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Antimicrobial activities of *Acacia* genus: A review

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ABSTRACT

More than 1 300 species of the vast genus *Acacia* are found in tropical habitats. They are crucial economic plants since they produce traditional medicines, timber, and gum. The pharmacological uses of the *Acacia* genus include anti-diarrheal, anti-malarial, chronic pain relief, wound healing, anti-cancer, anti-rheumatism, and anti-diabetes activities. It is also used for treating various illnesses such as gastroenteritis, allergies, Alzheimer's disease, cough, and cardiovascular disease. The present review aims to summarize the antimicrobial activities including the antibacterial and antifungal activity of the *Acacia* genus. The literature was searched in books and online databases including SciFinder, Google Scholar, Scopus, PubMed, and scientific journals using the most relevant keywords: *Acacia*+antimicrobial, *Acacia*+antibacterial, and *Acacia*+antifungal.

KEYWORDS: *Acacia*; Antimicrobial; Antibacterial; Antifungal; Polyphenols; Flavonoids

1. Introduction

Since ancient times, it is well evidenced that plants are potential medicinal sources and are widely used in Ayurvedic, Unani, Chinese, and other medical systems[1]. Humans have relied on nature for thousands of years to encounter their basic health necessities, specifically for the usage of a variety of ailments[2]. Before the development of modern medicine, plants served as medicines in traditional medicinal systems, moreover, more than 60% of people worldwide use them today[3]. According to the latest numbers, more than a thousand plant species have been utilized either in their raw form or in their structured form as crude extracts in diverse cultures[4].

The *Acacia* species are typically called the wattles in Australia and thorn trees in Africa. They are crucial economic plants because they produce traditional medicines, wood, gum, tannins, and gum arabic. Many cultures have historically employed the bark, flowers, leaves, pods, seeds, and roots of *Acacia* to treat a variety of illnesses[5,6]. Because many kinds of *Acacia* trees, particularly those that grow in arid climates, have spines and thus are called "thorn trees". These can also be branches that have grown to be short, harsh, and acrid[7]. The genus *Acacia* is widely dispersed throughout the world, with communities in North and South America, Africa, and the Australia-Pacific region[8].

The plant *Acacia* belongs to the tribe Acacieae, which is part of the Fabaceae family subfamily Mimosoideae. About 1 300 different species of the herb *Acacia* can be found throughout the world and also there is potential therapeutic use of *Acacia* species in both diet and ethnopharmacology. *Acacia* is found over the whole tropical world, primarily discovered in dry environments, including savannas, forests, and temperate, subtropical, and tropical regions. Moreover, this tropical grassland is a massive genus of woody, legumes, pod-bearing shrubs, and trees[9,10]. Due to its resistance to drought, capacity to improve soil through nitrogen fixation, fodder as well as for shade and live fence, the genus *Acacia* is rapidly gaining appeal[11]. Since ancient times, various forms of healing have been accomplished using plants and plant extracts. In traditional medicine, the genus *Acacia* is used to relieve inflammation and pain[12,13].

The primary goal of this review is to summarize the antimicrobial

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activities reported in the *Acacia* genus to date. The relevant literature was searched using the most specific keywords as"*Acacia*+antimicrobial", "*Acacia*+antibacterial", and "*Acacia*+antifungal". Various offline and online electronic databases were used such as books, SciFinder, PubMed, Scopus, and Google Scholar for the preparation of this manuscript. The flowchart of literature screening is shown in Figure 1.

1.1. Traditional uses of Acacia genus

Due to their adaptability and accessibility, *Acacia* has a very long history. It has been said that the ancient Egyptians employed a variety of *Acacia* species to treat a range of ailments, including internal bleeding, diarrhea, and skin conditions[14]. In sub-Saharan[15], Chinese[16], and Asian traditional medicine, for example in Ayurvedic (Indian) and Unani (Greco-Arabic)[17], *Acacia* genus is also quite prevalent. The phytoconstituents present in the *Acacia* with strong free radical scavenging and antioxidant properties are responsible for some pharmacological and biological properties, including antibacterial, anti-inflammatory, anti-hypertensive, antiplatelet, hypoglycemic, anti-atherosclerotic, and analgesic activities[18].

1.2. Pharmacological properties of Acacia genus

The most vital component to eradicate the uncertainty regarding the use of medicinal plants as medications for adjunct medicine is the fact that pharmacological action is primarily based on experience. However, the possible ethnopharmacological properties of *Acacia* species in diverse traditional systems of medicine, particularly those of Africa and Asia, where herbal pharmacopeia are mainly lacking, justify the verification demand for reliable and safe usage of *Acacia* genus. A variety of conditions, including diarrhea, Alzheimer's disease, gastroenteritis, wounds, malaria, allergies, coughs, diabetes, cardiovascular disorders, chronic pain, and inflammatory illnesses like rheumatism and cancer, are among the many conditions for which traditional uses of *Acacia* species were generally supported by modern pharmacological studies[4].

1.3. Phytochemicals reported in Acacia genus

Acacia is a rich source of a wide range of chemical compounds[10]. The diverse genus *Acacia* contains several bioactive substances, including alkaloids (phenethylamine, amphetamine, candicine, mescaline, trichocereine, and hordenine)[19]; cyanogenic glycosides (linamarin, procacipetalin, heterodendrin, prunasin, sambunigrin, and lotaustralin); flavonoids (epicatechin, robinetinidol, fasciculiferin, melacacidin, galangin, myricetin, chrysin, and apigenin)[20]; terpenoids (acaciaside A&B and acacigenin)[21], phenolic compounds (ellagic acid, ferulic acid, and gallic acid) and tannins (gallotannin)[22,23]. Over the past seven decades, 152 active ingredients have been found in the *Acacia* genus and the medicinal compounds are mainly present in the pods, root, bark, and leaves of the *Acacia* shrubs. Numerous other compounds such as flavonol and flavone glycosides, as well as aglycones, flavan-3-ols, flavan-3,4-diols, kaempferol-3 acid, quercetin, amyrin, glucoside isoquercetin sitosterol, and botulin were also found in various species of *Acacia*[24,25]. Several secondary metabolites from medicinal plants from multiple nations were evaluated on how well they could inhibit a wide range of infectious microorganisms and these metabolites exhibit antibacterial action both *in vivo* and *in vitro*[26,27].

Symbiotic relationships between medicinal plants and the microorganisms that are vital to plant health enable the production of a variety of biologically active chemicals. It is known that medicinal plants with antibacterial properties encourage the growth of endophytic bacteria that are more hostile to human pathogens[28,29]. Further research on plant-based antimicrobials is urgently required because they offer a major unexplored supply of medications. Antimicrobials produced from plants with immense medicinal potential have a long history of offering desperately needed new treatments[30].

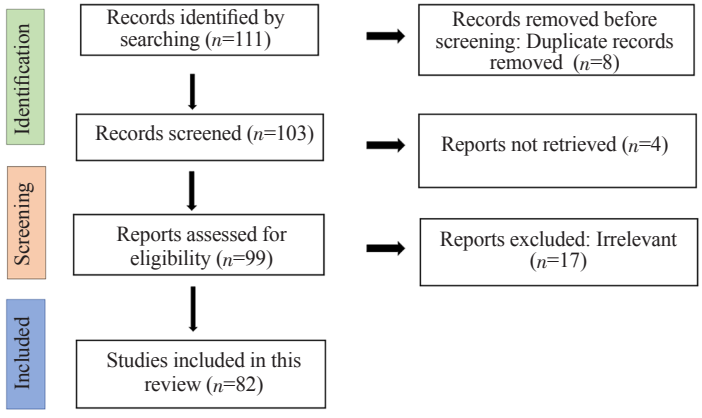

Figure 1. A flowchart of literature screening.

2. Antibacterial activity of *Acacia* genus

The most commonly mentioned pharmacological action of *Acacia* species is its antimicrobial properties. While *Acacia* plants were used as antimicrobial agents extensively in folklore medicine, the abundance of written work is likely a result of how easy and inexpensive it is to conduct antibacterial and antifungal studies. The minimum inhibitory concentration (MIC) in liquid culture media and zone of inhibition (ZOI) in solid culture media are typically used to express antimicrobial activity. To evaluate the antibacterial efficacy quantitatively, MIC is a more often used metric[31].

Before the development of current antibiotics, herbal remedies were used to treat microbiological infections. Numerous medicinal plants have been proven successful in treating bacterial illnesses[32]. Plants are a rich source of antibacterial drugs, due to a wide range of bioactive substances that plants produce, which are most likely established as a chemical defense against disease or predation[33]. Here, the antibacterial activity of various *Acacia* species has been discussed below.

2.1. Disc diffusion method–based antibacterial activities of Acacia genus

Arias *et al*. reported the antibacterial activity of *Acacia aroma* ethanolic and aqueous extracts from different parts (leaves, flowers, and stems) against Gram-positive bacteria [*Enterococcus faecalis* (*E. faecalis*), *Staphylococcus aureus* (*S. aureus*), *S. aureus* ATCC 29213, coagulase-negative staphylococci, *Streptococcus agalactiae*, *Streptococcus pyogenes* (*S. pyogenes*), *E. faecalis* ATCC 29212] as well as Gram-negative bacteria [*Escherichia coli* (*E. coli*), *Klebsiella pneumoniae* (*K. pneumoniae*), *Proteus mirabilis* (*P. mirabilis*), *Enterobacter cloacae* (*E. cloacae*), *Serratia marcescens* (*S. marcescens*), *Morganella morganii*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa* (*P. aeruginosa*), *Stenotrophomonas maltophilia*, *E. coli* ATCC 35218, *P. aeruginosa* ATCC 27853, *E. coli* ATCC 25922] using disk diffusion method. Each ethanolic extract was found active against Gram-positive bacteria while only leaf and flower extracts were found active against Gram-negative bacteria[34].

Different extracts from *Acacia arabica* (*A. arabica*) leaf were analyzed for their antibacterial activities against various bacterial strains [*E. coli*, *S. aureus*, *K. pneumoniae*, *Proteus vulgaris* (*P. vulgaris*), *Salmonella typhi* (*S. typhi*), *Shigella flexneri*, *Salmonella paratyphi* (*S. paratyphi*), *Salmonella typhimurium* (*S. typhimurium*), *P. aeruginosa*, *Enterobacter aerogenes* (*E. aerogenes*)]. Among these extracts, the methanol extract of *A. arabica* showed the most potent results with ZOI of 22, 25, 22, 18, 26, 15, 23, 17, 20, and 24 mm for *E. coli*, *S. aureus*, *E. aerogenes*, *P. aeruginosa*, *S. typhi*, *S. typhimurium*, *P. vulgaris*, *K. pneumoniae*, *S. paratyphi*, and *Shigella flexneri*, respectively[35]. In another study, the antibacterial activity of *Acacia berlandieri* and *Acacia rigidula* leaf extracts (acetone, methanol, and acetic acid) was evaluated against numerous bacterial strains (*Yersinia enterocolitica*, *E. coli*, *S. aureus*, *Providencia alcalifaciens*, *E. aerogenes*, *S. marcescens*, *K. pneumoniae*, *P. aeruginosa*, and *E. faecalis*) using disc diffusion method. Based on the mean zones of inhibition, the antibacterial activity of both *Acacia* species differs from each other. Three of the nine bacterial species (*Providencia alcalifaciens*, *P. aeruginosa*, and *Yersinia enterocolitica*) were resistant to *Acacia berlandieri* with MIC of 6.00-8.99 mm. However, the extracts of *Acacia rigidula* were effective against the six bacterial species, and out of the six bacterial species, four were Gram-negative (*Providencia alcalifaciens*, *P. aeruginosa*, *Yersinia enterocolitica*, and *E. coli*) and two were Gram-positive (*S. aureus* and *E. faecalis*) with mean ZOI ranging from 8.70 to 17.56 mm for acetone extract, 7.80-14.43 mm for methanol extract and 6.00-12.33 mm for acetic acid extract[36].

In a study by Saini *et al*., five different species of *Acacia* species were investigated, including *Acacia nilotica* (*A. nilotica*), *Acacia catechu* (*A. catechu*), *Acacia senegal* (*A. senegal*), *Acacia tortilis* (*A. tortilis*), and *Acacia jacquemontii* for antibacterial activity. *A. catechu* and *A. nilotica* showed the most potent activity toward three bacteria (*E. coli*, *S. aureus*, and *S. typhi*). Among these species, methanolic extracts of the plant *A. nilotica* (pods) and *A. catechu* (bark) were reported to be the most effective. The methanolic extract of *A. nilotica* (pods) demonstrated significant activity against *E. coli*, whereas *A. catechu* showed noteworthy activity against *S. aureus*. The *A. nilotica n*-hexane extract, on the other hand, was also discovered to be particularly effective against *S. typhi*. In contrast, *Acacia jacquemontii* showed the lowest antibacterial activity[37].

Mutai *et al*. tested the antibacterial activity of (20S)-oxolupane-30-al, (20R)-oxolupane-30-al, and betulinic acid isolated from stem bark of *Acacia mellifera* against *S. aureus* ATCC 25923, *E. coli* ATCC 25922, and *E. faecalis*. At a concentration of 1 mg/mL, (20S)-oxolupane-30-al, (20R)-oxolupane-30-al, and betulinic acid demonstrated antibacterial action against *S. aureus* ATCC 25923 with ZOI of 10, 10, and 9 mm, respectively. However, no antibacterial effect on *E. coli* ATCC 25922 and *E. faecalis* was observed[38].

In a previous study, Ntshanka *et al*. used the ethanol, methanol, acetone, and chloroform extracts of *Acacia mearnsii* (*A. mearnsii*) leaf to assess their antibacterial properties against Gram-positive bacteria such as (*S. aureus* and *E. faecalis*) as well as Gram-negative bacteria such as (*P. aeruginosa* and *E. coli*). According to their results, *A. mearnsii* ethanol and methanol extracts displayed maximum activity, with 23 mm ZOI against *P. aeruginosa* whereas *A. mearnsii* ethanol and chloroform leaf extracts showed antibacterial activity against *P. aeruginosa* and *E. faecalis*, with concentrations of 39.06 and 78.13 mg/mL, respectively[39].

Amoussa *et al*. revealed the antibacterial activity of betulinic acid-3-*trans*-caffeate isolated from *Acacia ataxacantha* bark against various bacterial strains such as [*S. aureus* ATCC 6538, *Staphylococcus epidermidis* (*S. epidermidis*) CIP 8039, *E. faecalis*

ATCC 29212, methicillin resistant *S. aureus* and *P. aeruginosa* CIP 82118], with ZOI of 15.7 to 23.3 mm. This compound showed the most significant inhibition against *S. epidermidis*, with an inhibition diameter of 23.3 mm. However, *P. aeruginosa* (Gram-negative bacteria) had intermediate sensitivity to betulinic acid-3-*trans*-caffeate, whereas Gram-positive bacteria displayed increased susceptibility. The MIC value for the investigated compounds varied from 12.5 to 50 μg/mL, indicating moderate antibacterial activity. The betulinic acid-3-*trans*-caffeate was active with the MIC and MBC values of 25 μg/mL against *S. aureus* and *P. aeruginosa*. In contrast, the MIC and MBC values against methicillin-resitant *S. aureus* and *E. faecalis* were observed as 50 μg/mL. This compound showed the lowest MIC value of 12.5 μg/mL against *S. epidermidis*[40]. Gum acacia from Omani and Sudan was tested for antibacterial activity using various extracts (hexane, chloroform, ethyl acetate, butanol, and water) against some bacterial strains (*S. aureus* Code No. 659, *E. coli* Code No. 846, *E. coli* Code No. 683 and *K. pneumoniae* Code No. 684). The highest activity against *K. pneumoniae* Code No. 684 was found in the chloroform extract at all concentrations (0.25, 0.5, 1, and 2 mg/mL) from Sudanese Gum acacia, and the lowest activity against *S. aureus* Code No. 659 was found in the *n*-butanol extract at all concentrations from the same source[41]. The antibacterial potential of *Acacia polyacantha* bark methanolic extract against *Bacillus subtilis* (*B. subtilis*), *S. aureus*, *E. coli*, and *P. aeruginosa* was investigated. At a higher concentration of 100 mg/mL, the highest activity was (19.00±0.05) mm against *E. coli* while at a lower concentration of 12.5 mg/mL, the lowest activity (10.3±0.1) mm against *B. subtilis*. *S. aureus* was affected at a concentration of 100 mg/mL with (13.6±0.02) mm ZOI. As a result, compared to the standard antibiotic, amoxicillin, *Acacia polyacantha* bark extract at 100 mg/mL showed a greater ZOI against *E. coli*, *P. aeruginosa*, and *B. subtilis*[42]. Methanolic extract of *Acacia caesia* stem was analyzed for the antibacterial activity against *E. coli* (ATCC 25922), *S. aureus* (ATCC 25923), and *P. aeruginosa* (ATCC 27853). The extract did not affect these microorganisms at a concentration of 25 μL. However, at a concentration of 100 μL, it displayed substantial activity comparable to that of ciprofloxacin. The ZOI of ciprofloxacin and the methanolic extract against *E. coli* was 30 mm and 17 mm, respectively. On the other hand, ZOI of 34 mm and 11 mm against *S. aureus* was observed for ciprofloxacin and the methanolic extract, respectively[43]. The summary of the above-mentioned antibacterial activities of *Acacia* genus is given in Table 1.

2.2. Agar diffusion method–based antibacterial activities of *Acacia* genus

The *n*-hexane, ethyl acetate, ethanolic and methanolic extracts of *Acacia mellifera* were examined to verify the antibacterial activity against Gram-positive [*Streptococcus pneumoniae* (*S. pneumoniae*) ATCC 10341 and *S. aureus* ATCC 25923] and Gram-negative (*K. pneumoniae* ATCC 10273 and *E. coli* ATCC 25922) bacteria using agar dilution and broth macro dilution method. The *n*-hexane and ethanol extracts showed varying inhibition against *S. pneumoniae* ATCC 10341, *S. aureus* ATCC 25923 and *E. coli* ATCC 25922 while the ethyl acetate extract only showed the inhibitory action against *S. pneumoniae* ATCC10341 and *E. coli* ATCC 25922[44].

Okoro *et al*. analyzed the antibacterial action of different extracts from *A. senegal* stem bark against *S. aureus*, *E. coli*, *S. pneumoniae*, *S. pyogenes*, *P. aeruginosa*, *P. vulgaris*, *S. typhi*, and *Shigella dysenteriae*. The ZOI of ethanolic extract was 8, 8, and 8 mm for *E. coli*, *P. aeruginosa*, and *S. typhi* respectively at 500 μg/mL whereas the methanolic extract showed 8, 8, 8, 8, 8, and 10 mm for *E. coli*, *K. pneumoniae*, *P. aeruginosa*, *P. vulgaris*, *S. typhi*, and *Shigella dysenteriae*, respectively at 500 μg/mL. Furthermore, the MIC and MBC for the ethanol and methanol extracts were observed at 50 mg/mL and 400 mg/mL[45]. *A. catechu* methanolic extract was found active against some pathogenic and non-pathogenic species (*B. subtilis*, *S. aureus*, *S. typhi*, *E. coli*, and *P. aeruginosa*). Aqueous extracts consistently had lower antibacterial activity than extracts made in organic solvents. Further research revealed that methanol extracts showed more inhibitory activities with ZOI of 18 to 22 mm, compared with other extracts[46].

The antibacterial activity of *A. nilotica* methanolic fruit extract was determined against clinical isolates of five Gram-negative bacteria (*E. coli*, *Shigella flexneri*, *S. typhi*, *P. aeruginosa*, and *K. pneumoniae*), and two Gram-positive bacteria [*Listeria monocytogenes* and *Bacillus cereus* (*B. cereus*)]. Most of the studied microorganisms were inhibited by the fruit methanolic extract, with ZOI ranging from 11 to 39 mm. The highest ZOI was found against *S. typhi* (39 mm) and *B. cereus* (30 mm) at 100 mg/mL[47]. The various extracts of *A. catechu* heartwood were investigated against Gram-positive bacteria (*S. aureus* and *B. subtilis*) and Gram-negative bacteria (*S. paratyphi*, *E. coli*, *Pseudomonas* sp., *Enterobacter* sp., *S. typhi*, *Shigella* sp., *Acinetobacter* sp., *P. mirabilis*, and *K. pneumoniae*). Methanol, diethyl ether, and ethyl acetate extracts are proven to have powerful antibacterial activity among various extracts. Moreover, the MBC of the ethyl acetate extract was 50, 100, 100 and 50 mg/mL against *B. subtilis*, *K. pneumoniae*, *S. aureus*, and *Shigella* spp, respectively[48].

Phyllodes of the plant *Acacia auriculiformis* (*A. auriculiformis*) and *Acacia bivenosa* were determined for the antibacterial activity against three Gram-positive bacteria (*S. aureus*, *S. pyogenes*, and *B. cereus*) and three Gram-negative bacteria (*K. pneumoniae*, *E. coli*, *P. aeruginosa*). *S. aureus*, *S. pyogenes* as well as *E. coli* responded favorably to the methanol extract of *A. auriculiformis* phyllodes. At a concentration of 6.0 mg, *Acacia bivenosa* extract exhibited inhibitions of 0.0-11.0 mm and 0.1-9.7 mm for *S. aureus* and *S. pyogenes* as opposed to *A. auriculiformis* extract, which showed ZOI of 0.2-22.7 mm, 0.1-26.0 mm and 0.2-13.7 mm against *S. aureus* and *S. pyogenes* and *E. coli*, respectively. Additionally, 2.0 mg of *Acacia bivenosa* extract showed 0.1-8.3 mm inhibition against *S. aureus*

while *A. auriculiformis* extract showed 0.2-19.0 mm and 0.1-17.7 mm inhibition against *S. aureus* and *S. pyogenes*, respectively[49].

Various fractions (*n*-hexane, dichloromethane, ethyl acetate, and aqueous) of *A. catechu* bark were analyzed for their antibacterial activity against several bacterial strains including *S. aureus* ATCC 25923, *E. coli* ATCC 25922, *K. pneumoniae* ATCC 13883, *S. typhi* ATCC 14028, and *Shigella sonnei* (*S. sonnei*) ATCC 25931. The results showed that as for the *n*-hexane fraction, the ZOI was 11 mm and 6 mm against *S. aureus* and *S. sonnei* whereas the dichloromethane fraction showed 9 mm and 7 mm of ZOI against *S. aureus* and *S. sonnei*. The ethyl acetate and aqueous fractions showed ZOI of 13, 8, and 12, as well as 14, 10, and 10 mm against *S. aureus*, *K. pneumoniae*, and *S. sonnei* respectively. The MIC and MBC against *S. aureus* ATCC 25923 were tested based on the ZOI and the aqueous fraction of the *A. catechu* bark extract exhibited MIC and MBC of 6.25 and 12.5 mg/mL, respectively[50].

Olajuyigbe *et al*. evaluated the antibacterial activity of acetone extract from *A. mearnsii* stem bark against *P. vulgaris* KZN, *S.*

Table 1. The antibacterial activity of *Acacia* species using disc diffusion method.

Species	Part used	Extract/Fraction/ Isolated compounds	Strains	Concentration tested	*In vitro*/*In vivo* studies	Ref.
Acacia aroma	Leaves, stems and flowers	Ethanolic and aqueous extract	*Staphylococcus aureus* (*S. aureus*), *Streptococcus pyogenes* (*S. pyogenes*), *Staphylococcus* spp, *Enterococcus faecium*, *Streptococcus agalactiae*, *Escherichia coli* (*E. coli*), *Stenotrophomonas maltophili*, *Klebsiella pneumoniae* (*K. pneumoniae*), *Proteus mirabilis*, *Enterobacter cloacae*, *Serratia marcescens* (*S. marcescens*), *Acinetobacter baumannii*, *Pseudomonas aeruginosa* (*P. aeruginosa*), *Enterococcus faecalis* (*E. faecalis*), and *Morganella morganii*	15 µL	*In vitro*	[34]
Acacia arabica	Leaf	Water, ethanol, methanol, and acetone extract	*E. coli*, *S. aureus*, *K. pneumoniae*, *Proteus vulgaris* (*P. vulgaris*), *Salmonella typhi* (*S. typhi*), *Shigella flexneri*, and *Salmonella paratyphi* (*S. paratyphi*)	2, 4, 6, 8 and 10 mg/ mL	*In vitro*	[35]
Acacia rigidula	Leaf	Acetone and methanolic extract	*E. coli*, *Providencia alcalifaacien*, *Enterobacter aerogenes*, *S. aureus*, *S. marcescens*, *P. aeruginosa*, *K. pneumoniae*, *Yersinia enterocolitica*, and *E. faecalis*	0.5 mg/mL	*In vitro*	[36]
Acacia berlandieri	Leaf	Acetone and methanolic extract	*P. aeruginosa*, *Enterobacter aerogenes*, *Yersinia enterocolitica*, *E. coli*, *S. aureus*, *K. pneumoniae*, *Providencia alcalifacien*, *S. marcescens*, and *E. faecalis*	0.5 mg/mL	*In vitro*	[36]
Acacia nilotica	Pods	Hexane and methanolic extract	*S. typhi*, *E. coli*, *Bacillus cereus* (*B. cereus*), *P. aeruginosa*, and *S. aureus*	5 mg/mL	*In vitro*	[37]
Acacia tortilis	Bark	Hexane and methanolic extract	*S. typhi*, *E. coli*, *B. cereus*, *P. aeruginosa*, and *S. aureus*	5 mg/mL	*In vitro*	[37]
Acacia senegal	Bark	Hexane and methanolic extract	*S. typhi*, *E. coli*, *B. cereus*, *P. aeruginosa*, and *S. aureus*	5 mg/mL	*In vitro*	[37]
Acacia catechu	Bark	Hexane and methanolic extract	*S. typhi*, *E. coli*, *B. cereus*, *P. aeruginosa*, and *S. aureus*	5 mg/mL	*In vitro*	[37]
Acacia jacquemontii	Whole plant	Hexane and methanolic extract	*S. typhi*, *E. coli*, *B. cereus*, *P. aeruginosa*, and *S. aureus*	5 mg/mL	*In vitro*	[37]
Aacia mellifera	Stem bark	Dichloromethane and methanol extract and isolated compounds: Oxolupane 30 al (20 S and 20 R) and betulinic acid	*S. aureus* ATCC 25923, *E. faecalis*, and *E. coli* ATCC 25922	10 µL	*In vitro*	[38]
Acacia mearnsii	Leaf	Ethanol, methanol, chloroform, and acetone extract	*P. aeruginosa*, *E. coli*, *S. aureus*, and *E. faecalis*	0.06 mg/mL	*In vitro*	[39]
Acacia ataxacantha	Bark	Lupeol, betulinic acid 3 *trans* caffeate and betulinic acid	*P. aeruginosa* CIP 82118, *S. aureus* ATCC 6538, *E. faecalis* ATCC 29212, methicillin resistant *Staphylococcus* and *Staphylococcus epidermidis* (*S. epidermidis*) CIP 8039	100 µg/disc	*In vitro*	[40]
Gum acacia	Gum	Hexane, chloroform, ethyl acetate, butanol, and water extract	*S. aureus* Code No. 659, *E. coli* Code No. 846, *E. coli* Code No. 683 and *K. pneumoniae* Code No. 684	0.25, 0.5, 1 and 2 mg/mL	*In vitro*	[41]
Acacia polyacantha	Bark	Methanolic extract	*Bacillus subtilis* (*B. subtilis*), *S. aureus*, *E. coli*, *P. aeruginosa*	12.5, 25, 50, and 100 mg/mL	*In vitro*	[42]
Acacia caesia	Stem	Methanolic extract	*E. coli*, *P. aeruginosa*, and *S. aureus*	25 and 100 µL	*In vitro*	[43]

aureus OK, *E. faecalis* KZN, *K. pneumoniae* KZN, *P. vulgaris* CSIR 0030, *B. cereus* ATCC 10702, *E. coli* ATCC 25922, *Bacillus pumilus* ATCC 14884, *S. typhi* ATCC 13311, *S. marcescens* ATCC 9986, *K. pneumoniae* ATCC 10031, and *P. aeruginosa* ATCC 19582. The crude extract was most effective against *P. vulgaris* CSIR 0030 as compared to other tested isolates, with an MIC of 39.1 μg/mL. The MIC values ranged from 39.1 to 625 μg/mL against Gram-negative bacterial strains, whereas those against Gram-positive bacterial strains ranged from 78.1 to 312.5 μg/mL[51].

In a study of Priyanka *et al*., chloroform, ethanol, ethyl acetate, methanol extracts of leaves and roots of *Acacia karoo* demonstrated antibacterial effects against various bacterial strains including *S. aureus*, *E. coli*, *S. typhi*, *P. aeruginosa*, *K. pneumoniae*, *P. vulgaris*, and *B. subtilis*. The methanolic leaf extract showed the maximum inhibition against *P. vulgaris* with 20.33 mm ZOI and the minimum inhibition against *S. typhi* with 10.33 mm ZOI. On the other hand, the ethyl acetate extract of *Acacia karoo* roots showed a maximum zone of inhibition of 33.3 mm against *S. aureus* while a minimum zone of inhibition of 8.67 mm against *E. coli*[52]. The summary of the above-mentioned antibacterial activities of *Acacia* genus is reported in Table 2.

2.3. Miscellaneous method–based antibacterial activities of *Acacia* genus

Different extracts of plant *Acacia ataxacantha* bark showed varying antibacterial activities against *S. aureus* ATCC 6538, *S. epidermidis* CIP8039, *E. faecalis* ATCC 29212, methicillin-resistant *S. aureus*, *E. coli* CIP 53126, and *P. aeruginosa* CIP 82118. The MIC of different extracts ranged from 325 μg/mL to 5 mg/mL[53]. The flower extract and a fraction of *Acacia podalyriifolia* were investigated for their antibacterial activities against *S. aureus* ATCC 6538, *S. epidermidis* ATCC 12229, and *S. pyogenes* ATCC 19615, *E. coli* ATCC 25922, *K. pneumoniae* ATCC 13883, *P. mirabilis* ATCC 43071, *P. aeruginosa* ATCC 27857 and *S. typhimurium* ATCC 14028. The ethanolic extract and dichloromethane fraction inhibited *S. aureus* and *S. epidermidis*

Table 2. The antibacterial activity of *Acacia* species using agar diffusion method.

Species	Part used	Extract/Fraction/ Isolated compounds	Strains	Concentration tested	*In vitro*/*In vivo* studies	Ref.
Acacia mellifera	Whole plant	*n*-hexane, ethyl acetate, methanol, ethanol extract and aqueous fraction	*S. aureus*, *E. coli*, *K. pneumoniae*, and *Streptococcus pneumoniae*	20 mg/mL	*In vivo*	[44]
Acacia sengel	Stem bark	Methanol, ethyl acetate, ethanol, petroleum ether, water and chloroform water interface	*Streptococcus pneumoniae*, *E. coli*, *S. aureus*, *K. pneumoniae*, *Shigella dysenteriae*, *S. typhi*, *S. pyogenes*, *P. aeruginosa*, and *P. vulgaris*	10, 50, 100, and 500 μg/mL	*In vitro*	[45]
Acacia catechu	Leaves	Hexane, acetone methanol, and aqueous extract	*P. aeruginosa*, *B. subtilis*, *E. coli*, *S. aureus*, and *S. typhi*	100 μL	*In vitro*	[46]
Acacia nilotica	Fruit	Methanolic extract	*S. typhi*, *K. pneumoniae*, *E. coli*, *Shigella flexneri*, *Listeria monocytogenes*, *P. aeruginosa*, and *B. cereus*	0.1 mL	*In vitro*	[47]
Acacia catechu	Heartwood	Methanol, chloroform, hexane, ethyl acetate and diethyl ether extract	*S. paratyphi*, *S. aureus*, *B. subtilis*, *E. coli*, *K. pneumoniae*, *Enterobacter* sp., *S. typhi*, *Shigella* sp, *Pseudomonas* sp., *Acenetobacter* sp., and *Proteus mirabilis*	50 μL	*In vitro*	[48]
Acacia auriculiformis	Phyllodes	Methanol extract	*K. pneumoniae*, *S. aureus*, *E. coli*, *S. pyogenes*, *B. cereus*, and *P. aeruginosa*	2.0 and 6.0 mg	*In vitro*	[49]
Acacia bivenosa	Phyllodes	Methanol extract	*K. pneumoniae*, *E. coli*, *S. aureus*, *S. pyogenes*, *B. cereus*, and *P. aeruginosa*	2.0 and 6.0 mg	*In vitro*	[49]
Acacia catechu	Bark	Ethanol extract and hexane, dichloromethane, and ethyl acetate fraction	*E. coli* ATCC 25922, *Shigella sonnei* ATCC 25931, *S. typhi* ATCC 14028, *K. pneumoniae* ATCC 13883, and *S. aureus* ATCC 25923	50 mg/mL	*In vitro*	[50]
Acacia mearnsii	Bark	Acetone extract	*P. vulgaris* KZN, *S. aureus* OK1, *E. coli* ATCC 25922, *B. cereus* ATCC 10702, *E. faecalis* KZN, *S. marcescens* ATCC 9986, *K. pneumoniae* KZN, *P. aeruginosa* ATCC 19582, *K. pneumoniae* ATCC 10031, *P. vulgaris* CSIR 0030, *Bacillus pumilus* ATCC 14884, and *S. typhi* ATCC 13311	20-10 000 μg/mL	*In vitro*	[51]
Acacia karoo	Leaves and roots	Chloroform, methanol, ethanol and ethyl acetate extract	*S. aureus*, *E. coli*, *S. typhi*, *P. aeruginosa*, *K. pneumoniae*, *P. vulgaris*, and *B. subtilis*	100 μL	*In vitro*	[52]

with an MIC of 1 mg/mL. Whereas, the ethyl acetate fraction showed MIC values of 0.125 and 0.25 mg/mL against *S. epidermidis* and *S. aureus*, respectively, and 0.50 mg/mL against *S. pyogenes*, *K. pneumoniae*, and *P. mirabilis*[54].

Acacia saligna flower water extract was evaluated against four phytopathogenic bacteria, including *Agrobacterium tumefaciens*, *E. cloacae*, *Erwinia amylovora*, and *Pectobacterium carotovorum*. The MIC values were 200, 300, 300, and 100 µg/mL against *Agrobacterium tumefaciens*, *E. cloacae*, *Erwinia amylovora*, and *Pectobacterium carotovorum*, respectively[55]. The antibacterial activity of leaf and bark extract and fraction, and isolated compound from *Acacia polyacantha* leaves was evaluated against *E. coli* (ATCC8739, ATCC10536, AG102, and AG100Atet), *E. aerogenes* (ATCC13048, CM64, EA27, and EA289), *K. pneumoniae* (ATCC11296, KP55, and KP63), *Providencia stuartii* (ATCC29916 and NEA16), and *P. aeruginosa* (PA01 and PA124). The MIC value of the leaf crude extract was below 100 µg/mL against *P. aeruginosa* and *Providencia stuartii* while for bark extract, the same MIC value was found against *E. aerogenes*. The results revealed that the extract was moderately effective[56]. A comparative study of fresh and dried leaf extracts of *Acacia galpinii*, *Acacia karroo*, *Acacia xanthophloea*, and *Acacia sieberiana* (*A. sieberiana*) was done to evaluate their antibacterial activities against *S. aureus* ATCC29213 and *E. coli* ATCC27853. Except for *Acacia xanthophloea* which was the most active with an MIC value of 78 µg/mL against *S. aureus* and 160 µg/mL against *E. coli*, the antibacterial activity of extracts from dried leaves was higher than that of fresh leaves. Moreover, *Acacia galpinii* extract was the least active (MIC > 5000 µg/mL)[57].

Various extracts of leaf, bark, and root of the plants *A. nilotica* and *A. sieberiana* were analyzed for their antimicrobial property against *Mycobacterium aurum*. The dichloromethane extract of *A. nilotica* as well as *A. sieberiana* showed no antimicrobial activity. The MIC value of ethanol extracts of leaves, bark and root of *A. nilotica* was reported as 0.78 mg/mL, however, the MIC of ethyl acetate extracts of *A. sieberiana* leaves and roots was 3.12 mg/mL[15]. Palombo *et al*. tested the antibacterial potential of *Acacia kempeana* and *Acacia tetragonophylla* leaf ethanolic extracts against *B. cereus* ATCC 11778, *E. faecalis* ATCC 19433, *E. coli* ATCC 11775, *K. pneumoniae* ACM number 90, *P. aeruginosa* ATCC 10145, *S. typhimurium* ATCC 13311, *S. aureus* ATCC 12600 and *S. pyogenes* ACM 178. According to the results, *Acacia kempeana* extract showed 9 mm and 6 mm ZOI for *B. cereus* and *E. faecalis*, respectively, while *Acacia tetragonophylla* extract showed 6 mm ZOI for *B. cereus*[58].

The methanolic leaf extract of *Acacia saligna* was analyzed for antibacterial activity and was found to be effective against all bacterial strains [*Listeria monocytogenes* (clinical isolate), *E. coli* ATCC 35210, *S. aureus* ATCC 6538, *B. cereus* ATCC 14579, *Micrococcus flavus* ATCC 10240 and *P. aeruginosa* ATCC 27853]. The study revealed that the MIC was (0.31±0.03) and (0.30±0.05) mg/mL against *E. coli* and *S. aureus*, respectively, and the MBC was (0.73±0.03), (0.72±0.01), and (0.73±0.03) mg/mL against *B. cereus*, *E. coli*, and *S. aureus*, respectively[59]. The crude water and methanolic extract, as well as isolated compounds of *Acacia seyal* bark were tested for their antibacterial activity. Except for *S. aureus*, the water extract exhibited no antibacterial action against all of the bacterial strains. In contrast, the methanolic extract showed antibacterial activity against *S. aureus*, *Corynebacterium urealyticum*, and *P. aeruginosa*[60].

The antibacterial properties of the crude extract and the three main fractions (pet-ether, ethanolic, and methanolic fraction) of *Acacia macrostachya* stem bark were examined. The high-throughput spot culture growth inhibition assay was used to analyze two Gram-positive bacteria (*S. aureus* ATCC 25923 and *S. pyogenes* clinical strain) and two Gram-negative bacteria (*E. coli* ATCC 25922 and *P. aeruginosa* ATCC 27853). The MIC against bacterial strains ranged from 250 to 500 µg/mL, with the crude extract having the best results against *E. coli* with an MIC of 250 µg/mL. Additionally, none of the bacterial strains were inhibited by the pet-ether fraction and none of the extract and fractions were effective against *S. aureus*[61]. The methanolic and aqueous extracts of *Acacia salicina* leaves were determined by using the microdilution method against *S. aureus* ATCC 25923, *E. faecalis* ATCC 29212, *E. coli* ATCC 25922, *Salmonella enteritidis* ATCC 13076 and *S. typhimurium* NRRLB 4420. The MBC ranged from 0.125 to more than 10 mg/mL, whereas the MIC ranged from 0.0625 to over 10 mg/mL. Hence, the plant leaf extract can be a potent antibacterial drug[62].

Ahmed *et al*. studied the antibacterial activity of *Acacia jacquemontii* methanolic and *n*-hexane extracts against *B. subtilis* ATCC1692, *Micrococcus luteus* ATCC 4925, *S. epidermidis* ATCC 8724, *Bacillus pumilus* ATCC 13835, *S. aureus* ATCC 6538, *E. coli* ATCC 25922, *Bordetella bronchiseptica* ATCC 7319, and *P. aeruginosa* ATCC 9027. The highest MIC of the methanolic and *n*-hexane extract was reported as 0.50 and 1.00 mg/mL against *B. subtilis*, respectively[63]. The stem bark extract of *A. nilotica* showed potential antibacterial activity against *Streptococcus viridans*, *S. aureus*, *E. coli*, *B. subtilis*, and *S. sonnei* with MIC values of 35 and 50 mg/mL as well as MBC values of 35 and 60 mg/mL against *B. subtilis* and *S. sonnei*, respectively[64]. The antibacterial activity of *A. sieberiana* stem bark, root bark, and leaves was examined against many bacterial strains, including *S. paratyphi* ATCC 9150, *K. pneumoniae* ATCC 13883, *S. sonnei* ATCC 25931, *E. cloacae* ATCC 23355, *P. aeruginosa* ATCC 27853, *E. coli* ATCC 25922, and *E. faecalis* ATCC 25923. All of the test bacteria were susceptible to the crude plant extracts. Root bark and stem bark showed significant antibacterial activity with MIC values of 0.16 mg/mL to 2.5 mg/mL[65]. Furthermore, Muddathir *et al*. determined the antibacterial activity of methanolic extract and its 4 elucidated fractions [F1-4] from *A. nilotica* bark against *Streptococcus sobrinus* and *Porphyromonas gingivalis* by using broth dilution method. The crude extract of *A. nilotica* showed MIC and MBC values of 0.5 mg/mL and 2 mg/mL against *Streptococcus sobrinus*

Table 3. The antibacterial activity of *Acacia* species using miscellaneous method.

Species	Part used	Extract/Fraction/ Isolated compounds	Strains	Method	Concentration tested	*In vitro*/*In vivo* studies	Ref.
Acacia ataxacantha	Bark	Dichloromethane, ethyl acetate, methanol and hydroalcolic extract	*S. aureus*, methicillin resistant *S. aureus*, *P. aeruginosa*, *S. epidermidis*, *E. faecalis*, and *E. coli*	Microdilution method	10 mg/mL	*In vitro*	[53]
Acacia podalyriifolia	Flower	Dichloromethane and ethanolic extract, and ethyl acetate fraction; naringenin, 5-β-*D*-glycosyl naringenin isolated compound	*K. pneumoniae*, *S. aureus*, *E. coli*, *S. epidermidis*, *P. aeruginosa*, *S. pyogenes*, *Proteus mirabilis*, and *S. typhimurium*	Minimum inhibitory concentration	0.075, 0.125, 0.25, 0.5, 1 and 2 mg/mL	*In vitro*	[54]
Acacia saligna	Flower	Water extract	*Agrobacterium tumefaciens*, *Erwinia amylovora*, *Carotovorum*, *Enterobacter cloacae*, and *Pectobacterium carotovorum* subsp.	Microdilution method	4-350 μg/mL	*In vitro*	[55]
Acacia polyacantha	Bark and leaf	Methanol extract of leaf and bark, leaf fraction, as well as isolated compounds from leaf extract	*E. coli*, *K. pneumoniae*, *P. aeruginosa*, *Providencia stuartii*, and *Enterobacter aerogenes*	Microplate dilution method	8-1 024 μg/mL	*In vitro*	[56]
Acacia galpinii	Leaf	Acetone and chloroform extract	*E. coli* and *S. aureus*	Serial dilution microliter method	20 mg/mL	*In vitro*	[57]
Acacia karroo	Leaf	Acetone and chloroform extract	*S. aureus* and *E. coli*	Serial dilution microliter method	20 mg/mL	*In vitro*	[57]
Acacia xanthophloea	Leaf	Acetone and chloroform extract	*S. aureus* and *E. coli*	Serial dilution microliter method	20 mg/mL	*In vitro*	[57]
Acacia sieberiana	Leaf	Acetone and chloroform extract	*S. aureus* and *E. coli*	Serial dilution microliter method	20 mg/mL	*In vitro*	[57]
Acacia nilotica	Leaf, bark, and root	Dichloromethane, ethyl acetate, and ethanol extract	*Mycobacterium aurum*	Microdilution method	0.195-1.5 mg/mL	*In vitro*	[15]
Acacia sieberiana	Leaf, bark, and root	Dichloromethane, ethyl acetate, and ethanol extract	*Mycobacterium aurum*	Microdilution method	0.195-1.5 mg/mL	*In vitro*	[15]
Acacia kempeana	Leaves	Ethanol extract	*E. coli*, *K. pneumoniae*, *P. aeruginosa*, *S. typhimurium*, *B. cereus*, *E. faecalis*, *S. aureus*, and *S. pyogenes*	Plate hole diffusion method	0.48, 0.405, 0.77, 0.8, 0.825, 1.01, 1.21, 1.375, 1.52, 1.63, 1.605 and 1.8 mg/mL	*In vitro*	[58]
Acacia tetragonophylla	Leaves	Ethanol extract	*K. pneumoniae*, *B. cereus*, *E. coli*, *S. typhimurium*, *E. faecalis*, *S. aureus*, *S. pyogenes*, and *P. aeruginosa*	Plate hole diffusion method	0.48, 0.405, 0.77, 0.8, 0.825, 1.01, 1.21, 1.375, 1.52, 1.63, 1.605 and 1.8 mg/mL	*In vitro*	[58]
Acacia saligna	Leaves	Methanol extract	*E. coli* ATCC 35210, *P. aeruginosa* ATCC 27853, *Listeria monocytogenes* clinical isolate, *Micrococcus flavus* ATCC 10240, *S. aureus* ATCC 6538, and *B. cereus* ATCC 14579	Microdilution method	2 μL	*In vitro*	[59]
Acacia seyal	Bark	Methanolic and water extract; methanolic extracts devoid of tannins and its12 fraction (F1 to F12); free tannin precipitate from methanolic extracts; isolated compounds: lupeol, epicatechin, and catechin	*E. coli*, *S. aureus*, *P. aeruginosa*, *Corynebacterium urealyticum*, *Shigella sonnei*, *Salmonella enterica* sv. *Typhi*, *K. pneumoniae*, *S. epidermidis*, and *Streptococcus agalactiae*	Broth microdilution method	0.05 mL	*In vitro*	[60]

Table 3. The antibacterial activity of *Acacia* species using miscellaneous method (continued).

Species	Part used	Extract/Fraction/ Isolated compounds	Strains	Method	Concentration tested	*In vitro*/*In vivo* studies	Ref.
Acacia macrostachya	Stem bark	Methanol extract, ethyl acetate, and methanol fraction as well as petroleum ether	*S. pyogenes*, *S. aureus* (ATCC 25923), *P. aeruginosa* (ATCC 27853), and *E. coli* (ATCC 25922)	High throughput spot culture growth inhibition assay	7.8-500 µg/mL	*In vitro*	[61]
Acacia salicina	Leaves	Methanol, aqueous, total oligomer and flavonoids extract	*S. aureus* ATCC25923, *S. typhimurium* NRRLB 4420, *E. coli* ATCC 25922, *E. faecalis* ATCC25922, and *Salmonella enteritidis* ATCC 13076	Microdilution method	62.5 µg/mL-10 mg/mL	*In vitro*	[62]
Acacia jacquemontii	Leaves	Methanol and *n*-hexane extract	*Bordetella bronchiseptica* ATCC 7319, *B. subtilis* ATCC1692, *S. aureus* ATCC 6538, *Micrococcus luteus* ATCC 4925, *Bacillus pumilus* ATCC 13835, *E. coli* ATCC 25922, *P. aeruginosa* ATCC 9027, and *S. epidermidis* ATCC 8724	Microdilution method	64 mg/mL	*In vitro*	[63]
Acacia nilotica	Bark	Ethyl acetate and methanolic extract	*S. aureus*, *B. subtilis*, *Streptococcus viridans*, *E. coli* and *Shigella sonnei*	Microdilution method	5, 10, 15, 20, 25, and 30 mg/mL	*In vitro*	[64]
Acacia sieberiana	Leave, stem bark, and root bark	Ethanolic extract	*S.paratyphi* ATCC 9150, *K. pneumoniae* ATCC 13883, *Shigella sonnei* ATCC 25931, *Enterobacter cloacae* ATCC 23355, *P. aeruginosa* ATCC 27853, and *E. coli* ATCC 25922	Broth dilution method	0.16-2.5 mg/mL	*In vitro*	[65]
Acacia nilotica	Bark	Methanolic extract and its elucidated fraction (F1-F4)	*Streptococcus sobrinus* 6715, and *Porphyromonas gingivalis* ATCC 33277	Broth dilution method	10-100 µL	*In vitro*	[66]

and *Porphyromonas gingivalis*, respectively. However, the fractions (F1 and F2) showed an MIC value of 0.3 mg/mL against *Porphyromonas gingivalis*. F2 also displayed an MBC value of 1 mg/mL against both bacteria[66]. The summary of the above-mentioned antibacterial activities of *Acacia* genus is reported in Table 3.

3. Antifungal activities reported in *Acacia* genus

Fungal infections are the main cause of sickness and mortality in people with immunological deficiencies, and they can be fatal in both developed and developing countries[67,68]. The majority of fungal infections are persistent and frequently require extended chemotherapy and involve specific dangers for persons with impaired immune systems[69]. The various antifungal activities reported in *Acacia* genus are highlighted in this section.

3.1. Disc diffusion method–based antifungal activities reported in Acacia genus

Two different *Acacia* species *A. arabica* and *Acacia raddiana* (*A. raddiana*) were studied for the antifungal activity against *Candida albicans* (*C. albicans*) and *Aspergillus niger* (*A. niger*). The ZOI diameter of *A. arabica* and *A. raddiana* extracts was 36.10 and 37.50 mm against *C. albicans*, as well as 59.50 and 68.40 mm against *A. niger*, respectively. Additionally, the MIC values for *A. arabica* extract were found to be 0.105 and 0.079 mg/mL against *C. albicans* and *A. niger*, respectively, whereas for *A. raddiana* extract, 0.088 and 0.079 mg/mL against *C. albicans* and *A. niger*, respectively. On the other hand, the minimum fungicidal concentration (MFC) for *A. arabica* was 0.105 and 0.158 mg/mL, while for *A. raddiana*, 0.088 and 0.158 mg/mL against *C. albicans* and *A. niger*, respectively[70].

The aqueous extract of *A. nilotica* leaves was screened against fungal strains [*C. albicans*, *A. niger*, and *Aspergillus fumigatus* (*A. fumigatus*)] to verify its antifungal activity. The ZOI was 10 and 11 mm against *C. albicans* at 10 and 20 mg/mL, respectively, 8, 8, and 12 mm against *A. niger* at 5, 10, and 20 mg/mL, respectively, and 8, 9, and 13 mm against *A. fumigatus* at 5, 10, and 20 mg/mL, respectively. However, no inhibition was observed at 2.5 mg/mL against each strain[71]. The isolated compounds from *Acacia ataxacantha* were analyzed for antifungal activity against *C. albicans*. The isolated compounds *i.e.*, lupeol and betulinic acid did not show any activity

against the test organism at 100 μg/mL whereas betulinic acid-3-*trans*-caffeate was effective against the test organism with a ZOI of 15.7 mm at the same concentration. The MIC and MFC of betulinic acid-3-*trans*-caffeate were 12.5 and 25 μg/mL, respectively[40]. The summary of the above-mentioned antifungal activities of *Acacia* genus is reported in Table 4.

3.2. Agar diffusion method–based antifungal activities of *Acacia* genus

A comparison of two different *Acacia* species *Acacia mangium* and *A. auriculiformis* was performed based on their antifungal properties. The heartwood extract, fraction, and isolated compounds of the plants were tested against two fungal strains *Phellinus noxius* and *Phellinus badius* using agar dilution bioassay. The results revealed that the methanol extract was found to be most effective against fungal growth. As compared to *A. auriculiformis*, *Acacia mangium* extracts had little or no effect on the growth of *Phellinus badius* and *Phellinus noxius*[72]. Five different extracts (*n*-hexane, chloroform, diethyl ether, ethyl acetate, and methanol) of *A. catechu* heartwood were determined for the antifungal properties against *Fusarium moniliforme* (*F. moniliforme*), *Fusarium oxysporum* (*F. oxysporum*), *Exherlium turticum* (*E. turticum*) and *Fusarium proliferatum*. The ethyl acetate extract displayed the highest ZOI against *F. oxysporum*. In comparison, the *n*-hexane extract demonstrated weak activity with a ZOI of 8 mm against *F. moniliforme* whereas the chloroform and methanol extracts displayed moderate activity with ZOI of 9, 9, and 10 mm, against *F. oxysporum*, *F. moniliforme* and *E. turticum*, respectively and 10, 7, and 8 mm against *F. oxysporum*, *Fusarium proliferatum* and *E. turticum*, respectively. Moreover, the diethyl ether and ethyl acetate displayed good activity with ZOI of 10, 11, 10, and 11 mm and 17, 9, 9, and 14 mm against *F. oxysporum*, *F. moniliforme*, *Fusarium proliferatum*, and *E. turticum*, respectively[48].

According to the study of Bwai *et al*., the fruit extracts of *A. nilotica* exhibited antifungal efficacy at doses from 125 mg/mL to 500 mg/mL. The extracts displayed ZOI of 9.00 mm to 17.00 mm against *A. niger* and *Aspergillus flavus* (*A. flavus*), respectively, whereas *F. oxysporum* was inhibited by the extracts at 500 mg/mL and 250 mg/mL with ZOI of 11.00 mm and 9.00 mm, respectively. However, only at 500 mg/mL, *A. nilotica* extracts exhibited antifungal activity against *Penicillium* spp[73]. The antifungal activity of *A. tortilis* gum aqueous extract was analyzed against eight fungal strains including *Aspergillus ochraceus*, *A. fumigatus*, *A. niger*, *Aspergillus parasiticus*, *Penicillium expansum*, *A. flavus*, *F. oxysporum*, and *Alternaria* sp. The aqueous extracts demonstrated enhanced antifungal activity with increasing extract dilution (1/100, 1/250, 1/500, 1/1 000 and 1/5 000). Among all fungal strains, *F. oxysporum* showed more resistance to the extracts[74].

The heartwood ethanolic extract and three fractions (petroleum ether, benzene, and ethyl acetate) of *A. raddiana* were found to be effective as an antifungal agent. The results showed that the ZOI of the ethanolic extract against *C. albicans* was 9.60 mm and the petroleum ether fraction effectively prevented all fungal strains. However, with 10.42 mm ZOI, *C. albicans* and *Trichophyton rubrum* showed the maximum inhibition. In addition, the benzene fraction was effective against all the fungal strain with the maximum inhibition of 10.21 mm against *Trichophyton rubrum* and *C. albicans*, respectively[75]. The crude extracts of *Acacia ampliceps* stem bark were determined for their antifungal activity against four fungal strains *Acremoniums* spp, *A. niger*, *Rhizopus* spp, and *Trichoderma*. The results showed that *A. niger* was more susceptible to the extracts than *Rhizopus* and *Acremonium* spp. The methanolic extract was more potent as compared to the ethanolic extract with the ZOI of 20, 20, and 22 mm at 1 000 μg/mL against *Acremonium* spp, *Rhizopus* spp., and *Trichoderma*, respectively[76].

Nilobamate isolated from *A. nilotica* was evaluated for antifungal activity against two fungal strains (*A. fumigatus* and *C. albicans*). Mbatchou *et al*, pointed out that the compound showed varying degrees of inhibition against *A. fumigatus* at different concentrations with no inhibitory activity against *C. albicans*[77]. *A. catechu* bark ethanolic extract was analyzed based on its antifungal activity against three human pathogenic fungal strains (*Microsporum gypseum*, *Epidermophyton floccosum*, and *Trichophyton rubrum*). It was noted that the ethanolic extract had no significant effect on each strain and could not be further used for cutaneous infection[78]. The methanolic and aqueous extracts of *Acacia concinna* leaf and seed were analyzed for its antifungal activity against some fungal strains [*Alternaria alternata* (*A. alternata*) K3, *F. oxysporum* S10, *Fusarium solani* L16, *A. flavus* J12, and *Colletotrichum falcatum* Went C9]. The results showed that the *Acacia concinna* extracts inhibited fungal growth[79]. The summary of the above-mentioned antifungal activities of *Acacia* genus is reported in Table 5.

Table 4. The antifungal activity of *Acacia* species using disc diffusion method.

Species	Part used	Extract/Fraction/Isolated compounds	Strains	Concentration tested	*In vitro*/*In vivo* studies	Ref.
Acacia arabica	Seeds	Hexane extract	*Candida albicans* (*C. albicans*) and *Aspergillus niger* (*A. niger*)	10 μL	*In vitro*	[70]
Acacia raddiana	Seeds	Hexane extract	*C. albicans* and *A. niger*	10 μL	*In vitro*	[70]
Acacia nilotica	Leaves	Hot aqueous extract	*C. albicans*, *A. niger*, and *Aspergillus fumigatus*	2.5, 5, 10 and 20 mg/mL	*In vitro*	[71]
Acacia ataxacantha	Bark	Lupeol, betulinic acid, and betulinic acid-3-*trans*-caffeate	*C. albicans*	100 μg/mL	*In vitro*	[40]

3.3. Miscellaneous method–based antifungal activities of Acacia genus

The ethanol extracts of *Acacia robusta* leaf and *A. nilotica* stem bark were screened for antifungal properties against [*C. albicans*, *Candida glabrata*, *Candida parapsilosis*, *Candida tropicalis*, *Candida krusei* (*C. krusei*), and *Cryptococcus neoformans*]. The MIC values of *Acacia robusta* were 1 000, 63, 500, 31, and 4 000 μg/mL against *Candida glabrata*, *Candida parapsilosis*, *Candida tropicalis*, *C. krusei*, and *Cryptococcus neoformans*, respectively, while for *A. nilotica*, 31, 63, 1 000, and 4 000 μg/mL against *Candida parapsilosis*, *Candida tropicalis*, *C. krusei*, and *Cryptococcus neoformans*, respectively[80].

The *in vitro* antifungal potential of *A. senegal* and *A. tortilis* was assessed against *Helminthosporium rostratum*, *Fusarium solani*, and *A. alternata*. At concentrations of 1.0%, 2.5%, and 5.0%, the aqueous extracts of *A. senegal* showed no inhibition against *A. alternata*. Moreover, *A. senegal* aqueous extracts exhibited a slight effect on the growth of *Helminthosporium rostratum* at 2.5% and 5.0% concentrations but no antifungal activity at 1.0% concentration. The growth of *A. alternata* was unaffected by the aqueous extract of *A. tortilis* at concentrations of 1.0% and 2.5%. However, at 5.0% concentration, it inhibited the growth of *A. alternata* by 47.9%. Furthermore, *Helminthosporium rostratum* showed no activity at 1.0% concentration, but at 2.5 % and 5.0%, it showed 5.3% and 43.8% of inhibition, respectively. Whereas, the modest efficacy of the extract of *A. tortilis* against *Fusarium solani* increased with increasing concentrations, showing 8.8%, 18.5%, and 19.4% of inhibition, respectively[81].

The leaf and stem methanolic extracts of *Acacia karoo* were determined for the antifungal property against *C. albicans* and

Table 5. The antifungal activity of *Acacia* species using agar diffusion method.

Species	Part used	Extract/Fraction/Isolated compounds	Strains	Concentration tested	*In vitro*/*In vivo* studies	Ref.
Acacia mangium	Heartwood	Methanol extract and diethyl ether, ethyl acetate, *n*-butanol fraction; 3,4',7,8-tetrahydroxyflavonone and teracacidin	*Phellinus noxius* and *Phellinus badius*	0.1, 1.0, and 10.0 mg/mL	*In vitro*	[72]
Acacia auriculiformis	Heartwood	Methanol extract and diethyl ether, ethyl acetate, *n*-butanol fraction; 3,4',7,8-tetrahydroxyflavonone and teracacidin	*Phellinus noxius* and *Phellinus badius*	0.1, 1.0, and 10.0 mg/mL	*In vitro*	[72]
Acacia catechu	Heartwood	Chloroform, methanol diethyl ether, hexane, and ethyl acetate extract	*Fusarium oxysporum* (*F. oxysporum*), *Fusarium moniliforme*, *Fusarium proliferatum*, and *Exherlium turticum*	5% solution	*In vitro*	[48]
Acacia nilotica	Fruit	Ethanol extract	*F. oxysporum*, *A. niger*, *Aspergillus flavus* (*A. flavus*), and *Penicillium* spp	125, 250 and 500 mg/mL	*In vitro*	[73]
Acacia tortilis	Gum	Aqueous extract	*Penicillium expansum*, *Aspergillus parasiticus*, *Aspergillus ochraceus*, *Aspergillus fumigatus*, *A. flavus*, *A. niger*, *F. oxysporum* and *Alternaria* sp	100, 250, 500, 1 000 and 5 000 mg/mL	*In vitro*	[74]
Acacia raddiana	Heartwood	Ethanol extract	*Aspergillus niger*, *A. flavus*, *Penicillium chrysogenum*, *C. albicans*, and *Trichophyton rubrum*	4 mg/mL	*In vitro*	[75]
Acacia ampliceps	Stem bark	Ethanol and methanol extract	*Acremonium* spp., *A. niger*, *Rhizopus* spp. and *Trichoderma* spp	500 and 1 000 μg/mL	*In vitro*	[76]
Acacia nilotica	Seed pods	Nilobamate	*Aspergillus fumigatus*, and *C. albicans*	500, 1 000, 1 500, 2 000 and 2 500 μg/mL	*In vitro*	[77]
Acacia catechu	Bark	Ethanol extract	*Microsporum gypseum* MTCC No. 2819, *Trichophyton rubrum* MTCC No. 296, and *Epidermophyton floccosum* MTCC No. 613	15, 25, and 50 mg/mL	*In vitro*	[78]
Acacia concinna	Leaf and seed	Methanolic and aqueous extract	*Alternaria alternata* K3, *F. oxysporum* S10, *Fusarium solani* L16, and *A. flavus* J12, *Colletotrichum falcatum*	0.04 mL	*In vitro*	[79]

Table 6. The antifungal activity of *Acacia* species using miscellaneous method.

Species	Part used	Extract/Fraction/ Isolated compounds	Strains	Method used	Concentration tested	*In vitro*/*In vivo* studies	Ref.
Acacia robusta	Leaves	Methanol extract	*Candida krusei*, *Cryptococcus neoformans*, *Candida glabrata*, *Candida parapsilosis*, *C. albicans*, and *Candida tropicalis*	Broth microdilution method	40%	*In vitro*	[80]
Acacia nilotica	Stem bark	Methanol extract	*Candida parapsilosis*, *C. albicans*, *Candida krusei*, *Cryptococcus neoformans*, *Candida glabrata*, and *Candida tropicalis*	Broth microdilution method	40%	*In vitro*	[80]
Acacia senegal	Gum	Aqueous extract	*Helminthosporium rostratum*, *Fusarium solani*, and *Alternaria alternata*	Poisoned food technique	1.0%, 2.5% and 5.0%	*In vitro*	[81]
Acacia tortilis	Gum	Aqueous extract	*Helminthosporium rostratum*, *Fusarium solani*, and *Alternaria alternata*	Poisoned food technique	1.0%, 2.5% and 5.0%	*In vitro*	[81]
Acacia karroo	Stem and leaves	Methanol extract	*C. albicans*, *Microsporum audouinii*	Micro dilution method	0.31-78.12 μg/mL	*In vitro*	[3]
Acacia mangium	Bark	Acetone, toluene/ ethanol, and water extract	*Coriolus versicolor*, *Poria placenta*	Growth inhibition assay	100 and 500 ppm	*In vitro*	[82]
Acacia mearnsii	Stem bark	Acetone extract	*Penicillium notatum*, *C. albicans*, *A. niger*, *Candida rugosa*, *Candida glabrata* ATCC 2001, *Absidia corymbifera*, *Fusarium sporotrichioides*, *Trichophyton tonsurans*, *Candida krusei*, *Trichophyton mucoides* ATCC 201382, *Aspergillus terreus*, and *A. flavus*	Serial tube dilution technique	100 and 500 ppm	*In vitro*	[51]

Microsporum audouinii. The MIC value was 78.12 and 625 μg/mL for the leaf extract while 156.25 and 78.12 μg/mL for the stem extract against *C. albicans* and *Microsporum audouinii*, respectively. Additionally, the MFC value was 312.50 and 1 250 μg/mL for the leaf extract, whereas 312.50 and 312.50 μg/mL for the stem extract against *C. albicans* and *Microsporum audouinii*, respectively[3]. *Acacia mangium* bark extract (acetone, toluene, and water) was examined to verify its antifungal property by using two fungal strains (*Coriolus versicolor* and *Poria placenta*). The ZOI of the acetone, toluene/ethanol, and water extracts was reported as 2.55, 2.00, and 5.29 mm and 6.86, 2.35, and 15.10 mm against *Coriolus versicolor* at 100 and 500 ppm. In contrast, the ZOI of acetone, toluene/ethanol, and water extracts was 5.69, 4.71, and 52.35 mm and 23.92, 42.16, and 55.59 mm against *Poria placenta* at 100 and 500 ppm[82].

The crude acetone extract of *A. mearnsii* stem bark was evaluated against 12 fungal strains (*C. albicans*, *Candida rugosa*, *C. krusei*, *Aspergillus terreus*, *A. flavus*, *Trichophyton tonsurans*, *Penicillium notatum*, *Absidia corymbifera*, *A. niger*, *Fusarium sporotrichioides*, *Trichophyton mucoides* ATCC 201382, and *Candida glabrata* ATCC 2001). The MIC and MFC ranged between 625-5 000 μg/mL and 625-5 000 μg/mL against various fungal strains, respectively[51]. The summary of the above-mentioned antifungal activities of *Acacia* genus is presented in Table 6.

4. Conclusion

The antimicrobial activities including antibacterial and antifungal activities of *Acacia* are highlighted in this article. The various bacterial and fungal stains such as *S. aureus*, *E. coli*, *S. typhi*, *P. aeruginosa*, *K. pneumoniae*, and *C. albicans*, *F. oxysporum*, *A. niger*, and *A. flavus* are inhibited by various extracts and phytoconstituents of *Acacia*. Overall, *Acacia* genus possesses moderate to high microbiological activity. Most of the species of *Acacia* genus are well explored for *in vitro* antimicrobial activities, but proper molecular mechanisms are still an issue of concern. Therefore, *Acacia* genus can be further explored for molecular pharmacological studies to produce potent antimicrobial agents.

Conflict of interest statement

All authors declare no conflict of interest.

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Authors' contributions

NKR contributed to conceptualization; DA was responsible for design of study and supervision, literature search, writing, and original draft preparation. Both NKR and DA contributed to the final version of the manuscript. All authors have read and agreed to the published version of the manuscript.

References

[1] Ziani BE, Carocho M, Abreu RM, Bachari K, Alves MJ, Calhelha RC, et al. Phenolic profiling, biological activities and *in silico* studies of *Acacia tortilis* (Forssk.) Hayne ssp. *Acacia raddiana* extracts. *Food Biosci* 2020; **36**: 100616. doi: 10.1016/j.fbio.2020.100616.

[2] Balganesh T, Kundu TK, Chakraborty TK, Roy S. Drug discovery research in India: Current state and future prospects. *ACS Med Chem Lett* 2014; **5**(7): 724-726.

[3] Nielsen TR, Kuete V, Jäger AK, Meyer JJM, Lall N. Antimicrobial activity of selected South African medicinal plants. *BMC Complement Altern Med* 2012; **12**(1): 1-6.

[4] Subhan N, Burrows GE, Kerr PG, Obied HK. Phytochemistry, ethnomedicine, and pharmacology of *Acacia*. *Stud Nat Prod Chem* 2018; **57**: 247-326.

[5] Agunu A, Yusuf S, Andrew GO, Zezi AU, Abdurahman EM. Evaluation of five medicinal plants used in diarrhoea treatment in Nigeria. *J Ethnopharmacol* 2005; **101**(1-3): 27-30.

[6] Lassack EV, McCarthy TM. *Australian medicinal plants: A complete guide to identification and usage.* 2nd edition. New Holland Publisher; 1983, p.186.

[7] Waly NM, Emad HM. Taxonomical studies of some *Acacia* spp. growing in Saudi Arabia. *Bull Env Pharmacol Life Sci* 2012; **1**(10): 55-62.

[8] Lorenzo P, González L, Reigosa MJ. The genus *Acacia* as invader: The characteristic case of *Acacia dealbata* Link in Europe. *Ann For Sci* 2010; **67**(1): 101.

[9] Alajmi MF, Alam P, Alqasoumi SI, Siddiqui NA, Basudan OA, Hussain A, et al. Comparative anticancer and antimicrobial activity of aerial parts of *Acacia salicina*, *Acacia laeta*, *Acacia hamulosa* and *Acacia tortilis* grown in Saudi Arabia. *Saudi Pharma J* 2017; **25**(8): 1248-1252.

[10]Ogunbinu AO, Okeniyi S, Flamini G, Cioni PL, Ogunwande IA, Babalol IT. Essential oil composition of *Acacia nilotica* Linn., and *Acacia albida* Delile (Leguminosae) from Nigeria. *J Essent Oil Res* 2010; **22**(6): 540-542.

[11]Aref IM, Khan PR, Al-Mefarrej H, Al-Shahrani T, Ismail A, Iqbal M. Cambial periodicity and wood production in *Acacia ehrenbergiana* Hayne growing on dry sites of Saudi Arabia. *J Environ Biol* 2014; **35**(2): 301.

[12]Geissler PW, Harris SA, Prince RJ, Olsen A, Achieng'Odhiambo R, Oketch-Rabah H, et al. Medicinal plants used by Luo mothers and children in Bondo district, Kenya. *J Ethnopharmacol* 2002; **83**(1-2): 39-54.

[13]Dongmo A, Nguelefack T, Lacaille-Dubois M. Antinociceptive and anti-inflammatory activities of *Acacia pennata* wild (Mimosaceae). *J Ethnopharmacol* 2005; **98**(1-2): 201-206.

[14]Aboelsoud NH. Herbal medicine in ancient Egypt. *J Med Plant Res* 2010; **4**(2): 82-86.

[15]Eldeen I, Van Staden J. Antimycobacterial activity of some trees used in South African traditional medicine. *S Afr J Bot* 2007; **73**(2): 248-251.

[16]Li RW, Myers SP, Leach DN, Lin GD, Leach G. A cross-cultural study: Anti-inflammatory activity of Australian and Chinese plants. *J Ethnopharmacol* 2003; **85**(1): 25-32.

[17]Kala CP, Dhyani PP, Sajwan BS. Developing the medicinal plants sector in northern India: Challenges and opportunities. *J Ethnobiol Ethnomed* 2006; **2**(1): 1-15.

[18]Singh R, Singh S, Kumar S, Arora S. Evaluation of antioxidant potential of ethyl acetate extract/fractions of *Acacia auriculiformis* A. Cunn. *Food Chem Toxicol* 2007; **45**(7): 1216-1223.

[19]Clement BA, Goff CM, Forbes TDA. Toxic amines and alkaloids from *Acacia berlandieri*. *Phytochemistry* 1997; **46**(2): 249-254.

[20]Seigler DS. Phytochemistry of *Acacia*-sensu lato. *Biochem Syst Ecol* 2003; **31**(8): 845-873.

[21]Haridas V, Higuchi M, Jayatilake GS, Bailey D, Mujoo K, Blake ME, et al. Avicins: Triterpenoid saponins from *Acacia victoriae* (Bentham) induce apoptosis by mitochondrial perturbation. *Proc Natl Acad Sci* 2001; **98**(10): 5821-5826.

[22]Readel K, Seigler D, Hwang K, Keesy J, Seilheimer S. Tannins from mimosoid legumes of Texas and Mexico. *Econ Bot* 2001; **55**(2): 212-222.

[23]Singh BN, Singh B, Singh R, Prakash D, Sarma B, Singh H. Antioxidant and anti-quorum sensing activities of green pod of *Acacia nilotica* L. *Food Chem Toxicol* 2009; **47**(4): 778-786.

[24]Amoussa AMO, Sanni A, Lagnika L. Chemical diversity and pharmacological properties of genus *Acacia*. *Asian J Appl Sci* 2020; **13**(2): 40-59.

[25]Sanchez C, Nigen M, Tamayo VM, Doco T, Williams P, Amine C, et al. *Acacia* gum: History of the future. *Food Hydrocoll* 2018; **78**: 140-160.

[26]Duarte MCT, Figueira GM, Sartoratto A, Rehder VLG, Delarmelina C. Anti-*Candida* activity of Brazilian medicinal plants. *J Ethnopharmacol* 2005; **97**(2): 305-311.

[27]Ghasemi PA, Jahanbazi P, Enteshari S, Malekpoor F, Hamedi B. Antimicrobial activity of some Iranian medicinal plants. *Arch Biol Sci*

2010; **62**(3): 633-641.

[28]Egamberdieva D, Shurigin V, Alaylar B, Wirth S, Bellingrath-Kimura SD. Bacterial endophytes from horseradish (*Armoracia rusticana* G. Gaertn., B. Mey. & Scherb.) with antimicrobial efficacy against pathogens. *Plant Soil Environ* 2020; **66**(7): 309-316.

[29]Nikolic M, Jovanovic KK, Markovic T, Markovic D, Gligorijevic N, Radulovic S, et al. Chemical composition, antimicrobial, and cytotoxic properties of five Lamiaceae essential oils. *Ind Crops Prod* 2014; **61**: 225-232.

[30]Mahato TK, Sharma K. Study of medicinal herbs and its antibacterial activity: A review. *J Drug Deliv Ther* 2018; **8**(5-s): 47-54.

[31]Mutai C, Bii C, Vagias C, Abatis D, Roussis V. Antimicrobial activity of *Acacia mellifera* extracts and lupane triterpenes. *J Ethnopharmacol* 2009; **123**(1): 143-148.

[32]Mazzei R, Leonti M, Spadafora S, Patitucci A, Tagarelli G. A review of the antimicrobial potential of herbal drugs used in popular Italian medicine (1850s-1950s) to treat bacterial skin diseases. *J Ethnopharmacol* 2020; **250**: 112443.

[33]Mohammed GJ, Kadhim MJ, Hameed IH. *Proteus* species: Characterization and herbal antibacterial: A review. *Int J Pharmacogn Phytochem Res* 2016; **8**(11): 1844-1854.

[34]Arias ME, Gomez J, Cudmani NM, Vattuone MA, Isla MI. Antibacterial activity of ethanolic and aqueous extracts of *Acacia aroma* Gill. ex Hook et Arn. *Life Sci* 2004; **75**(2): 191-202.

[35]Tambekar DH, Khante B, Chandak B, Titare A, Boralkar S, Aghadte S. Screening of antibacterial potentials of some medicinal plants from Melghat forest in India. *Afr J Tradit Complement Altern Med* 2009; **6**(3). doi: 10.4314/ajtcam.v6i3.57158.

[36]Cavazos P, Gonzalez D, Lanorio J, Ynalvez R. Secondary metabolites, antibacterial and antioxidant properties of the leaf extracts of *Acacia rigidula* benth. and *Acacia berlandieri* benth. *SN Appl Sci* 2021; **3**(5): 1-14.

[37]Saini ML, Saini R, Roy S, Kumar A. Comparative pharmacognostical and antimicrobial studies of *Acacia* species (Mimosaceae). *J Med Plant Res* 2008; **2**(12): 378-386.

[38]Mutai C, Bii C, Rukunga G, Ondicho J, Mwitari P, Abatis D, et al. Antimicrobial activity of pentacyclic triterpenes isolated from *Acacia mellifera*. *Afr J Tradit Complement Altern Med* 2009; **6**(1): 42-48.

[39]Ntshanka NM, Ejidike IP, Mthunzi FM, Moloto MJ, Mubiayi KP. Investigation into the phytochemical profile, antioxidant and antibacterial potentials of *Combretum molle* and *Acacia mearnsii* leaf parts. *Biomed Pharmaco J* 2020; **13**(4): 1683-1694.

[40]Amoussa AMO, Lagnika L, Bourjot M, Vonthron-Senecheau C, Sanni A. Triterpenoids from *Acacia ataxacantha* DC: Antimicrobial and antioxidant activities. *BMC Complement Altern Med* 2016; **16**(1): 1-8.

[41]Al Alawi SM, Hossain MA, Abusham AA. Antimicrobial and cytotoxic comparative study of different extracts of Omani and Sudanese Gum acacia. *Beni–Suef Univ J Basic Appl Sci* 2018; **7**(1): 22-26.

[42]Daffalla HM, Ali KS, Tajelser T, Hagr TE, Ahmed NS, Ahmed RH. Larvicidal and antibacterial activities of methanol extract of *Acacia polyacantha* Willd. *J Adv Res Pharm Sci Pharmacol Interv* 2018; **2**(2): 7-11.

[43]Babu RA, Aswathy TR, Indu S, Nair AS. Pharmacognostic and antibacterial activity evaluation of *Acacia caesia* (L.) Willd. *J Pharmacogn Phytochem* 2020; **9**(3): 48-54.

[44]Lalitha S, Rajeshwaran K, Kumar PS, Deepa K, Gowthami K. *In vivo* screening of antibacterial activity of *Acacia mellifera* (BENTH) (Leguminosae) on human pathogenic bacteria. *Glob J Pharmacol* 2010; **4**(3): 148-150.

[45]Okoro S, Kawo A, Arzai A. Phytochemical screening, antibacterial and toxicological activities of *Acacia senegal* extracts. *Bayero J Pure Appl Sci* 2012; **5**(1): 163-170.

[46]Negi BS, Dave BP. *In vitro* antimicrobial activity of *Acacia catechu* and its phytochemical analysis. *Indian J Microbiol* 2010; **50**(4): 369-374.

[47]Gmaraldeen SM, Magzoub AA, Badri AM, Garbi MI, Saleh MS. Antibacterial activity of *Acacia nilotica* fruits extract against pathogenic bacteria. *Int J Appl Res* 2016; **2**(6): 103-106.

[48]Joshi S, Subedi YP, Paudel SK. Antibacterial and antifungal activity of heartwood of *Acacia catechu* of Nepal. *J Nepal Chem Soc* 2011; **27**: 94-99.

[49]Pennacchio M, Kemp AS, Taylor RP, Wickens KM, Kienow L. Interesting biological activities from plants traditionally used by Native Australians. *J Ethnopharmacol* 2005; **96**(3): 597-601.

[50]Aryal B, Adhikari B, Aryal N, Bhattarai BR, Khadayat K, Parajuli N. LC-HRMS profiling and antidiabetic, antioxidant, and antibacterial activities of *Acacia catechu* (Lf) willd. *Biomed Res Int* 2021; **2021**. doi: 10.1155/2021/7588711.

[51]Olajuyigbe OO, Afolayan AJ. Pharmacological assessment of the medicinal potential of *Acacia mearnsii* De Wild.: Antimicrobial and toxicity activities. *Int J Mol Sci* 2012; **13**(4): 4255-4267.

[52]Priyanka C, Kumar P, Bankar SP, Karthik L. *In vitro* antibacterial activity and gas chromatography-mass spectroscopy analysis of *Acacia karoo* and *Ziziphus mauritiana* extracts. *J Taibah Univ Sci* 2015; **9**(1): 13-19.

[53]Amoussa A, Lagnika L, Sanni A. *Acacia ataxacantha* (bark): Chemical composition and antibacterial activity of the extracts. *Int J Pharm Pharm Sci* 2014; **6**(11): 138-141.

[54]Andrade CA, Carvalho JLS, Cunico MM, Lordello ALL, Higaskino CEK, Almeida SCC, et al. Antioxidant and antibacterial activity of extracts, fractions and isolated substances from the flowers of *Acacia podalyriifolia* A. Cunn. ex G. Don. *Braz J Pharma Sci* 2010; **46**(4): 715-722.

[55]Al-Huqail AA, Behiry SI, Salem MZ, Ali HM, Siddiqui MH, Salem AZ. Antifungal, antibacterial, and antioxidant activities of *Acacia saligna* (Labill.) HL Wendl. flower extract: HPLC analysis of phenolic and flavonoid compounds. *Molecules* 2019; **24**(4): 700.

[56]Mambe FT, Na-Iya J, Fotso GW, Ashu F, Ngameni B, Ngadjui BT, et al. Antibacterial and antibiotic modifying potential of crude extracts, fractions, and compounds from *Acacia polyacantha* willd. against MDR Gram-negative bacteria. *Evid Based Complement Alternat Med* 2019;

2019. doi: 10.1155/2019/7507549.

[57]Katerere D, Eloff J. Variation in chemical composition, antibacterial and antioxidant activity of fresh and dried *Acacia* leaf extracts. *S Afr J Bot* 2004; **70**(2): 303-305.

[58]Palombo EA, Semple SJ. Antibacterial activity of traditional Australian medicinal plants. *J Ethnopharmacol* 2001; **77**(2-3): 151-157.

[59]Elansary HO, Szopa A, Kubica P, Ekiert H, Al-Mana F, Al-Yafrsi MA. Antioxidant and biological activities of *Acacia saligna* and *Lawsonia inermis* natural populations. *Plants* 2020; **9**(7): 908.

[60]Elmi A, Spina R, Risler A, Philippot S, Mérito A, Duval RE, et al. Evaluation of antioxidant and antibacterial activities, cytotoxicity of *Acacia seyal* Del bark extracts and isolated compounds. *Molecules* 2020; **25**(10): 2392.

[61]Barfour AF, Mensah AY, Asante-Kwatia E, Danquah CA, Anokwah D, Adjei S, et al. Antibacterial, antibiofilm, and efflux pump inhibitory properties of the crude extract and fractions from *Acacia macrostachya* stem bark. *Sci World J* 2021; **2021**. doi: 10.1155/2021/5381993.

[62]Boubaker J, Mansour HB, Ghedira K, Ghedira LC. Polar extracts from (Tunisian) *Acacia salicina* Lindl. Study of the antimicrobial and antigenotoxic activities. *BMC Complement Altern Med* 2012; **12**(1) :1-10.

[63]Ahmed M, Ahmad S, Aati HY, Sherif AE, Ashkan MF, Alrahimi J, et al. Phytochemical, antioxidant, enzyme inhibitory, thrombolytic, antibacterial, antiviral and *in silico* studies of *Acacia jacquemontii* leaves. *Arab J Chem* 2022; **15**(12): 104345.

[64]Banso A. Phytochemical and antibacterial investigation of bark extracts of *Acacia nilotica*. *J Med Plant Res* 2009; **3**(2): 82-85.

[65]Kirabo I, Mabiki FP, Mdegela RH, Obbo CJ. *In vitro* antibacterial potential of extracts of *Sterculia africana*, *Acacia sieberiana*, and *Cassia abbreviata* ssp. *abbreviata* used by yellow baboons (*Papio cynocephalus*) for possible self-medication in Mikumi National Park, Tanzania. *Int J Zool* 2018; **2018**. doi: 10.1155/2018/9407962.

[66]Muddathir AM, Mohieldin EA, Mitsunaga T. *In vitro* activities of *Acacia nilotica* (L.) delile bark fractions against oral bacteria, glucosyltransferase and as antioxidant. *BMC Complement Med Ther* 2020; **20**(1): 1-9.

[67]Murtaza G, Mukhtar M, Sarfraz A. A review: Antifungal potentials of medicinal plants. *J Bioresour Manag* 2015; **2**(2): 4.

[68]Moye-Rowley W. Multiple mechanisms contribute to the development of clinically significant azole resistance in Aspergillus fumigatus. *Front Microbiol* 2015; **6**: 70.

[69]Martin KW, Ernst E. Herbal medicines for treatment of fungal infections: A systematic review of controlled clinical trials. *Mycoses* 2004; **47**(3□4): 87-92.

[70]Tissouras F, Larid M, Lotmani B. Antifungal activities of seeds oils *Acacia arabica* and *Acacia raddiana* from the Hoggar region (southern Algeria). A*dv Environ Biol* 2014; **8**(10): 137-141.

[71]Sharma AK, Kumar A, Yadav SK, Rahal A. Studies on antimicrobial and immunomodulatory effects of hot aqueous extract of *Acacia nilotica* L. leaves against common veterinary pathogens. *Vet Med Int* 2014; **2014**. doi: 10.1155/2014/747042.

[72]Mihara R, Barry KM, Mohammed CL, Mitsunaga T. Comparison of antifungal and antioxidant activities of *Acacia mangium* and *Acacia auriculiformis* heartwood extracts. *J Chem Ecol* 2005; **31**(4): 789-804.

[73]Bwai M, Uzama D, Abubakar S, Olajide O, Ikokoh P, Magu J. Proximate, elemental, phytochemical and anti-fungal analysis of *Acacia nilotica* fruit. *Pharma Biol Eval* 2015; **2**(3): 52-59.

[74]Najett M, Snoussi M, Abderrahim C. Phytochemical screening and antifungal activity evaluation of gum arabic (*Acacia tortilis* forssk). *Plant Arch* 2020; **20**(2): 4022-4026.

[75]Singh R, Choudhary A, Ram R. Pharmacological assessment of the heartwood of *Acacia raddiana* Willd for antifungal potential. *Mater Today Proc* 2022; **62**(8): 5230-5234.

[76]Fatima MSK, Anwar M, Rahman S, Sajad MA. Antifungal activity of crude extracts of stem-bark of *Acacia ampliceps* Maslin. (Family Leguminosae). *Pure Appl Biol* 2019; **8**(2): 1690-1697.

[77]Mbatchou VC, Oumar AA. Antifungal activity of Nilobamate isolated from *Acacia nilotica* wild. *Phytopharmacology* 2012; **3**(1): 208-213.

[78]Thendral T, Lakshmi T. Antifungal activity of *Acacia catechu* bark extract against dermatophytes: An *in vitro* study. *J Adv Pharm Edu Res* 2017; **7**(1): 25-27.

[79]Rajagopal R, Kuppusamy P, Sathya R, Nandhakumari P, Bensy AD, Biji GD. Antifungal phytochemicals from the methanol and aqueous extract of *Acacia concinna* and *Lantana camara* and synergistic biological control of the Hibiscus mealybug (*Maconellicoccus hirsutus*). *Physiol Mol Plant Pathol* 2022; **119**. doi: 10.1016/j.pmpp.2022.101813.

[80]Hamza OJ, van den Bout-van CJ, Matee MI, Moshi MJ, Mikx FH, Selemani HO, et al. Antifungal activity of some Tanzanian plants used traditionally for the treatment of fungal infections. *J Ethnophamacol* 2006; **108**(1): 124-32.

[81]Fatimah AO. Antifungal activity and Fourier transform infrared spectrometric characterization of aqueous extracts of *Acacia senegal* and *Acacia tortilis* on phytopathogenic fungi. *J Pharm Res Int* 2019; **31**(2): 1-11.

[82]Rosdiana NA, Dumarçay S, Gerardin C, Chapuis H, Santiago-Medina FJ, Sari RK, et al. Characterization of bark extractives of different industrial Indonesian wood species for potential valorization. *Ind Crops Prod* 2017; **108**: 121-127.

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