. The methanol-water extract showed antimicrobial activity against *Lactobacillus brevis*, *L. plantarum*, *E. coli* and *Proteus vulgaris*. The MIC of the extracts ranged between 1.57 and 12.5mg/ml except in *E. coli* with value greater than 12.5 mg/ml. The methanol-water extract inhibited significantly *L. brevis* while the PBS extract had considerable activity against *P. vulgaris* [80].

Ynalvezet al (2012) reported the antimicrobial activity of crude petroleum ether (CPE), defatted ethanol ether (DEE) and defatted ethanol chloroform (DEC) extracts against *Escherichia coli*, methicillin-susceptible *S. aureus* (MSSA), MRSA and vancomycin-resistance *Enterococcus faecium* (VREF). Among the three organic extracts, DEE showed the greatest zone of inhibitions against the four microorganisms tested which were significantly higher at the 5% level than CPE, DEC and the negative control. The DEE showed the highest antimicrobial activity greatest against *E. coli*, MSSA, MRSA and VREF [81]. In another findings, the ethanol and methanol extract of *Z. zanthoxyloides* were reported to have antibacterial activities against *E. faecalis*, *B. cereus*, *B. subtilis* and *P. aeruginosa* [79].

### **Alstonia boonei**

*Alstonia boonei* is a large evergreen tree belonging to the family Apocynaceae. It is one of the widely used medicinal plants in Africa which has been useful in the treatment of various diseases [82]. It is taken internally or used to bath as a remedy for dizziness, and given after childbirth and to aid the delivery. The leaves, pulped to a mash, are applied topically to reduce oedema, and leaf sap is used to cleanse sores [83]. The stem bark of *A. boonei* is used in traditional medicine to treat fever, painful micturition, insomnia, malaria and chronic diarrhoea, rheumatic pains, as anti-venom for snake bites and in the treatment of arrow poisoning (Asuzu, 1991). Therapeutically, the bark of the plant has been found to possess antibacterial properties [84]. Ajose et al., 2019 reported the antibacterial effect of the leaf, bark and leaf and bark of *Alstonia boonei* against *E. coli*, *S. aureus*, *P. aeruginosa*, *S. pneumoniae*, *Proteus mirabilis*, *K. pneumoniae*, *Shigella dysenteriae* and *Salmonella typhimurium* [85].

### **Zingiber officinale**

Ginger is a thick tuberous rhizome that belongs to the family Zingiberaceae. It is a perennial herb with purple flowers and erect leafy aerial stem that can grow up to 1 meter in height. Its roots are used as

spice in cooking throughout the world. The plant has a long history of cultivation that is believed to have originated in China before the spread to South-East Asia, West Africa, India, and the Caribbean [86]. Ginger has been used in the management of gastrointestinal conditions such as nausea and vomiting, diarrhoea, dyspepsia and other conditions such as rheumatism, and colds [87]. Some documented pharmacological activity of ginger and its derivatives include hypoglycaemic [88], antioxidant/anti-inflammatory [89, 90], analgesic [91], antiplatelet [91], antiemetic [92], and antimicrobial [93].

Organic extracts of ginger rhizome have been reported in several studies to be effective against *S. aureus*, *E. coli*, *Proteus mirabilis*, *Streptococcus pyogenes*, *S. typhi*, *S. aureus*, *P. aeruginosa* [94-96], *S. pneumoniae*, and *H. influenzae* [97]. The aqueous rhizome extract has also shown potential antibacterial activity against *S. aureus*, *S. typhi*, *Proteus mirabilis*, *P. aeruginosa*, *E. coli*, *S. Pyogenes* [95, 96] and cariogenic microorganisms; *Streptococcus mutans* and *Streptococcus sanguine* [98].

### **Petiveria alliacea**

*Petiveria alliacea* belongs to a family of flowering plants known as Phytolaccaceae. The plant is popularly known as Guinea hen weed in English [99] and also referred to as 'arunyanyan' in the southern part of Nigeria where it grows in abundance [100]. It is an herbaceous shrub with deep roots and matures after several years, growing up to 1 m in height. The roots and leaves have a strong acrid, garlic-like odor while the fruits are narrowly oblong 6-8 mm long, and the flowers are small, greenish and piccate. *P. alliacea* has been used in traditional medicine in the treatment of an array of disorders [101]. Various extracts of *P. alliacea* have been reported to have immunomodulatory [102], antiviral [103], insecticidal [104], hyperglycaemic [105], and antimicrobial effects [106, 107].

The aqueous, ethanol, methanol and chloroform leaves and root extracts of *P. alliacea* have been evaluated for antibacterial activity against several bacteria including *E. coli*, *B. subtilis*, *Micrococcus sp*, and *S. aureus* and *K. pneumoniae* [100, 108].

The antibacterial activity of both soft extract and blended extract of *P. alliacea* against *Enterococcus faecalis*, *P. aeruginosa*, *S. aureus*, and *E. coli* was evaluated by Ania and colleagues. The result showed that the blended extract was more active than the soft extract against all four bacteria with greatest activity against *P. aeruginosa* and least activity against *E. coli* and *E. faecalis* [109].

### **Hymenocardia acidaTul**

*Hymenocardia acida* belongs to the Phyllanthaceae plant family. It is a small African tree or shrub that grows about 9 m tall. The branchlets become rusty brown as the bark peels. The bole is short, often flattened and usually crooked. The branches form a fairly heavy, somewhat rounded crown. The bark is smooth or flaky, pinkish-brown when fresh but becoming pale brown or grey later. The plant is native to Angola, Cameroon, Chad, Congo, Cote d'Ivoire, Gambia, Ghana, Guinea-Bissau, Kenya, Mali, Mozambique, Niger, Nigeria, Senegal, Tanzania, Togo, Uganda, Zambia, Zimbabwe and has been used locally as food and medicine. *H. acida* has been used in traditional medicine to treat sickle-cell disease [110], cancer [111], malaria [112], and hypertension [113]. Basic preclinical studies have revealed the cytotoxicity [114], antiplasmodial [112], anti-sickling [110, 115], antitrypanosomal [116], antioxidant [117], antibacterial [118], mucociliary [119], and vasorelaxant [113] activities of the crude extracts of *H. acida*.

Aqueous and organic extracts of various parts of *H. acida* have demonstrated significant antibacterial activity against *S. aureus*, *S. pyogenes*, *S. mutans*, *S. auricularis*, *B. subtilis*, *B. cereus*, *S. epidermidis*, *M. kristinae*, *E. coli*, *S. poon* and *S. Marcescens* [118]. The ethanolic and aqueous stem extract of *H. acida* have been reported to possess activity against *S. aureus*, *S. pyogenes*, *S. mutans*, *S. auricularis* and *B. Subtilis* [120]. In 2014, Starks and colleagues went further to isolate one chromene stilbenoids and six chromane stilbenoids from the ethanolic stem extract of *H. acida*. They evaluated the compounds for antibacterial activity and found several of them to be moderately active against clinically isolated MRSA [121].

### *Nymphaea lotus* Linn

Also known as water lily, *Nymphaea lotus* belongs to Nymphaeaceae family. *N. lotus* is a floating leafed macrophyte and water lily, native to Africa and specific areas in Europe. *N. lotus* is widespread in Africa and parts of temperate and tropical Asia to which it is native (Plant Gene Resources of Canada, 2016). The plant has a number of medicinal properties including its use for sedation [122], and is often introduced into new areas as an ornamental. Several studies using the ethanol leaves extract of *N. lotus* have found it to have significant antibacterial activity against *S. aureus*, *Streptococcus pyogenes*, *E. coli*, *K. Pneumoniae* and *P. aeruginosa*. [123, 124]. The whole plant extract has also shown activity against fish bacteria such as *Escherichia coli*, *Vibrio anguillarum*, *Pseudomonas fluorescens*, *Aeromonas hydrophila* and *Salmonella typhi*. [125].

### *Anacardium occidentale* Linn

The cashew tree belongs to the Anacardiaceae plant family. The plant is a tropical large and evergreen tree that can grow up to 14 m high. The tree has short, often irregularly shaped trunk, obovate and leathery leaves that are spirally arranged. [126]. Different parts of the plant ranging from root, stem, bud, stalk, leaves, apple, bark, nut oil and gum have been employed in traditional medicine to treat a variety of ailment including but not limited to diarrhoea, haemorrhoids, infections, tooth ache, hypertension, diabetes mellitus, inflammatory disorders and cancer. The plant has been reported to contain bioactive substances that have several pharmacological activities such as antioxidant [127, 128], hypolipidemic [129, 130], analgesic [131], anti-inflammatory [127], antimicrobial [132, 133], antisickling [134], cytotoxic [135, 136], hypoglycaemic [130, 137], and antihypertensive [138] effects.

Several researches have been published to support the antibacterial activity of *Anacardium occidentale*. These researches have varied however, in the plant part used, the solvent of extraction and the pharmacological test models. The leaves and stem bark extracts of *A. occidentale* have been reported to be effective against *S. aureus*, *S. faecalis*, *K. pneumoniae*, *S. pneumoniae* and *Streptococcus albus*, *P. Aeruginosa* and *E. coli* [128, 139-141]. Interestingly, the ethanolic leaf extract of *A. occidentale* has also been reported to have superior antibacterial activity against dental pathogens *Enterococcus faecalis*, *S. aureus*, *Streptococcus mutans*, and *E. coli*, when compared to iodine-based mouth washes [136].

### CONCLUSION

In conclusion, several studies were conducted to investigate the antibacterial activity of different extracts and fractions of these medicinal plants which indicated their promising pharmacological activity against bacterial strains. The results also showed that scientific evaluations on the medicinal plants based on their traditional uses could

give an insight towards discovery of novel antibacterial agents. However, the studies conducted are mostly *in vitro* evaluation which may not guarantee that the extracts and fractions of the plants could demonstrate same *in vivo* antibacterial actions. Therefore, further studies to investigate the activity of the plants on bacterial strains using *in vivo* experiments are required to further validate these results. Moreover, further studies should be conducted to evaluate the effects of the plants against multi-drug resistant bacterial strains. Also, cellular and molecular mechanisms of antibacterial activities of the extracts and fractions of these plants are needed in an attempt to develop novel antibacterial agents.

### Conflict of interests

The authors declare that they have no conflict of interest

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#### HOW TO CITE THIS ARTICLE

Ahmad MH, Muhammad AU, Dalhat AD, Salauddeen MA. Nigerian Medicinal Plants with Potential Antibacterial Property: A Review. *J Phytopharmacol* 2021; 10(1):26-34.