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Review

Efficacy and Mechanism of Traditional Medicinal Plants and Bioactive Compounds against Clinically Important Pathogens

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Abstract: Traditional medicinal plants have been cultivated to treat various human illnesses and avert numerous infectious diseases. They display an extensive range of beneficial pharmacological and health effects for humans. These plants generally synthesize a diverse range of bioactive compounds which have been established to be potent antimicrobial agents against a wide range of pathogenic organisms. Various research studies have demonstrated the antimicrobial activity of traditional plants scientifically or experimentally measured with reports on pathogenic microorganisms resistant to antimicrobials. The antimicrobial activity of medicinal plants or their bioactive compounds arising from several functional activities may be capable of inhibiting virulence factors as well as targeting microbial cells. Some bioactive compounds derived from traditional plants manifest the ability to reverse antibiotic resistance and improve synergetic action with current antibiotic agents. Therefore, the advancement of bioactive-based pharmacological agents can be an auspicious method for treating antibiotic-resistant infections. This review considers the functional and molecular roles of medicinal plants and their bioactive compounds, focusing typically on their antimicrobial activities against clinically important pathogens.

Keywords: traditional medicinal plants; bioactive compounds; antimicrobial activities; mechanisms

1. Introduction

The incidence of microbial infectious diseases and their hitches consistently elevates, mostly due to microbial drug resistance to presently offered antimicrobial agents [1]. These multidrug-resistant microbes cause various infections globally and are connected with greater levels of morbidity and mortality [2]. These augmentations of antibiotic resistance and higher recurrence rates of such common infections have a great impact on our society [3–5]. Several investigations associated with antimicrobial resistance predict that the mortality toll owing to antimicrobial resistance may exceed 10 million by 2050, theoretically leading to greater mortality in the context of other infectious diseases and malignancies [6]. It is well known that infections are generally difficult to treat due to the development of biofilm in the host, which aids the proliferation of microbes as well as the aggressiveness of the infections [7]. Studies have also well-established that the physical structures of biofilm establishing organisms confer natural resistance to hostile environments, including antimicrobial agents [8]. Therefore, it is an urgent requirement to generate novel antimicrobial drugs which can inhibit the development of, or abolish the complete biofilms, and hence increase the vulnerability of microbes to antimicrobials. The requisite for new antimicrobials which could meritoriously fight against antimicrobial resistant clinical pathogens is extremely augmented.

Plant-derived antimicrobials have been established to be one of the most auspicious sources considered as safe due to their natural origin when compared with synthetic compounds [9,10]. There is an accumulating interest in the practice of either crude extract of medicinal plants, as well as the screening plant-derived compounds as an alternative therapy for microbial infections [11]. Plants generally produce a diverse range of bioactive compounds which have been widely used in clinical practice [12]. Remarkably, a significant number of marketed drugs are obtained from nature or result in natural products through either chemical transformations or de novo synthesis [13]. Plant-derived compounds are a group of secondary metabolites that are used to treat chronic as well as infectious diseases. These traditional medicinal plants or active compounds remain included as part of the habitual treatment of various maladies [9]. These compounds could have other target sites than conventional antimicrobials as well as diverse mechanisms of action against pathogenic microbes. An electronic search was performed using PubMed, Science Direct, and Google Scholar using the keywords "medicinal plants" AND "bioactive compounds" AND "antimicrobial activities" AND "antibiotic resistance" in "Title/Abstract/Keywords" without date restriction in order to identify all published studies (in vitro, in vivo, clinical and case-control) that have investigated the connection between medicinal plants and their antimicrobial effects. Antimicrobial mechanisms were gathered and for review.

2. Traditional Medicinal Plants

The species of the plant kingdom are estimated to number about 500,000 and only a minor portion of them have been investigated for antimicrobial activity [9,14]. Traditional medicinal plants can be cultivated by humans over centuries without existing systematic standards and analysis due to their safety and efficacy. Hence, bioactive compounds derived from these medicinal plants apparently have more potential to succeed in toxicology screening when compared with the de novo synthesis of chemicals. The cumulative attention on traditional ethnomedicine may lead to the revealing of innovative therapeutic agents since traditional medicinal plant contains potential antimicrobial components that are beneficial for the development of pharmaceutical agents for the therapy of ailments. Nowadays, studies are progressively turning their consideration to traditional medicine and advancing better drugs to treat diabetes, cancer, and microbial infections [15,16]. A large number of studies have been piloted using medicinal plant extracts and their active principles on bacteria, fungi, algae, and viruses in different localities of the world [9,10]. Various families of traditional medicinal plants have been scientifically tested for their antimicrobial activities and are presented in Table 1. The extracts of plant organs, namely the root, stem, rhizome, bulb, leaf, bark, flower, fruit, and seed, may encompass distinctive phytochemicals with antimicrobial activities [17]. It is well-known that sole plant species of traditional medicine are habitually used to heal a great number of infections or diseases [18]. The plant extracts with an antiquity of folk use should be confirmed using contemporary methods for activities against human pathogens with the intention of identifying potential novel therapeutic drugs.

Table 1. Antimicrobial screening performed on various medicinal plants.

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Barleria prionitis L.	Acanthaceae	Leaves	Pet. Ether	3.33–33.3 mg/mL	*B. subtilis, M. luteus, B. cereus, S. mutans, S. aureus, L. sporogenes*	*S. typhi, V. Cholera, M. luteus, Citrobacter*	-	[19]
			Chloroform	5–50 mg/mL	*B. subtilis, L. sporogenes*	*S. typhi, V. cholerae, Citrobacter, Providencia*	-	
			Methanol	10–100 mg/mL	*B. subtilis, L. sporogenes*	*V. cholerae, S. typhi,*	-	
			Ethanol	50–600 µg/mL	-	*S. typhi*	-	
		Bark	Acetone	25, 50, 100 mg/mL	*Bacillus* spp., *S. mutans, S. aureus,*	*Pseudomonas* spp.,	*S. cerevisiae, C. albicans*	
			Ethanol	25, 50, 100 mg/mL				
			Methanol	25, 50, 100 mg/mL				
Adhatoda vasica L.	Acanthaceae	Leaves	Aqueous	4% v/v	*M. tuberculosis,*	*E. coli, S. typhi*	-	[20]
			Methanol	625 µg/mL	*S. aureus*	*E. coli, S. typhi*	-	
Pellaea calomelanos L.	Adiantaceae	Leaves, Rhizomes	Aqueous, Dichloromethane/ Methanol	250 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Sambucus australis Cham. & Schltdl.	Adoxaceae	Leaves and Bark	Hexane Ethanol	50 µg/mL	*S. aureus, S. agalactiae*	*E. coli, S. typhimurium* and *K. pneumoniae*	*C. albicans*	[22]
Carpobrotus edulis L N.E.Br.	Aizoaceae	Leaves	Aqueous Dichloromethane/ Methanol	100 µg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrataC. krusei*	[23]
Achyranthes aspera L.	Amaranthaceae	Root, Leaves, Stem	Ethanol	1 mg/mL	*S. aureus, B. subtilis,*	*E. coli, P. vulgaris, K. pneumoniae*	-	[16]
Alternanthera Sessile L.	Amaranthaceae	Leaves	Ethanol	75 µg/mL	*S. pyogenes*	*S. typhi*	-	[24,25]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Amaranthus caudatus L.	Amaranthaceae	Leaves	Ethyl Acetate Chloroform Methanol	162.2–665 mg/mL 1.25 mg/mL 3–5 mg/mL	*S. aureus, Bacillus spp.*	*E. coli, S. typhi, P. mirabilis*	-	[26]
Amaranthus hybridus L.	Amaranthaceae	Leaves	Ethyl Acetate Chloroform Methanol	200–755 mg/mL 1.25 mg/mL 3–5 mg/mL	-	*E. coli, S. typhi, k. pneumoniae, P. aeruginosa*	-	[26]
Amaranthus spinosus L.	Amaranthaceae	Leaves	Ethyl Acetate Chloroform Methanol	129 mg/mL 1.25 mg/mL 3–5 mg/mL	-	*S. typhi*	-	[26]
Boophane disticha L.f.	Amaryllidaceae	Leaves	Aqueous, Dichloromethane/ Methanol	20–100 mg/mL 750–12,000 μg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Scadoxus puniceus (L.) Friis &Nordal.	Amaryllidaceae	Rhizomes, Roots	Aqueous Dichloromethane/ Methanol	50 μg/mL 750–12,000 μg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Harpephyllum caffrum Bernh. exKrauss	Anacardiaceae	Bark, Leaves	Aqueous Dichloromethane/ Methanol	125–500 μg/mL 750–12,000 μg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Lannea discolor Engl.	Anacardiaceae	Leaves	Aqueous Dichloromethane/ Methanol	50–200 μg/mL 750–12,000 μg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Polyalthia cerascides L.	Annonaceae	Stem Bark	Dichloromethane	100 μg/mL	*C. Dipthieriae*	-	-	[27]
Berula erecta Huds., Coville	Apiaceae	Rhizome, Leaves, Stem	Aqueous Dichloromethane/ Methanol	2–16 μg/mL 750–12,000 μg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Acokanthera oppositifolia L. Codd.	Apocynaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	25–200 µg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Plumeria ruba L.	Apocynaceae	Leaves	Aqueous Dichloromethane/ Methanol	50–200 µg/mL 100 µg/mL	*S. epidermidis*	*E. coli*	-	[16]
Acokanthera oppositifolia (Laim.) Codd.,	Apocynaceae	Leaves	Aqueous Dichloromethane/ Methanol	10–50 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Rauvolfia caffra Sond.	Apocynaceae	Leaves	Aqueous Dichloromethane/ Methanol	25, 50 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Calotropis gigantea L.	Apocynaceae	Latex	Ethanol	1–8 mg/mL	-	-	*C. albicans, T. mentagrophytes, T. rubrum*	[16]
Plumeria alba L.	Apocynaceae	Root	Methanol	10–40 µg/mL	-	*E. coli*		[16]
Ilex mitis Radlk.	Aquifoliaceae	Bark, Leaves	Aqueous Dichloromethane/ Methanol	1–8 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Anchomanes difformis Engl.	Araceae	Roots	Methanol	20–100 mg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Zantedeschia aethiopica Spreng	Araceae	Leaves	Aqueous Dichloromethane/ Methanol	50 µg/mL 15–150 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Arum dioscoridis L.	Araceae	Leaves	Aqueous	125–500 µg/mL	*S. aureus, S. pneumoniae*	*E. coli, S. typhi, P. aeruginosa*	-	[29]
Aristolochia Indica L.	Aristolochiaceae	Leaves	Ethanol	1–8 mg/mL	-	-	*A. niger A. flavus A. fumigatus*	[3,4,30,31]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Vernonia blumeoides Hook. f.	Asteraceae	Aerial Part	Ethanol	100 µg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Artemisia afra Jacq. ex Willd.	Asteraceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	2–16 µg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Tarchonanthus camphoratus L.	Asteraceae	Leaves	Aqueous Dichloromethane/ Methanol	25–200 µg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Helichrysum paronychioides L.	Asteraceae	Whole Plant	Pet ether Methanol	50–200 µg/mL 50–200 µg/mL	*B. cereus*	*S. flexneri*	*C. glabrata*, *C. krusei*, *T. rubrum* and *T. tonsurans*	[2]
Senecio longiflorus L.	Asteraceae	Stem and Leaves	Pet ether Methanol	125–625 µg/mL 50–200 µg/mL	*B. cereus*	*S. flexneri*	*C. glabrata*, *C. krusei*, *T. rubrum* and *T. tonsurans*	[2]
Dahlia pinnata L.	Asteraceae	Leaves	Chloroform	2–16 µg/mL	–	*E. aerogenes*, *P. aeruginosa*	–	[16]
Athrixia phylicoides DC.	Asteraceae	Leaves	Aqueous Dichloromethane/ Methanol	25–200 µg/mL 750–12,000 µg/ml	*S. aureus*, *methicillin- resistant S. aureus*, *gentamycin– methicillin-resistant S. aureus*, *S. epidermidis*, *B. agri*, *P. acnes*	*P. aeruginosa*	*T. mentagrophytes*, *M. canis*	[21]
Dicoma anomala Sond.	Asteraceae	Tuber	Aqueous Dichloromethane/ Methanol	50–200 µg/mL 750–12,000 µg/mL	*S. aureus*, *methicillin- resistant S. aureus*, *gentamycin– methicillin-resistant S. aureus*, *S. epidermidis*, *B. agri*, *P. acnes*	*P. aeruginosa*	*T. mentagrophytes*, *M. canis*	[21]
Vernonia natalensis Sch. Bip. exWalp.	Asteraceae	Leaves, Roots	Aqueous Dichloromethane/ Methanol	10–50 µg/mL 750–12,000 µg/mL	*S. aureus*, *methicillin- resistant S. aureus*, *gentamycin– methicillin-resistant S. aureus*, *S. epidermidis*, *B. agri*, *P. acnes*	*P. aeruginosa*	*T. mentagrophytes*, *M. canis*	[21]
Achillea millefolium L.	Asteraceae	Leaves	Ethanol	100 µg/mL	*S. aureus*	*P. aeruginosa S. typhi*, *E. coli*	*C. albicans*	[29]
Blumea balsamifer (Linn.) D.C.	Asteraceae	Whole Plant	Ethanol	250 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Impatiens balsamina L.	Balsaminaceae	Leaf	Ethanol	50–200 µg/ml	methicillin-resistant *S. aureus*	-	-	[28]
Berberis chitria L.	Berberidaceae	Roots	Ethanol, Methanol	5.5–6.5 mg/mL 2.5–3.5 mg/mL	*S. aureus*	*E. coli*	-	[33]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Alnus nepalensis D. Don.	Betulaceae	TBL	Ethanol	50–200 µg/mL	Methicillin-resistant *S. aureus*	-	-	[32]
Tecoma capensis Lindl.	Bignoniaceae	Leaves, Stem	Aqueous, Dichloromethane/ Methanol	10–50 µg/mL 2.5 mg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Spathodea campanulata L.	Bignoniaceae	Leaves Flowers	Ethanol	221–254 µg/mL 156–173 µg/mL	*B. subtilis*, *S. aureus*,	*E. coli*, *K. pneumonia*, *P. vulgaris*, *S. typhi*, *Pseudomonas* spp., *V. cholerae*	-	[6,34,35]
Kigelia africana (Lam.) Benth.	Bignoniaceae	Fruit	Aqueous Dichloromethane/ Methanol	2–16 µg/mL 750–12,000 µg/mL	*S. aureus*, *methicillin- resistant S. aureus*, *gentamycin– methicillin-resistant S. aureus*, *S. epidermidis*, *B. agri*, *P. acnes*	*P. aeruginosa*	*T. mentagrophytes*, *M. canis*	[21]
Opuntia ficus-indica Mill.	Cactaceae	Leaves	Aqueous Dichloromethane Methanol	25–200 µg/mL 750–12,000 µg/mL	*S. aureus*, *methicillin- resistant S. aureus*, *gentamycin– methicillin-resistant S. aureus*, *S. epidermidis*, *B. agri*, *P. acnes*	*P. aeruginosa*	*T. mentagrophytes*, *M. canis*	[21]
Senna italic L.	Caesalpiniaceae	Leaves	Acetone	2.5 mg/mL	*B. cereus*, *B. pumilus*, *B. subtilis*, *S. aureus*, *E. faecalis*,	-	-	[36]
Cassia fistula L.	Caesalpiniaceae	Seeds	Aqueous Ethanol	780–6250 µg /mL 2–16 µg/mL	*S. aureus*	-	-	[6]
Warburgia salutaris (G. Bertol.) Chiov.	Canellaceae	Bark, Twigs	Aqueous	5.0–10 mg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
			Dichloromethane, Methanol	50–200 µg/mL 750–12,000 µg/mL	*S. aureus*, *methicillin- resistant S. aureus*, *gentamycin– methicillin-resistant S. aureus*, *S. epidermidis*, *B. agri*, *P. acnes*	*P. aeruginosa*	*T. mentagrophytes*, *M. canis*	[21]
Cadaba fruticosa L.	Capparaceae	Leaves	Acetone Aqueous Benzene Butanol Chloroform Ethanol	100–200 µg/mL 4–16 µg/mL 4–16 µg/mL 4–16 µg/mL 4–16 µg/mL 4–16 µg/mL	*S. pyogens*, *S. aureus*, *B. subtilis*	*S. typhi*, *P. vulgaris*, *K. pneumoniae*, *P. aeruginosa*, *E. coli*	-	[37]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Boscia senegalensis Del.	Capparidaceae	Roots	Methanol	10–20 µg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Celastrus orbiculatus Thunb.	Celastraceae	Vane	Ethanol	1–2 mg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Euonymus fortunei (Turcz.); Hand. Mazz.	Celastraceae	Leaves	Ethanol	10–40 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Chenopodium ambrosioides Bert. ex Steud.	Chenopodiaceae	Leaves	Aqueous Dichloromethane/ Methanol	2–16 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Garcinia mangostana L.	Clusiaceae	Fruit Shell	Ethanol	25–200 µg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Garcinia morella Desr.	Clusiaceae	Whole Plant	Ethanol	100–400 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Terminalia paniculata L.	Combretaceae	Stem Bark	Ethyl Acetate Methanol	3.25, 3.5 mg/mL 5–20 µg/mL	*S. aureus, B. subtilis*	-	-	[38]
Terminalia sericea Burch. ex DC.	Combretaceae	Roots	Aqueous Dichloromethane/ Methanol	100–300 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Eupatorium odoratum L.	Compositae	Leaves	Benzene Aqueous Acetone	300–600 µg/mL 300–600 µg/mL 300–600 µg/mL	*B. cereus, S. aureus*	*E. coli, K. pneumoniae, V. cholerae*	*C. albicans*	[39]
Acmella paniculata L.	Compositae	Whole Plant	Chloroform Pet. ether Methanol	15 µg/mL 5–15 µg/mL 5–15 µg/mL	-	*E. aerogenes*	-	[40]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Cotyledon orbiculata L.	Crassulaceae	Leaves	Aqueous Dichloromethane Methanol	5–30 µg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Cotyledono rbiculata Forssk.	Crassulaceae	Leaves	Aqueous Dichloromethane/ Methanol	25–200 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Mormodica basalmina L.	Cucurbitaceae	Whole Plant	Methanol	500 µg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Coccinia grandis L.	Cucurbitaceae	Leaves	Aqueous Dichloromethane/ Methanol	500 µg/mL 2 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Luffa acyntangula L.	Cucurbitaceae	Leaves	Aqueous Dichloromethane Methanol	5 mg/mL 2 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Mukia maderspatana L.	Cucurbitaceae	Leaves	Aqueous Dichloromethane/ Methanol	5 mg/mL 1 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Trichosanthes cucumerina L.	Cucurbitaceae	Leaves	Aqueous Dichloromethane/ Methanol	5 mg/mL 1 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Momordica balsami-na L.	Cucurbitaceae	Leaves, Roots	Acetone	500 µg/mL	*B. cereus, B. pumilus, B. subtilis, S. aureus, E. faecalis*	*E. coli, E. cloaceae, K. pneumoniae, P. aeruginosa, S. marcescens*	-	[42]
Carex prainii C.B. Clarke	Cyperaceae	Whole Plant	Ethanol	15–45 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Dioscorea dregeana T. Durand & Schinz.	Dioscoreaceae	Tuber	Aqueous Dichloromethane/ Methanol	5–30 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Sansevieria hyacinthoides L.	Dracaenaceae	Leaves, rhizome	Aqueous, Dichloromethane/ Methanol	1–4 mg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrataC. krusei*	[23]
Diospyros mespiliformis Hochst. exA. DC.	Ebenaceae	Leaves	Aqueous Dichloromethane/ Methanol	15–45 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Phyllanthus amarus Schum. Thonn.	Euphorbiaceae	Whole Plant	Methanol	650–600 µg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Croton gratissimus Burch.	Euphorbiaceae	Leaves, Stem,	Aqueous Dichloromethane/ Methanol	5 mg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrataC. krusei*	[23]
Spirostachys africana Sond.	Euphorbiaceae	Leaves, Bark	Aqueous Dichloromethane/ Methanol	490 µg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrataC. krusei*	[23]
Acalypha indica L.	Euphorbiaceae	Leaves	Aqueous	4% v/v	*M. tuberculosis*	-	-	[43]
Bridelia micrantha Baill.	Euphorbiaceae	Bark, Leaves	Aqueous Dichloromethane/ Methanol	5 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Emblica officinalis L.	Euphorbiaceae	Leaves	Benzene Aqueous Acetone	350–600 µg/mL 300–600 µg/mL 300–600 µg/mL	*B. cereus, S. aureus*	*E. coli, K. pneumoniae, V. cholerae*	*C. albicans*	[39]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Hevea brasiliensis L.	Euphorbiaceae	Leaves	Benzene Aqueous Acetone	350–600 µg/mL 300–600 µg/mL 300–600 µg/mL	*B. cereus*, *S. aureus*	*E. coli*, *K. pneumoniae*, *V. cholerae*	*C. albicans*	[39]
Mallotus yunnanensis Pax et. Hoffm.	Euphorbiaceae	Tender Branches & Leaves	Ethanol	8–256 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Acacia albida Del.	Fabaceae	Stem Bark	Methanol	50 µg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Acacia catechu (L. f.) Willd	Fabaceae	Wood	Ethanol	100 µg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Peltophorum ptercarpum (DC.)	Fabaceae	Bark	Ethanol	4% v/v	methicillin-resistant *S. aureus*	-	-	[28]
Acacia erioloba Edgew.	Fabaceae	Bark and Leaves	Aqueous Dichloromethane/ Methanol	1.56–3.12 mg/mL 750–12,000 µg/mL	*S. aureus*, *methicillin– resistant S. aureus*, *gentamycin– methicillin-resistant S. aureus*, *S. epidermidis*, *B. agri*, *P. acnes*	*P. aeruginosa*	*T. mentagrophytes*, *M. canis*	[21]
Dichrostachys cinerea L.	Fabaceae	Stem	Aqueous Dichloromethane/ Methanol	129 mg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata* *C. krusei*	[23]
Albizia odoratissima (L.f.) Benth	Fabaceae	Leaves	Hexane Chloroform Ethyl Acetate Methanol	7.5–15 mg/mL 859–6875 µg/mL 136–546 µg/mL 136–546 µg/mL	*S. aureus*	*K. pneumoniae*, *E. coli*, *P. aeruginosa*, *P. vulgaris*	-	[44]
Prosopis juliflora L.	Fabaceae	Pod	Chloroform	250 µg/mL	*M. luteus*, *S. aureus*, *S. mutans*	-	-	[36]
Bauhinia macranthera Benth. Ex Hemsl.	Fabaceae	Leaves	Aqueous, Dichloromethane/ Methanol	1.56–3.12 mg/mL 750–12,000 µg/mL	*S. aureus*, *methicillin- resistant S. aureus*, *gentamycin– methicillin-resistant S. aureus*, *S. epidermidis*, *B. agri*, *P. acnes*	*P. aeruginosa*	*T. mentagrophytes*, *M. canis*	[21]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Erythrina lysistemon Hutch.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	4 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes, S. mutans, S. sanguis, L. acidophilus L. casei*	*P. aeruginosa, P. gingivalis F. nucleatum*	*T. mentagrophytes, M. canis, C. albicans C. glabrata C. krusei*	[21]
Elephantorrhiza elephantina (Burch.) Skeels	Fabaceae	Leaves, roots and rhizomes	Aqueous Dichloromethane/ Methanol	1–4 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes, B. cereus*	*P. aeruginosa, S. flexneri*	*T. mentagrophytes, M. canis, C. glabrata, C. krusei, T. rubrum* and *T. tonsurans*	[21]
Albizia lebbeck L.	Fabaceae	Leaves	Benzene, Aqueous and Acetone	350–600 µg/mL	*B. cereus, S. aureus*	*E. coli, K. pneumoniae, V. cholera*	*C. albicans*	[39]
Adenanthera pavonina L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	5 mg/mL 60 µg mg/mL	*B. cereus, S. aureus*	-	-	[41]
Alysicarpus vaginalis L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	5 mg/mL 2 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Bauhinia acuminate L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	5 mg/mL 50 µg mg/mL	*B. cereus, S. aureus*	-	-	[41]
Bauhinia purpurea L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	5 mg/mL 1 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Bauhinia racemose L.	Fabaceae	Leaves, Stem Bark	Aqueous Dichloromethane/ Methanol	500 µg/mL 500 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Cassia alata L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	250 µg/mL 500 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Cassia auriculata L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	1 mg/mL 4 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Cassia fistula L.	Fabaceae	Root Bark, Stem Bark	Aqueous Dichloromethane/ Methanol	1–5 mg/mL 500–1000 µg/mL	*B. cereus, S. aureus*	-	-	[41]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Cassia tora L.	Fabaceae	Leaves, Root Bark, Stem Bark	Aqueous Dichloromethane/ Methanol	250–4000 µg/mL 1000–4000 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Crotalaria retusa L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	4 mg/mL 60 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Crotalaria verrucosa L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	1 mg/mL 1 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Derris Scandens L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	100 µg/mL 4 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Desmodium triflorum (L.) DC. var. majus Wight & Arn.	Fabaceae	Stem Bark	Aqueous Dichloromethane/ Methanol	1 mg/mL 25 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Erythuria variegate L.	Fabaceae	Leaves, Stem Bark	Aqueous Dichloromethane/ Methanol	1–5 mg/mL 250–1000 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Indigofera tinctoria L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	500 µg/mL 4 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Mimosa pudica L.	Fabaceae	Stem Bark	Aqueous Dichloromethane/ Methanol	1–2 mg/mL 250–5000 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Myroxylon balsamum L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	1 mg/mL 500 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Pterocarpus marsupium Roxb.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	4 mg/mL 250 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Pterocarpus santalinus L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	2 mg/mL 4 mg/mL	*B. cereus, S. aureus*	-	-	[41]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Saraca asoca (Roxb.) Willd	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	120 µg/mL 5 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Sesbania grandiflora (L.) Poiret	Fabaceae	Stem Bark, Root Bark, Leaves	Aqueous, Dichloromethane/ Methanol	2 mg/mL 100 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Tamarindus indica L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	250–500 µg/mL 60–100 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Tephrosia purpurea L. Pers.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol	5 mg/mL 5 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Butea monosperma L.	Fabaceae	Leaves	Aqueous Dichloromethane/ Methanol Ethanol	4 mg/mL 2 mg/mL 100–200 µg/mL	*B. cereus, S. aureus*, methicillin-resistant *S. aureus*	-	-	[41,45]
Senna alata	Fabaceae	Leaf	Ethanol	100 µg/mL	methicillin-resistant *S. aureus*	-	-	[46]
Quercus infectoria Olivier	Fagaceae	Nutgalls	Ethanol	100–200 µg/mL	methicillin-resistant *S. aureus*	-	-	[16]
Cyclobalanopsis austroglauca Y.T. Chang	Fagaceae	TBL	Ethanol	8–256 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Scaevola spinescens L.	Goodeniaceae	Aerial parts	Ethyl Acetate, Methanol	500 µg/mL	*S. pyogenes, S. aureus*	-	-	[38]
Gunnera perpensa L.	Gunneraceae	Leaves, Rhizome	Aqueous, Dichloromethane/ Methanol	4 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin–methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Eucomis punctate L'Her.	Hyacinthaceae	Leaves	Aqueous, Dichloromethane/ Methanol	500 µg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Drimia sanguinea L.	Hyacinthaceae	Bulb	Pet ether	18.75, 37.5, 300, 600, 1200 µg/mL	*B. cereus*	*S. flexneri*	*C. glabrata*, *C. krusei*, *T. rubrum* and *T. tonsurans*	[2]
Hypoxis hemerocallidea L.	Hypoxidaceae	Leaves	Pet ether	195–12,500 µg/mL	*B. cereus*	*S. flexneri*	*T. rubrum*, *T.urans*, *C. glabrata C. krusei*	[47]
			Methanol	390–3125 µg/mL				
Curculigo orchioides Gaertn.	Hypoxidaceae	Whole Plant	Ethanol	8–256 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Illicium simonsii Maxim.	Illiciaceae	TBL	Ethanol	8–256 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Aristea ecklonii Baker.	Iridaceae	Leaves and Roots	Aqueous Dichloromethane/ Methanol	129 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin–methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes*, *M. canis*	[21]
Tetradenia riparia Hochst.	Lamiaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	200–755 mg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata* *C. krusei*	[23]
Thymus vulgaris L.	Lamiaceae	Leaves	Essential Oil	50 µg/mL	methicillin-resistant *S. aureus*	-	-	[48]
Mentha aquatica L.	Lamiaceae	Aerial Parts	Methanol Chloroform Acetone	1.56–3.12 mg/mL 128 µg/mL 32–128 µg/mL	*S. aureus*	*E. coli*, *P. aeruginosa*, *S. heidelberg*, *K. pneumoniae*, *E. aerogenes*, *M. morganii*	-	[49]
Stachys guyoniana Noë ex. Batt.	Lamiaceae	Leaves	*n*-Butanol Ethyl Acetate Chloroform	4 mg/mL 128 µg/mL 32–128 µg/mL	*S. aureus*	*E. coli*, *P. aeruginosa*, *S. heidelberg*, *K. pneumoniae*, *E. aerogenes*, *M. morganii*	-	[49]
Ocimum basilicum L.	Lamiaceae	Stem, leaves	Ethanol	1–4 mg/mL	*S. aureus*	-	-	[38]
Ocimum gratissimum L.	Lamiaceae	Leaves	Methanol	780–6250 µg/mL	*S. aureus*	*S. typhi*, *E. coli*, *S. paratyphi*	-	[38]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Ocimum sanctum L.	Lamiaceae	Whole Plant	Methanol	360 μg/mL	*S. aureus, S. saprophyticus*	*S. typhi, E. coli, S. paratyphi*	-	[6]
Mentha longifolia Huds.	Lamiaceae	Leaves	Aqueous Dichloromethane/ Methanol	150, 300, 600 μg/mL 750–12,000 μg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin–methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Melissa officinalis L.	Lamiaceae	Leaves	Ethanol	49 μg/mL	-	*K. pneumoniae*	-	[42]
Ocimum americanum L.	Lamiaceae	Leaves	Acetone	2.5 mg/mL	*B. cereus, B. pumilus, B. subtilis, S. aureus, E. faecalis*	-	-	[16]
Machilus salicina Hance.	Lauraceae	Tender Branches & Leaves	Ethanol	500 μg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Meliosma squamulata Hance.	Lauraceae	TBL	Ethanol	1–4 mg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Sophora alopecuroides	Leguminosae	Aerial Parts, Seeds	Ethanol	129 mg/mL	*B. subtilis, S. aureus, B. subtilis*	*P. aeruginosa*	-	[50]
Acacia karroo Hayne.	Leguminosae	Leaves, Stem	Aqueous, Dichloromethane/ Methanol	200–755 mg/mL 750–12,000 μg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Acacia polyacantha Willd.	Leguminosae	Leaves, Stem	Aqueous	50 μg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
			Dichloromethane/ Methanol	750–12,000 μg/mL				
Dalbergia obovate E. Mey.	Leguminosae	Leaves, stem	Aqueous Dichloromethane/ Methanol	1.56–3.12 mg/mL 750–12,000 μg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Sophora jaubertii	Leguminosae	Aerial Parts, Seeds	Ethanol	4 mg/mL	*B. subtilis, P. aeruginosa, S. aureus*	-	-	[38]
Glycyrrhiza glabra L.	Leguminosae	Leaves	Methanol	1–4 mg/mL	*K. kristinae, M. luteus, S. auricularis, B. megaterium*	*A. bohemicus, E. coli*	-	[51]
Allium cepa L.	Liliaceae	Bulb	Aqueous	780–6250 µg/mL	*M. tuberculosis*	-	-	[43]
Allium sativum L.	Liliaceae	Bulb	Aqueous	4% v/v	*M. tuberculosis*	-	-	[43]
Allium vera L.	Liliaceae	Gel	Aqueous	4% v/v	*M. tuberculosis*	-	-	[43]
Lobelia nicotianaefolia L.	Lobeliaceae	Root	Chloroform Acetone Ethanol	129 mg/mL 6 mg/mL 6 mg/mL	*S. aureus*	*P. aeruginosa*	-	[39]
Woodfordia fruticose L.	Lythraceae	Flower	Aqueous Dichloromethane/ Methanol	200–755 mg/mL 100 mg/mL	*S. aureus, B. cereus*	*S. typhi, E. coli, S. dysenteriae. V. cholerae*	-	[37]
Manglietia hongheensis Y.m Shui et. W.H. Chen.	Magnoliaceae	TBL	Ethanol	50 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Malva parviflora L.	Malvaceae	Leaves	Aqueous Dichloromethane/ Methanol	500 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin–methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Sida rhombifolia L.	Malvaceae	Stem	Chloroform	162.2–665 mg/mL	*S. lutea, B. subtilis,*	*E. coli, Shigella shiga*	-	[38]
Walsura robusta L.	Meliaceae	Wood	Ethanol	250 µg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Swietenia mahagoni	Meliaceae	Seed	Ethanol	500 µg/mL	methicillin-resistant *S. aureus*	-	-	[52]
Azadirachta indica	Meliaceae	LeavesStem	MethanolAqueous	1.56–3.12 mg/mL	*M. luteusS. aureus, S. pyogenes*	*P. vulgarisE. coli, P. aeruginosa*	–	[53]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Ekebergia capensis Sparrm.	Meliaceae	Bark, Leaves	Aqueous Dichloromethane/ Methanol	1.59–25 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Trichilia emetica Vahl	Meliaceae	Leaves	Aqueous Dichloromethane/ Methanol	50–600 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Melia azedarach L.	Meliaceae	Leaves	Methanol Ethanol Pet.ether Aqueous	3.33–33.3 mg/mL 500 µg/mL 1.56–3.12 mg/mL 10–30 mg/mL	*B. cereus, S. aureus*	*E. coli, P. aeruginosa*	*A. niger, A. flavus, F. oxysporum, R. stolonifer*	[16]
Melianthus comosus Vahl.	Melianthaceae	Leaves	Aqueous Dichloromethane/ Methanol	50 mg/mL 4–64 mg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes,* methicillin-resistant *S. aureus*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[28]
Melianthus major L.	Melianthaceae	Leaves	Ethanol	10–100 mg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Melianthus major L.	Melianthaceae	Leaves	Aqueous Dichloromethane/ Methanol	5–50 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Cissampelos torulosa E. Mey. Ex Harv.	Menispermaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	25, 50, 100 mg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Tinospora crispa L.	Menispermaceae	Stem	Ethanol	10 mg/mL	methicillin-resistant *S. aureus*	-	-	[21]
Cissampelos capensis Thunb.	Menispermaceae	Leaves	Aqueous Dichloromethane/ Methanol	3.33–33.3 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Ficus natalensis Hochst.	Moraceae	Leaves	Aqueous Dichloromethane/ Methanol	250 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Ficus sur Forssk.	Moraceae	Bark, Leaves	Aqueous, Dichloromethane/ Methanol	10–100 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Moringa oleifera Lam.	Moringacceae	Leaf	Ethanol	5–50 mg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Myrothamnus flabellifolia Welw.,	Myrothamnaceae	Leaves	Aqueous Dichloromethane/ Methanol	156–625 µg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Embelia ruminate (E. Mey.exA.Dc.) Mez	Myrsinaceae	leaves	Aqueous Dichloromethane/ Methanol	350–600 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Embelia burm f.	Myrsinaceae	Leaves	Ethanol	500 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Callistemon rigidus R.Br.	Myrtaceae	Leaf	Methanol	800 mg/disc	methicillin-resistant *S. aureus*	-	-	[28]
Psidium guajava L.	Myrtaceae	Leaf	Ethanol	600, 1200 µg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Heteropyxis natalenesis Harv.	Myrtaceae	Leaves, Stem	Aqueous, Dichloromethane/ Methanol	5 mg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Eucalyptus camaldulensis Dehnh.	Myrtaceae	Bark	Aqueous Dichloromethane/ Methanol	9.375, 18.75, 37.5, 75, 150, 300, 600 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Eucalyptus deglupta	Myrtaceae	Leaves	Benzene Aqueous Acetone	37.5, 75, 150, 300, 600 µg/mL 4–8 mg/mL 6 mg/mL	*B. cereus, S. aureus*	*E. coli, K. pneumoniae, V. cholerae*	*C. albicans*	[39]
Myrtus communis L.	Myrtaceae	Leaves	Ethanol	12.5–50 mg/mL	*B. cereus, L. monocytogenes*	*E. coli*	*C. albicans*	[42]
Nelumbo nucifera L.	Nelumbonaceae	Flower	Ethanol	8–32 mg/mL	*B. subtilis, S. aureus,*	*E. coli, K. pneumonia, P. aeruginosa*	-	[54]
Nymphaea lotus L.	Nymphaeaceae	Leaf	Ethanol	500 µg/mL	methicillin-resistant *S. aureus*	-	-	[21]
Oxalis corniculata L.	Oxalidaceae	Leaves	Aqueous Benzene Acetone	5 mg/mL 37.5, 75, 150, 300, 600 µg/mL 6 mg/mL	*B. cereus, S. aureus*	*E. coli, K. pneumoniae, V. cholera*	*C. albicans*	[39]
Paeonia lactiflora Pall.	Paeoniaceae	Leaves	Ethanol	22.4–52.3 µg/mL	*K. kristinae, M. luteus, S. auricularis, B. megaterium*	*A. bohemicus, E. coli*	-	[51]
Argemone mexicana	Papaveraceae	Stem	Chloroform	32.4–55.8 µg/mL	*S. aureus*	*E. coli, P. aeruginosa, k. pneumoniae*	-	[55]
Passiflora Mexicana L.	Passifloraceae	Aerial Parts	Ethanol	33.7–58.3 µg/mL	*S. aureus*	-	-	[21]
Cleistanthus collinus	Phyllanthaceae	Leaves	Benzene Aqueous Acetone	100 mg/mL 4–8 mg/mL 5 mg/mL	*B. cereus, S. aureus*	*E. coli, K. pneumoniae, V. cholerae*	*C. albicans*	[39]
Piper nigrum L.	Piperaceae	Bark, Seeds	Ethanol Acetone Dichloromethane/Methanol	500 µg/mL 6 mg/mL 12.5–50 µg/mL	*S. aureus, B. cereus, S. fecalis*	*P. aeruginosa, E. coli, S. typhi*	-	[38]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Pittosporum viridiflorum Sims.	Pittosporaceae	Leaves	Aqueous Dichloromethane/ Methanol	600 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Spinifex littoreus	Poaceae	Grass	Acetone	2.5 mg/mL	-	-	Dermatophytes	[27]
Polygonum molle D. Don.	Polygonaceae	Whole Plant	Ethanol	25–50 µg/mL	Methicillin-resistant *S. aureus*	-	-	[32]
Eichhornia crassipes L.	Pontederiaceae	Leaves, Shoot	Ethanol Chloroform Aqueous	500–4000 µg/mL 32.4–55.8 µg/mL 2.5–15 µg/mL	*M. luteus*	*R. rubrum*	*M. ruber, A. fumigates*	[56]
Punica granatum L.	Punicaceae	Fruit Shell	Ethanol	70 mg/mL	Methicillin-resistant *S. aureus*	-	-	[28]
Clematis brachiate Thunb.	Ranunculaceae	Flower, Leaves, Stem, Root	Aqueous, Dichloromethane/ Methanol	1 mg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata* *C. krusei*	[23]
Ziziphus mucronata Willd.	Rhamnaceae	Bark, Leabes	Aqueous Dichloromethane/ Methanol	2.5 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes, S. mutans, S. sanguis, L. acidophilus L. casei*	*P. aeruginosa, P. gingivalis F. nucleatum*	*T. mentagrophytes, M. canis, C. albicans C. glabrata C. krusei*	[21]
Eriobotrya japonica (Thunb.) Lindl.	Rosaceae	Leaves	Ethanol	2–16 µg/mL	*K. kristinae, M. luteus, S. auricularis, B. megaterium*	*A. bohemicus, E. coli*	-	[51]
Pavetta crassipes K. Schum.	Rubiaceae	Leaf	Methanol	12.5–50 mg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Uncaria gambir (Hunter) Roxb.	Rubiaceae	Leaf, Stem	Ethanol	8–32 mg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Vangueria spinose L.	Rubiaceae	Leaves	Ethyl Acetate	500 µg/mL	*S. aureus*	*E. coli, K. pneumoniae, P. aeruginosa*	-	[57]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Pentanisia prunelloides Walp.	Rubiaceae	Root Bark	Aqueous Dichloromethane/ Methanol	5 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Rothmannia capensis Thunb.	Rubiaceae	Leaves	Aqueous Dichloromethane/ Methanol	22.4–52.3 µg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Geophila repens L.	Rubiaceae	Leaves, Stem Bark	Aqueous Dichloromethane/ methanol	1 mg/mL 250 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Guettarda speciose L.	Rubiaceae	Leaves	Aqueous Dichloromethane/ Methanol	2 mg/mL 2 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Haldina cordifolia L.	Rubiaceae	Leaves	Aqueous Dichloromethane/ Methanol	1 mg/mL 500 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Hedyotis auricularia L.	Rubiaceae	Leaves	Aqueous Dichloromethane/ Methanol	300 µg/mL 250 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Knoxia zeylanica L.	Rubiaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	250 µg/mL 1 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Mitragyna parvifolia L.	Rubiaceae	Leaves	Aqueous Dichloromethane/ Methanol	300 µg/mL 1 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Morinda umbellate L.	Rubiaceae	Leaves, Stem Bark	Aqueous Dichloromethane/ Methanol	100 µg/mL 250 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Nauclea orientalis L.	Rubiaceae	Leaves	Aqueous Dichloromethane/ Methanol	500 µg/mL 500 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Oldenlandia biflora L.	Rubiaceae	Leaves	Aqueous Dichloromethane/ Methanol	2 mg/mL 5 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Oldenlandia herbacea L.	Rubiaceae	Stem, Root	Aqueous Dichloromethane/ Methanol	5mg/mL 60 µg/mL	*B. cereus, S. aureus*	-	-	[41]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Ophiorrhiza mungos L.	Rubiaceae	Leaves	Aqueous Dichloromethane/ Methanol	2 mg/mL 500 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Paederia foetida L.	Rubiaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	300 µg/mL 60 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Pavetta lanceolate Eckl.	Rubiaceae	Leaves	Aqueous Dichloromethane/ Methanol	1 mg/mL 250 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Spermacoce hispida L.	Rubiaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	300 µg/mL 120 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Wendlandia bicuspidate Wight & Arn.	Rubiaceae	Leaves	Aqueous Dichloromethane/ Methanol	60 µg/mL 5 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Chassalia kolly	Rubiaceae	Whole Plant	Mthanol	5 mg/mL	*S. aureus*	*E. coli, P. aeruginosa, S. typhi, P. aeruginosa*	-	[16]
Randia dumetorum L.	Rubiaceae	Fruits	Methanol	9.375, 18.75, 37.5, 75, 150, 300, 600 µg/mL	*S. aureus, S. epidermidis, B. subtilis*	*E. coli, S. typhi*	-	[23]
Mitragyna speciosa L.	Rubiaceae	Leaves	Methanol	37.5, 75, 150, 300, 600 µg/mL	*S. typhi*			[42]
Clausena anisate (Willd) Hook. f. ex.	Rutaceae	Leaves, Stem, Twigs	Aqueous Dichloromethane/ Methanol	12.5–50 mg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Zanthoxylum capense Harv.	Rutaceae	Stem	Aqueous Dichloromethane/ Methanol	8–32 mg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Aegle marmelos L.	Rutaceae	Leaves and Fruits	Methanol	500 µg/ml	*S.aureus, B. cereus*	*E. coli, S. typhi, P. aeruginosa, S. boydii, K. aerogenes, P.vulgaris,*		[20]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Evodia daneillii (Benn) Hemsl.	Rutaceae	Tender Branches & Leaves	Ethanol	3.33–33.3 mg/mL	Methicillin-resistant *S. aureus*	-	-	[32]
Skimmia arborescens Anders.	Rutaceae	TBL	Ethanol	250 mg/mL	Methicillin-resistant *S. aureus*	-	-	[32]
Salvadora australis	Salvadoraceae	Leaves	Acetone	10–100 mg/mL	*B. cereus, B. pumilus, B. subtilis, S. aureus, E. faecalis*	-	-	[18]
Viscum capense L.f.	Santalaceae	Leaves	Aqueous Dichloromethane/ Methanol	5–50 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Dodonaea angustifolia (L.f.) Benth	Sapindaceae	Leaves	Ethanol	156–625 µg/mL	methicillin-resistant *S. aureus*	-	-	[28]
Dodonaea viscosa Jacq.	Sapindaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	350–600 µg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Cardiospermum halicacabum L.	Sapindaceae	Leaves	*n*-Butanol Ethyl acetate Chloroform	500 µg/mL 60 µg/mL 40 µg/mL	*S. aureus, S. agalactiae*	*E. coli*, *S. typhimurium* and *K. pneumoniae*	*T. rubrum, C. albicans*	[58]
Dodonaea angustifolia L. f.	Sapindaceae	Leaves	Aqueous Dichloromethane/ Methanol	800 mg/disc 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Englerophytum magalismontanum Sonder.	Sapotaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	600, 1200 µg/mL 750–12,000 µg/mL	*S. mutans*, *S. sanguis*, *L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrataC. krusei*	[23]
Schisandra viridis A.c. Smith.	Schisandraceae	Vane	Ethanol	5 mg/mL	Methicillin-resistant *S. aureus*	-	-	[32]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Halleria lucida L.	Scrophulariaceae	Leaves Stem	Aqueous Dichloromethane/ Methanol	1–8 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Brandisia hancei Hook.f.	Scrophulariaceae	Whole Plant	Ethanol	3.33–33.3 mg/mL	Methicillin-resistant *S. aureus*	-	-	[32]
Selaginella tamariscina (Seauv.) Spring.	Selaginellaceae	Whole Plant	Ethanol	250 mg/mL	Methicillin-resistant *S. aureus*	-	-	[32]
Datura stramonium L.	Solanaceae	Leaves, Stem, Fruit	Aqueous Dichloromethane/ Methanol	10–100 mg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Solanum incanum L	Solanaceae	Leaves	Aqueous Dichloromethane/ Methanol	5–50 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Solanum trilobatum L.	Solanaceae	Leaves	Acetone Aqueous Benzene Butanol Chloroform Ethanol	156–625 µg/mL 250 mg/mL 10–100 mg/mL 5–50 mg/mL 60 µg/mL 5 mg/mL	*S. pyogens, S. aureus, B. subtilis*	*S. typhi, P. vulgaris, K. pneumoniae, P. aeruginosa, E. coli*	-	[37]
Datura metel L.	Solanaceae	Leaves	Aqueous Dichloromethane/ Methanol	350–600 µg/mL 1 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Solanum macrocarpon L.	Solanaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	500 µg/mL 60 µg/mL	*B. cereus, S. aureus*	-	-	[41]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Solanum melongena L.	Solanaceae	Leaves, Root Stem	Aqueous Dichloromethane/ Methanol	800 mg/disc 100 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Solanum nigrum L.	Solanaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	600, 1200 µg/mL 1 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Solanum torvum Sw.	Solanaceae	Leaves	Aqueous Dichloromethane/ Methanol	3.33–33.3 mg/mL 60 µg/mL	*B. cereus, S. aureus*	-	-	[41]
Solanum virginianum L.	Solanaceae	Leaves, Stem, Root	Aqueous Dichloromethane/ Methanol	250 mg/mL 4 mg/mL	*B. cereus, S. aureus*	-	-	[41]
Withania somnifera (L.) Dunal	Solanaceae	Roots & Leaves	Aqueous Dichloromethane/ Methanol	10–100 mg/mL 1 mg/mL	*B. cereus, S. aureus,* methicillin-resistant *S. aureus*	-	-	[41,59]
Cola acuminate L.	Sterculiaceae	Stem	Acetone Methanol	5–50 mg/mL 100 µg/mL	*S. aureus*	-	*C. albicans*	[16]
Schima sinensis (Hemsl. et. Wils) Airy-shaw.	Theaceae	Tbl	Ethanol	156–625 µg/mL	methicillin-resistant *S. aureus*	-	-	[32]
Coriandrum sativum	Umbelliferae	Seeds	Aqueous	350–600 µg/mL	*S. aureus*	*K. pneumoniae, P. aeruginosa,*	*A. niger, P. lilacinum*	[27]
Clerodendrum inerme L	Verbenaceae	Leaves	Methanol	500 µg/mL	*S. aureus*	-	*A. niger*	[60]
Lantana rugosa Thunb.	Verbenaceae	Leaves	Aqueous Dichloromethane/ Methanol	800 mg/disc 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]

Table 1. *Cont.*

Botanical Name	Family	Plant Used	Extracts	MIC *	Gram Positive	Gram Negative	Fungi	References
Lantana camara L.	Verbenaceae	Leaves, Flower	Chloroform Acetone Methanol Aqueous	600, 1200 µg/mL 5 mg/mL 1–8 mg/mL 1–2 mg/mL	*S. aureus, B. cereus*	*E. coli, S. typhi, P. aeruginosa, K. aerogenes, P. vulgaris, S. Boydii, K. pneumoniae, V. cholerae*	*A. fumigatus, A. flavus, A. niger, C. albicans*	[39]
Lantana indica L.	Verbenaceae	Leaves	Methanol Aqueous	3.33–33.3 mg/mL 4 mg/mL	*B. subtilis, S. aureus, S. pyogenes,*	*E. coli, P. vulgaris, K. pneumoniae*	*C.albicans,*	[61]
Cyphostemma lanigerum Harv.	Vitaceae	Leaves, Stem	Aqueous Dichloromethane/ Methanol	250 mg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata* *C. krusei*	[23]
Cyphostemma setosum Roxb.	Vitaceae	Leaves, Stem, Fruit	Aqueous Dichloromethane/ Methanol	10–100 mg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Aloe arborescens Mill.	Xanthorrhoeaceae	Leaves	Aqueous Dichloromethane/ Methanol	5–50 mg/mL 750–12,000 µg/mL	*S. aureus, methicillin- resistant S. aureus, gentamycin– methicillin-resistant S. aureus, S. epidermidis, B. agri, P. acnes*	*P. aeruginosa*	*T. mentagrophytes, M. canis*	[21]
Siphonochilus aethiopicus Schweinf.,	Zingiberaceae	Leaves, Stem, Root	Aqueous Dichloromethane/ Methanol	156–625 µg/mL 750–12,000 µg/mL	*S. mutans, S. sanguis, L. acidophilus L. casei*	*P. gingivalis F. nucleatum*	*C. albicans C. glabrata C. krusei*	[23]
Curcuma xanthorrhiza	Zingiberaceae	Rhizome	Ethanol	350–600 µg/mL	methicillin-resistant *S. aureus*	-	-	[46]
Kaempferia pandurata Roxb.	Zingiberaceae	Rhizome	Ethanol	500 µg/mL	methicillin-resistant *S. aureus*	-	-	[46]
Peganum harmala L.	Zygophyllaceae	Seeds	Ethanol	800 mg/disc	*S. aureus*	*E. coli*	-	[21]

* **MIC** (minimum inhibitory concentration) is the lowest drug concentration at which a given antimicrobial extract inhibits the visible growth of a tested organism. **MIC absolute value**: the given absolute value of drug concentration inhibits the growth of all tested organisms/ **MIC ranges**: the given range of drug concentrations (minimum to maximum) inhibit the growth of the individual to all tested organisms.

Phytocomponent Fractions and Antimicrobial Methods

Fresh or dried plant extracts were prepared using aqueous and different organic solvents in traditional extraction techniques (maceration, percolation, Soxhlet extraction). During the extraction method, the solvents penetrate into the plant material and dissolve active compounds with a related polarity [62]. At the completion of the technique, solvents have been vaporized, resulting in the formation of a concentrated mixture that yields the active compounds [63]. A successful extraction is mainly reliant on the nature of the solvent utilized during the extraction. The most regularly established extracts are aqueous extract followed by organic solvents, which include using methanol, ethanol, hexane, isopropanol, ethyl acetate, benzene, acetone, chloroform, and dichloromethane [64].

Two popular types of antibacterial susceptibility test, namely diffusion and dilution methods, are generally performed to determine the antibacterial efficacy of the plant materials. The method of diffusion is a screening test to classify bacteria that aid susceptibility or resistance to the tested plant material based on the size or diameter of the inhibition zone [62]. On the other hand, the activity of plant materials is determined as minimum inhibitory concentration (MIC) in the dilution method. In the MIC method, the lowest concentration is capable of inhibiting bacterial growth. Redox indicators and turbidity are most often measured for the analysis of results in broth dilution methods. The turbidity can be calculated colorimetrically while changing the indicator color represents the inhibition of bacterial growth [62]. The screening of traditional plant extracts has been of great attention to researchers investigating novel bioactive compounds effective in the treatment of microbial infections. Plant extracts exhibit: (a) direct antimicrobial activity presenting effects on metabolism and development of microbes and (b) indirect activity as antibiotic resistance adapting substances which, joint with antibiotics, upsurge their efficiency. Numerous studies have considered the antimicrobial screening of traditional plant extracts. The studies of medicinal plants from diverse topographical areas include: Armenia [65], Iran [66], Mexico [67], Saudi Arabia [68], Libya [26], Ethiopia [64], India [63], Poland [69], Cameroon [70], Nigeria [71], and other Middle Eastern countries [72]. Based on the available information, the traditional plant extracts showed antimicrobial activity against a huge number of pathogenic bacteria, fungi, viruses, algae, protozoan, and Trypanosoma [26,63,64,66].

3. Bioactive Compounds (Bioactive Phytocomponents)

Traditional medicinal plants possess various chemical substances that support certain physiological and biochemical activities in the human body and they are known as phytochemicals or phytocomponents. These chemicals are non-nutritive substances used to heal various infectious diseases, as well as provide disease preventive properties [9,10]. With advances in phytochemical practices, numerous active principles have been isolated from medicinal plants and presented as a valuable drug in contemporary systems of medicine. Mostly, the pharmacological activity of medicinal plants resides in their secondary metabolites, which are relatively smaller in quantity in contrast to the primary molecules such as carbohydrates, proteins, and lipids. Plant secondary metabolites are commonly accountable for their antimicrobial properties [62]. These metabolites offer clues to manufacture new structural types of antimicrobial and antifungal chemicals that are comparatively safe to humans [62]. The classes of secondary metabolites that have greater antimicrobial properties are flavonoids (flavones, flavonols, flavanols, isoflavones, anthocyanidins), phenolic acids (hydroxybenzoic, hydroxycinnamic acids), stilbenes, lignans, quinones, tannins, coumarins (simple coumarins, furanocoumarins, pyranocoumarins), terpenoids (sesquiterpene lactones, diterpenes, triterpenes, polyterpenes), alkaloids, glycosides, saponins, lectins, steroids, and polypeptides [6,16,56,62,73–83]. These compounds have copious mechanisms that underlie antimicrobial activity, e.g., disturbing microbial membranes, weakening cellular metabolism, control biofilm formation, inhibiting bacterial capsule production, attenuating bacterial virulence by controlling quorum-sensing, and reducing microbial toxin production [3–6,73–85]. Various bioactive compounds have been scientifically tested for their antimicrobial activities and are presented in Table 2.

Table 2. Antimicrobial activities of bioactive compounds.

Botanical Name	Family	Extracts	Bioactive Compounds	MIC *	Organism Inhibited	References
Allium sativum L.	Alliaceae	Methanol	Cyanidin-3-(6′-malonyl)-glucoside, vanillic acid caffeic acid, p-coumaric acid, ferulic acid, sinapic acid, L-alliin, alliin isomer and methiin	-	*B. cereus, L. monocytogenes S. aureus, P. aeruginosa, E. coli*	[11]
Searsia chirindensis (Baker f.) Moffett	Anacardiaceae	Ethanol Dichloromethane/ Methanol n-butanol Ethyl Acetate Crude	Methyl gallate myricetin-3-O-arabinopyranoside myricetrin-3-O-rhamnoside kaempferol-3-O-rhamnoside quercetin-3-O-arabinofuranoside	30–130 µg/mL 60–250 µg/mL 60–250 µg/mL 130–250 µg/mL 250 µg/mL 250–6250 µg/mL 130–3125 µg/mL 60–780 µg/mL 60–780 µg/mL	*C. jejuni, E. coli, S. flexneri, S. aureus*	[86]
Xylopia aethiopica (Dunal) A. Rich.	Annonaceae	Aqueous	1R-a-Pinene, β-Pinene, 2-Carene, Cyclohexene,5-methyl-3-(1-methylethenyl)-trans-(-)-Bicyclo [3.1.0] hexane,6-isopropylidene-1-methyl-, Eucalyptol, Ethyl 2-(5-methyl-5-vinyltetrahydrofuran-2-yl) propan-2-yl carbonate, Isogeraniol, α-Campholenal, L-trans-Pinocarveol, Pinocarvone, Myrtenal, (-)-Spathulenol	1–256 µg/mL	*S. aureus, B. licheniformis, E. coli, K. pneumoniae*	[87]

Table 2. *Cont.*

Botanical Name	Family	Extracts	Bioactive Compounds	MIC *	Organism Inhibited	References
Polyalthia cerasoides	Annonaceae	Hexane Dichloromethane	N-(4-hydroxy-β-phenethyl-4-hydroxy cinnamide	64–128 µg/mL 32–256 µg/mL	*C. diphtheria, B. subtilis, B. cereus, M. lutens*	[88]
Unonopsis lindmanii R. E. Fries	Anonaceae	Hexane	Gallic acid, kaempferol, ellagic acid, epicatechin, vitexin, corilagin	25–250 µg/mL	*C.albicans*	[89]
Allagoptera leucocalyx (Drude) Kuntze,	Arecaceae	Hexane	Gallic acid, kaempferol, ellagic acid, epicatechin, vitexin, corilagin	162.2–665 mg/mL	*C.albicans*	[89]
Bactris glaucescens Drude	Arecaceae	Hexane	Gallic acid, kaempferol, ellagic acid, epicatechin, vitexin, corilagin	200–755 mg/mL	*C.albicans*	[89]
Scheelea phalerata Mart	Arecaceae	Hexane	Gallic acid, kaempferol, ellagic acid, epicatechin, vitexin, corilagin	129 mg/mL	*C.albicans*	[89]
Artemisia herba-alba Asso	Asteraceae	Aqueous	1,8-cineole, β-thujone, α-thujone, camphor	640–2500 µg/mL	*T. rubrum and E. floccosum*	[90]
Vernonia adoensis Sch. Bip. ex Walp.	Asteraceae	Acetone	Chondrillasterol	50 µg/mL	*S. aureus, K. pneumonia, P. aeruginosa*	[1]

Table 2. *Cont.*

Botanical Name	Family	Extracts	Bioactive Compounds	MIC *	Organism Inhibited	References
Matricaria chamomilla	Asteraceae	Ethanol	Phenolic acid	1.56–3.12 mg/mL	*S. typhimurium*	[19]
Solidago graminifolia L. Salisb.	Asteraceae	Ethanol Methanol Aqueous	di-C-glycosylflavones (schaftoside, isoschaftoside), caftaric acid, gentisic acid, chlorogenic acid, *p*-coumaric acid, ferulic acid, hyperoside, rutin, quercitrin, quercetin, Luteolin, kaempferol, gallic acid, protocatechuic acid, vanillic acid, syringic acid, rosmarinic acid	40–3120 µg/mL 90–3120 µg/mL 190–6250 µg/mL	*S. aureus, C. albicans, C. parapsilosis.*	[12]
Baccharis trimera	Asteraceae	Crude	Polyphenols, flavonoids, alkaloids, and terpenes	7.8–500 µg/mL	*E. coli, S. aureus, P. aeruginosa, C. albicans, C. tropicalis, C. parapsilosis, Epicoccum sp., C. sphaerospermum, C. neoformans, P. brasiliensis, C. gatti, Pestalotiopsis sp., C. lunatus, Nigrospora sp.*	[88]
Tecoma stans	Bignoniaceae	Aqueous	Phenolic compounds	50–600 µg/mL	*S. aureus*	[91]
Bixa orellana L.	Bixaceae	Aqueous	Bixin, catechin, chlorogenic acid, chrysin, butein, hypolaetin, licochalcone A, and xanthohumol.	16–32 µg/mL	*B. cereus, S. aureus*	[9]
Trichodesma indicum	Boraginaceae	Ethanol	Lanast-5-en-3β-D- glucopyranosyl-21(24)-oilde	2.4–19.2 µg/mL	*S. aureus*	[92]

Table 2. *Cont.*

Botanical Name	Family	Extracts	Bioactive Compounds	MIC *	Organism Inhibited	References
Boswellia dalzielii Hutch.	Burseraceae	Crude	Oleic acid, squalene and n-hexadecanoic acid	-	*S. pyogenes*, *S. aureus*, *E. coli*, *E. faecalis*, *K. pneumonia*, *P. aeruginosa*, *P. mirabilis*, *S. typhi*, and *C. albicans*	[93]
Caesalpinia coriaria (Jacq) Willd	Caesalpiniaceae	Aqueous Ethanol	Methyl gallate and gallic acid	1.56–25 mg/mL 390–6250 µg/mL	S. typhi, E. coli, P. aeruginosa, L. monocytogenes, S. aureus.	[94]
Senna aculeate (Bth.) Irw et Barn	Ceasalpinioideae	Hexane	Gallic acid, kaempferol, ellagic acid, epicatechin, vitexin, corilagin	25, 50, 100 mg/mL	*C.albicans*	[89]
Kochia scoparia	Chenopodiaceae	Crude	Polyphenols, flavonoids, alkaloids, and terpenes	3.125 mg/mL	*C. graminicola, T. deformans, A. flavus, H. carbonum, C. zeaemaydis, C. macrocarpum, P. innundatus, S. japonicas, E. ficariae, P. herbarum, M. verticillata, Rhisoclosmatium* sp., *S. pseudodichotomus, S. kneipii, R. solani, P. sojae.*	[8]
Buchenavia tomentosa (Mart) Eichler	Combretaceae	Hexane	Gallic acid, Kaempferol, Ellagic acid, epicatechin, Vitexin, Corilagin	10 mg/mL	*C.albicans*	[89]

Table 2. *Cont.*

Botanical Name	Family	Extracts	Bioactive Compounds	MIC *	Organism Inhibited	References
Terminalia phanerophlebia Engl. & Diels	Combretaceae	Crude Dichloromethane Hexane Ethyl Acetate n-butanol	Methyl gallate (methyl-3,4,5-trihydroxybenzoate) and a phenylpropanoid glucoside, 1,6-di-O-coumaroyl glucopyranoside	125 µg/mL 16–250 µg/mL 31–250 µg/mL 8–125 µg/mL 31–250 µg/mL	*M. aurum, M. tuberculosis, S. aureus, K. pneumoniae*	[95]
Buchenavia tomentosa L.	Combretaceae	Crude	Gallic acid, quinic acid, kaempferol, (-) epicatechin, ellagic acid, buchenavianine, eschweilenol b, eschweilenol c, vitexin, corilagin, 1α,23β-dihydroxy-12-oleanen-29-oicacid-23β-o-α-l-4-acetylramnopiranoside and punicalin	200–12500 µg/mL	*Candida albicans, Candida tropicalis, Candida parapsilosis, Candida glabrata, Candida krusei and Candida dubliniensis.*	[96]
Diadema setosum f. depressa Dollfus & Roman.	Diadematidae	Acetone	Polyunsaturated fatty acids (PUFAs) and β-carotene	500–4000 µg/mL	*S. typhi, S. typhimurium, S. flexneri, P. aeruginosa, A. hydrophila, Acinetobacter sp, C. freundii and K. pneumonia, B. subtilis, S. epidermidis S. aureus*	[1]
Monotes kerstingii Gilg	Dipterocarpaceae	Crude	Stilbene-coumarin derivative, coumarin-carbinol and fatty glycoside	1–8 mg/mL	*B. subtilis, Septoria tritici* Desm	[7]
Croton doctoris S Moore	Euphorbiaceae	Hexane	Gallic acid, kaempferol, ellagic acid, epicatechin, vitexin, corilagin	500 µg/mL	*C.albicans*	[89]

Table 2. *Cont.*

Botanical Name	Family	Extracts	Bioactive Compounds	MIC *	Organism Inhibited	References
Jatropha weddelliana Baillon	Euphorbiaceae	Hexane	Gallic acid, kaempferol, ellagic acid, epicatechin, vitexin, corilagin	4–32 µg/mL	*C.albicans*	[89]
Cassia alata	Fabaceae	Ethanol	4-butylamine, cannabinoid, dronabinol, methyl-6-hydroxy	1.25, 1.5 mg/mL	*S. aureus, E. coli, P. aeruginosa, C. albicans*	[28]
Dalbergia scandens Roxb., Corom.	Fabaceae	Ethanol	Dalpanitin, vicenin-2 and 3, rutin	780–6250 mg/mL	*B. cereus, S. aureus, E. coli, P. aeruginosa, C. albicans*	[41]
Acacia nilotica	Fabaceae	Crude	Alkaloids	600–1200 µg/mL	*S. aureus*	[27]
Salvia sessei Benth	Lamiaceae	Hexane Dichloromethane Methanol	Sessein, isosessein	12.5–100 µg/mL 100 µg/mL 12.5–100 µg/mL	*S. haemolyticus, S. hominis, E. faecalis, S. epidermis, S. pyogenes, S.aureus*	[14]
Mentha piperita	Lamiaceae	Methanol	1,1-diphenyl-2-picrylhydazyl-hydrate	1–4 mg/mL	*S. aureus, E. coli, C. albicans*	[97]

Table 2. *Cont.*

Botanical Name	Family	Extracts	Bioactive Compounds	MIC *	Organism Inhibited	References
Ocimum basilicum L.	Lamiaceae	Ethanol	Gallic acid, 3,4-dihydroxy benzoic acid, 4-hydroxy benzoic acid, 2,5 dihydroxybenzoic acid, chlorogenic acid, vanillic acid, Epicatechin, caffeic acid, p-coumaric acid, ferulic acid, rutin, ellagic acid, naringin, quercetin, cinnamic acid, α-pinene, camphene, sabinene, β-pinene, myrcene, 3-octanol, α-terpinene, *p*-cymene, limonene, 1,8-cineole, *(Z)*-β-ocimene, *(E)*-β-ocimene, γ-terpinene, *cis*-sabinene hydrate, terpinolene, linalool, nonanal, pentylisovalerate, 1-octen-3-yl acetate, *cis*-*p*-menth-2-en-1-ol, 3-octyl acetate, α-campholenal, camphor, *trans*-verbenol, δ-terpineol, 4-terpineol, α-terpineol, *cis*-dihydrocarvone, *trans*-carveol, *(Z)*-3-hexenyl isovalerate, pulegone, neral, carvone, linalyl acetate, bornyl acetate, dihydroedulan IA, isodihydrocarvyl acetate, α-terpinyl acetate, *cis*-carvyl acetate, neryl acetate, geranyl acetate, β-elemene, *(Z)*-jasmone, β-caryophyllene, β-copaene, aromadendrene, α-humulene, *(E)*-β-farnesene, *cis*-muurola-4(14), 5-diene germacrene D, bicyclogermacrene, germacrene A, δ-cadinene, *(E)*-α-bisabolene, *(E)*-nerolidol, Spathulenol, caryophyllene oxide, viridiflorol, 1, 10-di-*epi*-cubenol, T-cadinol, T-muurolol, monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, oxygenated sesquiterpenes, apocarotenes non-terpene derivatives	16–256 µg/mL	*S. epidermidis S. aureus*, *B. subtilis*, *E. coli*, *P. aeruginosa*, *K. pneumoniae*, *C. glabrata*, *C. albicans*	[98]

Table 2. *Cont.*

Botanical Name	Family	Extracts	Bioactive Compounds	MIC *	Organism Inhibited	References
Thymus algeriensis Boiss. & Reut	Lamiaceae	Ethanol	Gallic acid, 3,4-dihydroxy benzoic acid, 4-hydroxy benzoic acid, 2,5 dihydroxybenzoic acid, chlorogenic acid, vanillic acid, epicatechin, caffeic acid, p-coumaric acid, ferulic acid, rutin, ellagic acid, naringin, quercetin, cinnamic acid, α-pinene, camphene, sabinene, β-pinene, myrcene, 3-octanol, α-terpinene, *p*-cymene, limonene, 1,8-cineole, *(Z)*-β-ocimene, *(E)*-β-ocimene, γ-terpinene, *cis*-sabinene hydrate, terpinolene, linalool, nonanal, pentylisovalerate, 1-octen-3-yl acetate, *cis*-*p*-menth-2-en-1-ol, 3-octyl acetate, α-campholenal, camphor, *trans*-verbenol, δ-terpineol, 4-terpineol, α-terpineol, *cis*-dihydrocarvone, *trans*-carveol, *(Z)*-3-hexenyl isovalerate, pulegone, neral, carvone, linalyl acetate, bornyl acetate, dihydroedulan IA, isodihydrocarvyl acetate, α-terpinyl acetate, *cis*-carvyl acetate, neryl acetate, geranyl acetate, β-elemene, *(Z)*-jasmone, β-caryophyllene, β-copaene, aromadendrene, α-humulene, *(E)*-β-farnesene, *cis*-muurola-4(14), 5-diene germacrene D, bicyclogermacrene, germacrene A, δ-cadinene, *(E)*-α-bisabolene, *(E)*-nerolidol, spathulenol, caryophyllene oxide, viridiflorol, 1, 10-di-*epi*-cubenol, T-cadinol, T-muurolol, monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, oxygenated sesquiterpenes, apocarotenes non-terpene derivatives	32–512 µg/mL	*S. epidermidis S. aureus*, *B. subtilis*, *E. coli*, *P. aeruginosa*, *K. pneumoniae*, *C. glabrata*, *C. albicans*	[98]

Table 2. *Cont.*

Botanical Name	Family	Extracts	Bioactive Compounds	MIC *	Organism Inhibited	References
Cinnamomun inerme	Lauraceae	Ethyl Acetate Hexane Acetone n-butanol	5-(1,5-dimethyl-2-4-hexenyl)- methyl phenol)	100–800 µg/mL 8000 µg/mL 8000 µg/mL 100–800 µg/mL	*S. aureus, E. coli*	[99]
Allium sativam	Liliaceae	Crude	Allicin	49 µg/mL	*C. albicans*	[100]
Strychnos nigritana Baker	Loganiaceae	Crude	Nigritanine, Speciociliatine, Mytragine Paynantheine Rhyncophylline	128–256 µg/mL	S. aureus	[10]
Mascagnia benthamiana (Gries) WR Anderson	Malpighiaceae	Hexane	Gallic acid, kaempferol, ellagic acid, epicatechin, vitexin, corilagin	17.84 mg/mL	*C.albicans*	[89]
Mouriri elliptica Mart	Memecylaceae	Hexane	Gallic acid, kaempferol, ellagic acid, epicatechin, vitexin, corilagin	100 µg/mL	*C.albicans*	[89]
Artocarpus communis	Moraceae	Crude	Atonin E, 2-(3,5-dihydroxy)-(Z)-4-(3 methyl but-1-etnyl	4–512 µg/mL	*P. aeruginosa, S.typhi, S.aureus, K.pneumoniae*	[101]
Myrtus nivellei Batt. & Trab.	Myrtaceae	Crude	1,8-cineole, limonene, isoamylcyclopentane, di-nor-sesquiterpenoids	5 mg/mL	*C. neoformans*	[102]

Table 2. *Cont.*

Botanical Name	Family	Extracts	Bioactive Compounds	MIC *	Organism Inhibited	References
Myrtus communis L	Myrtaceae	Crude	α-pinene, 1,8-cineole, linalool, and linalyl acetate	156–625 μg/mL	*E. floccosum, M. canis, T. rubrum*	[102]
Piper nigrum	Piperaceae	Aqueous	Piperine	500–1000 μg/mL	*E. coli, M. luteus*	[91]
Citrus aurantium L.	Rutaceae	Ethanol	Polyphenols, flavonoids, alkaloids, and terpenes	1562–6250 μg/mL	Amoxycillin resistant *B. cereus*	[13]
Salix babylonica L.	Salicaceae	Hydroalcoholic	Luteolin, luteolin 7-*O*-glucoside	1.56–100 mg/mL	*E. coli, S. aureus* and *L. monocytogenes*	[103]
Verbascum glabratum subsp. bosnense (K. Malý) Murb	Scrophulariaceae	Ethanol	quercitrin and rosmarinic acid, 4-hydroxybenzoic acid, salicylic acid, morin, and apigenin	600, 1200 μg/mL	*E. coli, S. aureus, Candida albicans*	[17]
Simaba ferruginea A. St.-Hil	Simaroubaceae	Methanol	Canthin-6-one, indole β-carboxylic	12.5–200 μg/mL	S. flexneri, S. aureus and S. aureus	[91]
Camellia sinensis	Theaceae	Aqueous	Catechin	7.81–31.25 μg/mL	*S. mutans*	[104]
Talaromyces sp.	Trichocomaceae	Aqueous	Talaropeptide A and B	5 mg/mL	*B. subtilis*	[18]
Hybanthus enneasperm us	Violaceae	Crude	Flavonoids, Tannins	37.5, 75, 150, 300, 600 μg/mL	*P. vulgaris, V. cholera*	[100]

4. Mechanism of Actions of Antibacterial Bioactive Compounds

As proven by in vitro experiments, medicinal plants produce a boundless quantity of secondary metabolites that have great antimicrobial activity [9,10,18]. These plant-produced low molecular weight antibiotics are classified according to two types, namely phytoanticipins, which are involved in microbial inhibitory actions, and phytoalexins, which are generally anti-oxidative and synthesized de novo by plants in response to microbial infection [16,74]. Plant antimicrobial secondary metabolites are generally categorized into three broad classes, namely phenolic compounds, terpenes, and alkaloids. Numerous studies have shown that the antimicrobial activity of the plant extracts and their active compounds have the following potential: to promote cell wall disruption and lysis, induce reactive oxygen species production, inhibit biofilm formation, inhibit cell wall construction, inhibit microbial DNA replication, inhibit energy synthesis, and inhibit bacterial toxins to the host [75,85,105–109]. In addition, these compounds may prevent antibacterial resistance as well as synergetics to antibiotics, which can ultimately kill pathogenic organisms (Figure 1).

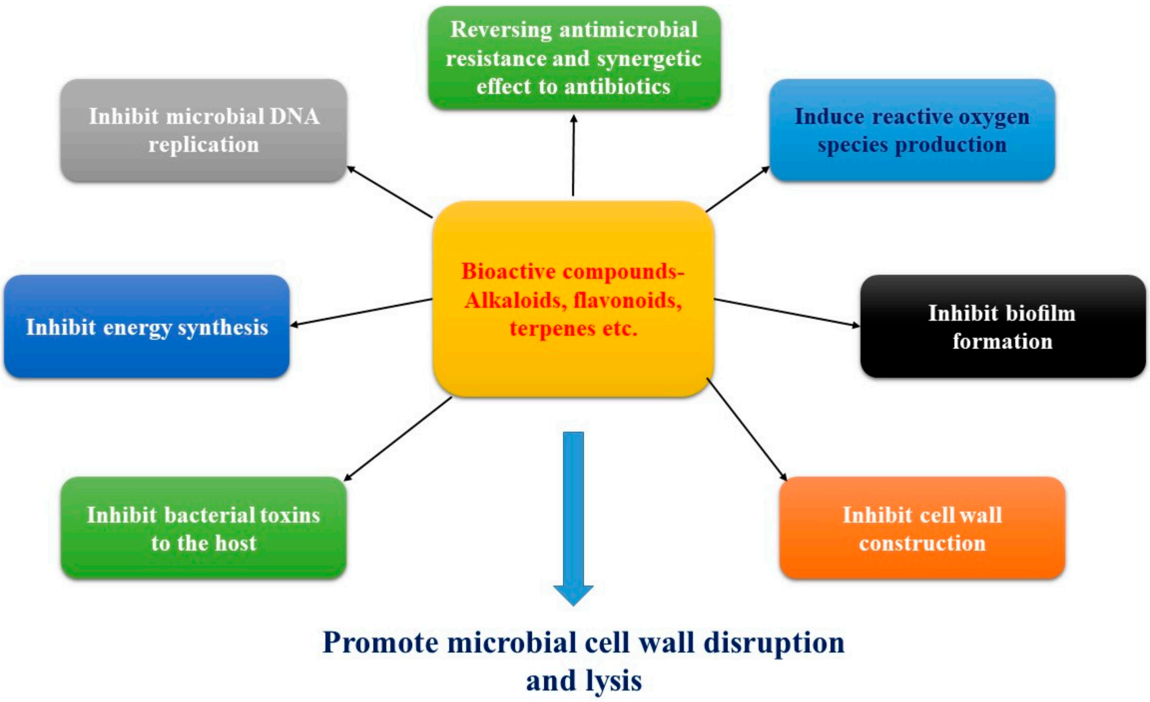


Figure 1. Mechanisms of antimicrobial activity of bioactive compounds.

4.1. *Promote Cell Wall Disruption and Lysis*

Phenolic compounds are a family of aromatic rings consisting of a hydroxyl functional group (-OH) which is alleged to absolute toxicity to microorganisms, although increased reactions of hydroxylation result in microbial cell lysis [110]. Quinones also have aromatic rings with two ketone molecules, which enables the production of an irreversible complex with nucleophilic amino acids, resulting in greater antimicrobial properties. These potential aromatic compounds are usually targeted to microbial cell surface adhesins, membrane-bound polypeptides, enzymes, and eventually lysis of the microbes [111]. Flavonoids are hydroxylated phenolic substances which are also able to complex with bacterial cell walls and disrupt microbial membranes [75,105]. Highly active flavonoids, quercetin (1), rutin (2), naringenin (3), sophoraflavanone (4), tiliroside (5) and 2, 4, 6-trihydroxy-30-methyl chalcone (6) (Figure 2) decreased lipid bilayer thickness and fluidity levels and increased membrane permeability, supporting the leaking of intracellular protein and ions in *S. aureus* and *S. mutans* [112,113]. These compounds contribute to the synergistic effect with ampicillin and tetracycline [114]. The other active flavonoids, acacetin (7), apigenin (8), morin (9), and rhamnetin (10) (Figure 2) cause weakening of the bacterial cell wall by disarrangement and disorientation of the lipid bilayer and ultimately persuade vesicle leakage [115–117]. The synthetic flavonoid lipophilic 3-arylidene (11) was found to be very active against *S. aureus*, *S. epidermidis*, and *E. faecalis* due to a bacterial cell clump that influences the integrity of the cell wall as a result of biofilm disruption [118]. Tannins are classes of another polymeric phenolic substance, characterized as astringency, which is capable to deactivate microbial adhesins, enzymes, and membrane transporter systems [105,119]. Coumarins (12) are benzo-α-pyrones known to stimulate macrophages, which could have an adverse effect on infections [7,120]. Terpenes are organic compounds containing isoprene subunits, which involve microbial membrane disruption [121,122]. Thymol (13), eugenol (14), Cinnamaldehyde (15), carvone (16), and carvacrol (17) (Figure 2) disintegrate the external membrane of various Gram-negative bacteria, releasing LPS and increasing the permeability [123–125].

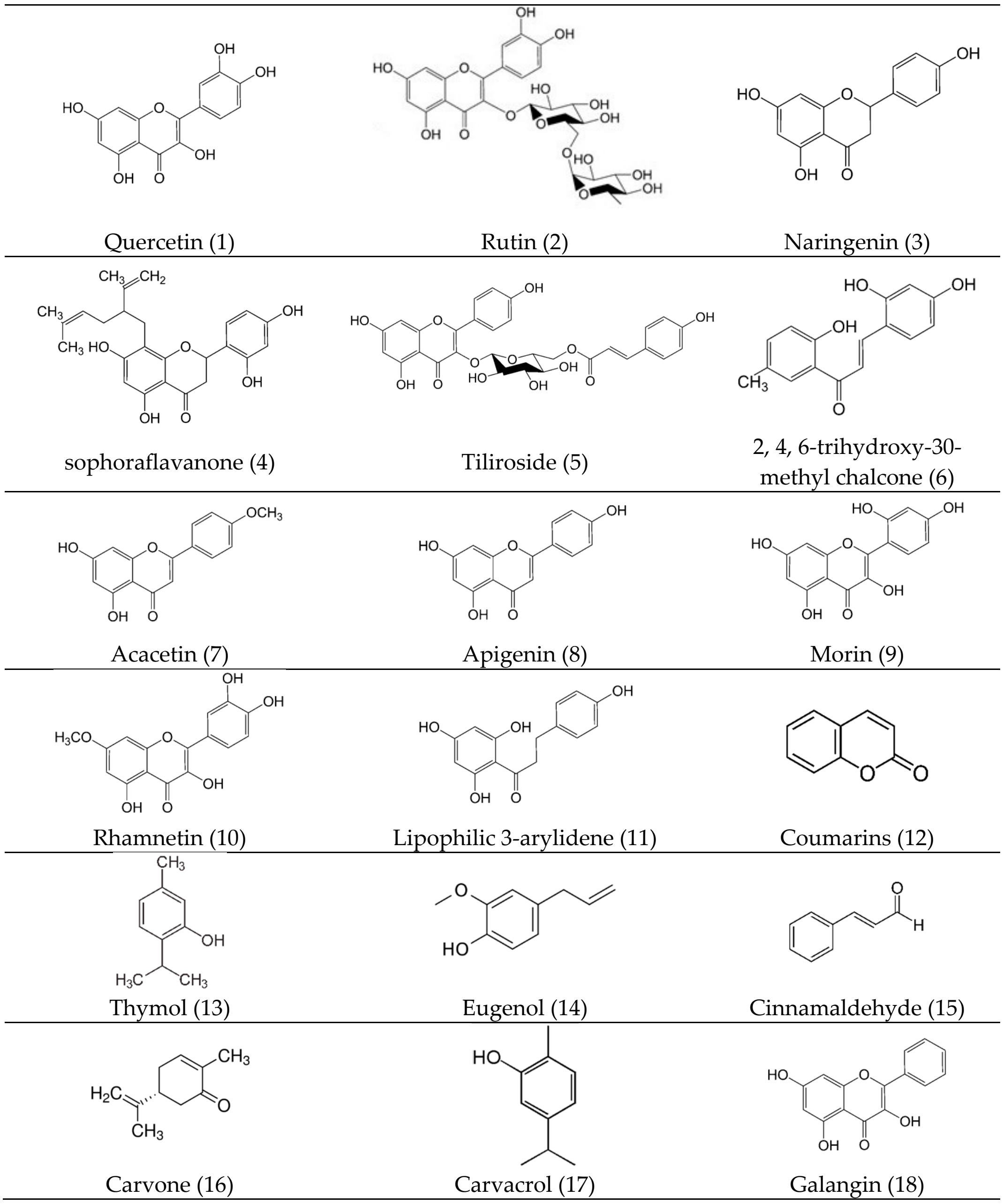
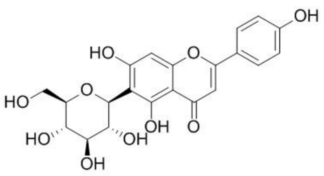
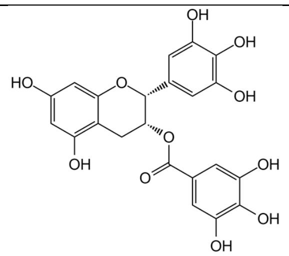


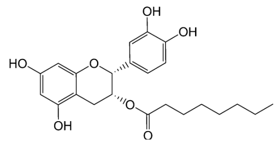
Figure 2. *Cont.*



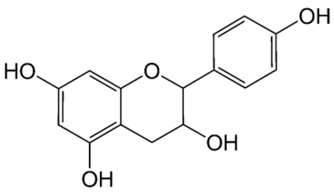
Isovitexin (19)



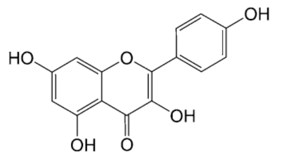
EGCG (20)



3-O-octanoyl-epicatechin (21)



5, 7, 40-trihydroxyflavanol (22)



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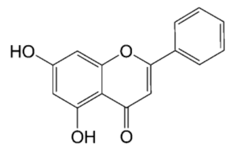

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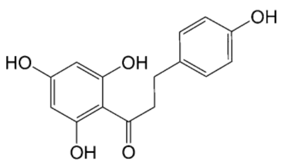
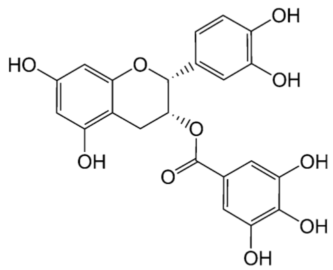
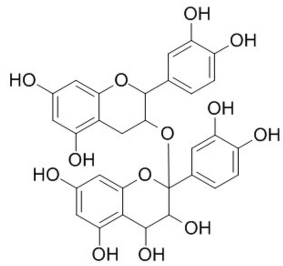


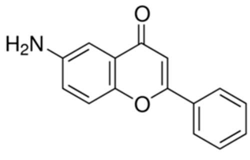
Phloretin (25)



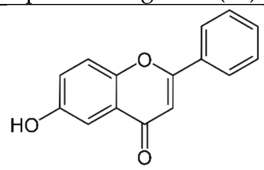
epicatechin gallate (26)



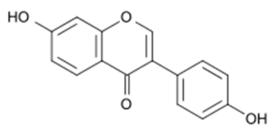
Proanthocyanidins (27)



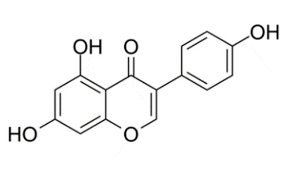
6-aminoflavone (28)



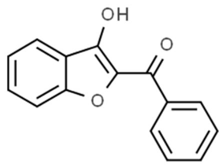
6-hydroxyflavone (29)



Daidzein (30)



Genistein (31)



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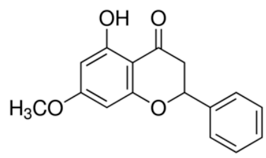

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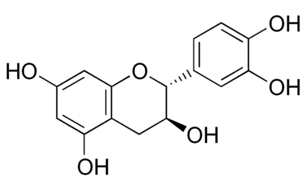
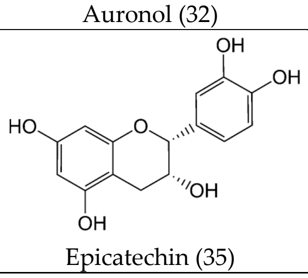
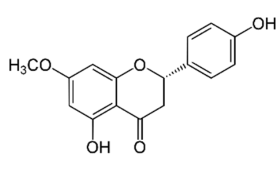


Catechins (34)



Epicatechin (35)



Sakuranetin (36)

Figure 2. *Cont.*

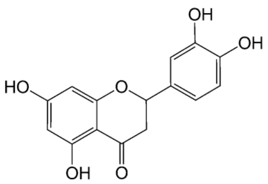
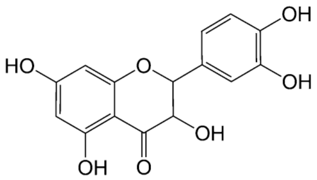
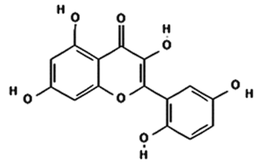
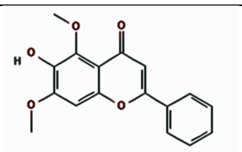
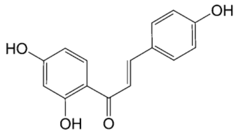
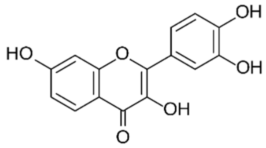
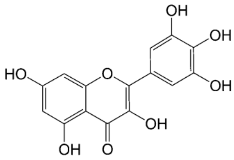
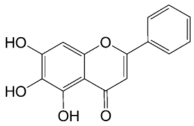
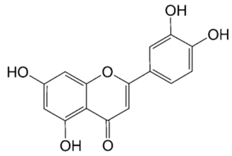
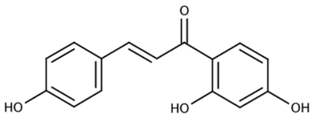
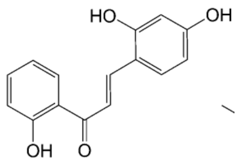
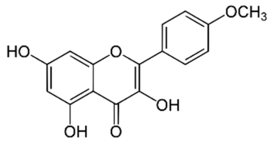
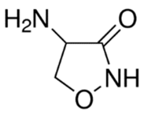
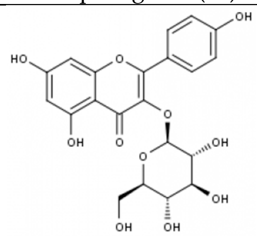
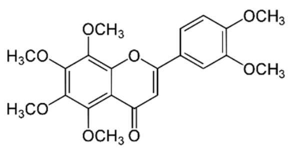
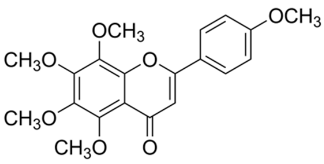
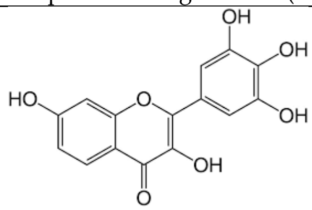
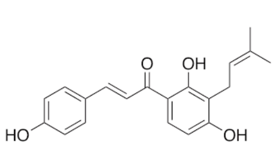
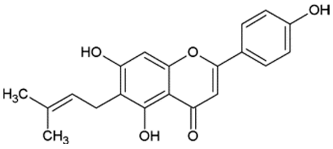
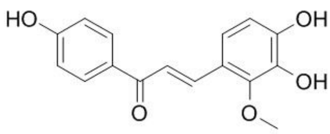
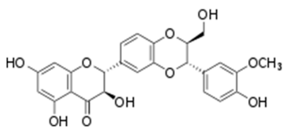
 Eriodictyol (37)	 Taxifolin (38)	 5, 6, 7, 40, 50-pentahydroxyflavone (39)
 5-hydroxy-40, 7-dimethoxyflavone (40)	 4, 20, 40-trihydroxychalcone (41)	 Fisetin (42)
 Myricetin (43)	 Baicalein (44)	 Luteolin (45)
 Butein (46)	 Isoliquirtigenin (47)	 Kaempferide (48)
 DL-cycloserine (49)	 kaempferide-3-O-glucoside (50)	 Nobiletin (51)
 Tangeritin (52)	 Robinetin (53)	 Iso bavachalcone (54)
 6-prenylapigenin (55)	 Licochalcones (56)	 Silibinin (57)

Figure 2. *Cont.*

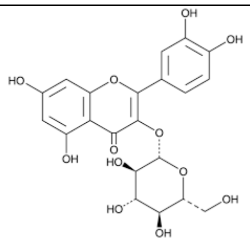
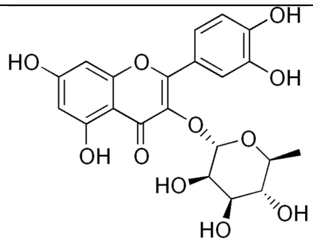
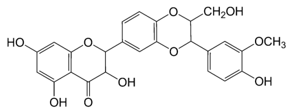
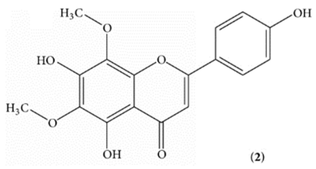
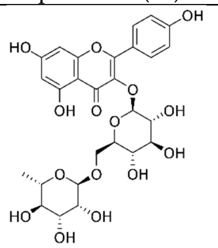
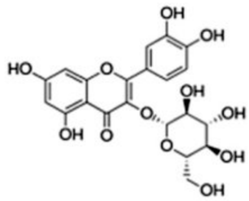
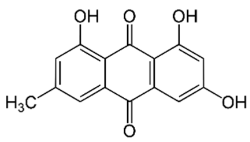
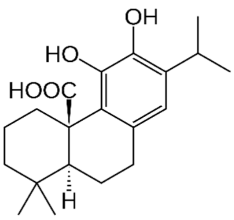
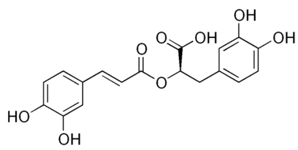
		
Isoquercetin (58)	quercitrin (59)	Silymarin (60)
		
40, 50, 5-trihydroxy-6, 7-dimethoxy-flavone (61)	kaempferol-3-O-rutinoside (62)	quercetin glycoside (63)
		
Emodin (64)	Carnosic acid (65)	Rosmarinic acid (66)

Figure 2. Chemical structures of antibacterial bioactive compounds.

4.2. Inhibition of Biofilm Formation

The key features of bacteria developing biofilms are generally 100–1000 times more resistant to antimicrobial drugs while related to their usual planktonic forms [64]. Interestingly, numerous researchers have described how flavonoids cause the aggregation of multicellular composites of bacteria and inhibit bacterial growth after aggregation, which indicates that flavonoids are potent antibiofilm compounds. The bioactive flavonoids such as galangin (18), isovitexin (19), EGCG (20) and 3-O-octanoyl-epicatechin (21), as well as 5, 7, and 40-trihydroxyflavanol (22) induce pseudo multicellular aggregation of *S. aureus* and *S. mutans* [106–109]. Quorum sensing involves cell signaling molecules called autoinducers present in *E. coli, Vibrio cholerae*, and *S. typhi*, which is a notable regulatory factor for biofilm formation [126]. Interestingly, apigenin (8), kaempferol (23), quercetin (1), and naringenin (3) are effective antagonists of cell–cell signaling [126,127] that have been revealed to inhibit enteroaggregative biofilm formation in *E. coli* and *P. aeruginosa* in a concentration-dependent manner [128,129]. Moreover, chrysin (24), phloretin (25), naringenin (3), kaempferol (23), epicatechin gallate (26), proanthocyanidins (27), and EGCG (20) (Figure 2) inhibited N-acyl homoserine lactones-mediated QS [130–132]. Hydrophilic flavonoids such as 6-aminoflavone (28), 6-hydroxyflavone (29), apigenin (8), chrysin (24), daidzein (30), genistein (31), auronol (32), and phloretin (25) (Figure 2) have inhibitory effects on *E. coli* biofilm formation [133,134]. In addition, Phloretin (25) inhibited fimbriae formation in *E. coli* by reducing the expression of the curli genes (csgA, csgB) and toxin genes (hemolysin E, Shiga toxin 2) [6], eventually inhibiting the formation of biofilm. Hence, phloretin (25) is well known as an antibiotic resistant compound. Pinostrobin (33), EGCG (20) and prenylated flavonoids enhanced membrane permeability in *E. faecalis, S. aureus, E. coli*, and *P. aeruginosa, Porphyromonas gingivalis*, which is consistent with its effect on efflux-pump inhibitors and anti-biofilm formation [34,135,136].

4.3. Inhibition of Cell Wall Construction

The bacterial cell wall is accountable for osmoregulation, respiration, the transport mechanism, and biosynthesis of lipids. For the execution of these functions, membrane integrity is very important, and its disruption can directly or indirectly cause metabolic dysfunction eventually leads to bacterial death. Catechins (34) attract lipid bilayers of the membrane which involves the following mechanisms [137]. Catechins form hydrogen bonds, which attract polar head groups of lipids at the membrane edge. Epicatechin (35) and epigallocatechin gallate (26) alter phospholipids, which can alter structural changes in the cell membrane. Moreover, these catechins promote the inactivation or inhibition of intracellular and extracellular enzyme synthesis [137]. Generally, the inhibition of enzymes in fatty acid biosynthesis is an excellent target for antimicrobial agents for blocking bacterial growth, especially the key enzyme fatty acid synthase II (FAS-II) inhibitor is significant as an antimicrobial drug. Quercetin (1), apigenin (8), and sakuranetin (36) have been demonstrated to inhibit 3-hydroxyacyl-ACP dehydrase from *Helicobacter pylori* [138] and eriodictyol (37). Further, naringenin (3) and taxifolin (38) (Figure 2) inhibit 3-ketoacyl- ACP synthase from *E. faecalis* [139]. Flavonoids such as Epigallocatechin gallate (EGCG) (20), 5, 6, 7, 40, 50- pentahydroxyflavone (39), and 5-hydroxy-40, 7-dimethoxyflavone (40) inhibit the malonyl CoA-acyl carrier protein transacylase that regulates bacterial FAS-II [140,141]. EGCG (20) inhibits 3-ketoacyl-ACP reductase and enoyl-ACP reductase and prevents fatty acid biosynthesis [142]. Quercetin (1), kaempferol (23), 4, 20, 40-trihydroxychalcone (41), fisetin (42), morin (9), myricetin (43), baicalein (44), luteolin (45), EGCG (20), butein (46), and isoliquirtigenin (47) (Figure 2) inhibit various enzymes involved in fatty acid synthesis, including, FAS-II, enoyl-ACP-reductase, β-ketoacyl-ACP reductase, and β-hydroxy acyl-ACP dehydratases in *Mycobacterium sp*. [143]. Baicalein (44), EGCG (20), galangin (18), kaempferide (48), DL-cycloserine (49), quercetin (1), apigenin (8), and kaempferide-3-O-glucoside (50) (Figure 2) inhibit the synthesis of peptidoglycan, which is an essential component of the bacterial cell wall, resulting in cell wall damage [144–146].

4.4. Inhibition of Prokaryotic DNA Replication

Alkaloids are nitrogenous compounds characterized by their alkaline nature, which aids the inhibition of cell respiration, intercalates with DNA, and inhibits various enzymes involved in replication, transcription, and translation [147]. Plant-based bioactive compounds such as quercetin (1), nobiletin (51), myricetin (43), tangeritin (52,) genistein (31), apigenin (8), chrysin (24), kaempferol (23), and 3, 6, 7, 30, 40-pentahydroxyflavone (39) have been recognized as noteworthy DNA gyrase inhibitors, which are essential for DNA replication in prokaryotes including *V. harveyi*, *B. subtilis*, *M. smegmatis*, *M. tuberculosis*, and *E. coli* [146,148–151]. These bioactive compounds binding to the β subunit of gyrase and the corresponding blockage of the ATP binding pocket eventually contribute to the antimicrobial activity. Bioactive compounds have mediated the dysfunction of DNA gyrase functions in a dose-dependent manner that leads to the impairment of cell division and/or completion of chromosome replication, resulting in the inhibition of bacterial growth [149]. Luteolin (45), morin (9), and myricetin (43) have been demonstrated to inhibit the helicases of *E. coli* [152]. Helicases consititute another significant replicative enzyme responsible for separating and/or rearranging DNA double-strands [153]. Furthermore, myricetin (43) and baicalein (44) have been proposed as potent inhibitors of numerous DNA and RNA polymerases, as well as viral reverse transcriptase, resulting in the inhibition of bacterial growth [154]. EGCG (20), myricetin (43), and robinetin (53) have been demonstrated as inhibitors of dihydrofolate reductase in *Streptomonas maltophilia*, *P.vulgaris*, *S. aureus*, *M. tuberculosis*, and *E. coli* [43,155,156]. Dihydrofolate reductase is key enzyme for the synthesis of the purine and pyrimidine rings of nucleic acid, resulting in reduced DNA, RNA, and protein synthesis [156].

4.5. Inhibition of Energy Production

Energy production or ATP synthesis is the supreme vital requirement for the existence and development of bacteria as these chemicals are the main source of living systems. The treatment of flavonoids such as isobavachalcone (54) and 6-prenylapigenin (55) with *S. aureus* cause membrane depolarization, resulting in bacterial cell wall lysis [101]. Similarly, licochalcones (56) inhibited oxygen consumption in *M. luteus*, interruping the electron transport system eventually killing the bacteria [6]. It has been described that flavonoids such as baicalein (44), morin (9), silibinin (57), quercetin (1), isoquercetin (58), quercitrin (59), and silymarin (60) can constrain the F1FO ATPase system of *E. coli* and result in the obstruction of ATP synthesis [157–159]. Additionally, EGCG (20), 40, 50, 5-trihydroxy-6, 7-dimethoxy-flavone (61), and proanthocyanidins (27) have also inhibited *S. mutans, P. aeruginosa* and *S. aureus* through the enzymatic activity of F1FO ATPase respectively [100,104,141].

4.6. Inhibition of Bacterial Toxins

It is noteworthy that catechins and other flavonoids can cause bacterial cell wall destruction, resulting in an inability to discharge toxins [160,161]. Catechins (34), pinocembrin, kaempferol, EGCG (20), gallocatechin gallate (26), kaempferol-3-O-rutinoside (62), genistein (31), quercetin glycoside (63), and proanthocyanidins (27) (Figure 2) are suggested to neutralize bacterial toxic factors initiating from *V. cholerae, E. coli, S. aureus, V. vulnificus, B. anthracis, N. gonorrhoeae*, and *C. botulinum* [162–165]. Bacterial hyaluronidases are enzymes formed by both Gram-positive and Gram-negative bacteria and directly interact with host tissues, causing the permeability of connective tissues and reducing the viscosity of body fluids due to hyaluronidase-mediated degradation [166]. Flavonoids such as myricetin (43) and quercetin (1) have been identified as hyaluronic acid lyase inhibitors in *Streptococcus equisimilis* and *Streptococcus agalactiae* [167].

4.7. Mechanism of Resistance to Antibacterial Agents

Pathogenic bacteria generally receive the resistance to various antibiotics through diverse mechanisms. Such mechanisms include: (a) bacteria can share the resistance genes through transformation, transduction, and conjugation; (b) bacteria produce various enzymes to deactivate the antibiotics through the process of phosphorylation, adenylation, or acetylation; (c) damage or alteration of the drug compound; (c) prevent the interaction of the drug with the target; (d) efflux of the antibiotic from the cell [168–170]. Emodin (1, 2, 8-trihydroxy-6-methylanthraquinone) (64) is an anthraquinone derivative which prevents the transformation of resistance genes in *S. aureus* [171]. Baicalein is a potent inhibitor of the expression of the SOS genes, *RecA, LexA*, and *SACOL1400* that prevent rifampin-resistant mutation in *S. aureus* [172]. Phenolic compounds such as Carnosic (65) and rosmarinic acids (66) inactivate cmeB, cmeF, and cmeR genes in *Campylobacter jejuni* [173].

4.8. Antimicrobial Action with Generation of Reactive Oxygen Species

Reactive oxygen species (ROS) can be formed by the partial reduction of molecular oxygen that targets the exertion of antimicrobial activity, which aids host defense against various disease-causing pathogens. The suggested method of antimicrobial activity of catechins (34) involves augmentation of the production of oxidative stress (ROS and RNS), which can alter membrane permeability and cause as cell wall damage [174]. In addition, catechins damage liposomes as they contain a high amount of negatively charged lipids and are susceptible to damage [175]. An earlier study indicated that catechins support the leaking of potassium and disturbs the membrane transport system in a methicillin-resistant *S. aureus* strain [85]. This team has further demonstrated that acylated 3-O-octanoyl-epicatechin (21) is a lipophilic compound that produces more outcomes in antibacterial activity.

5. Conclusions

Since time immemorial, traditional medicinal plants have been cultivated by diverse populations to treat a great number of infectious diseases. Various investigations on the pharmacognostics and kinetics of medicinal plants have shown that crude extracts and plant-derived bioactive compounds may enhance the effects of traditional antimicrobials, which may be cost-effective, have fewer side effects, and improve the quality of treatment. Numerous studies have shown that the antimicrobial activity of plant extracts and their active compounds have the following potential: promote cell wall disruption and lysis, induce reactive oxygen species production, inhibit biofilm formation, inhibit cell wall construction, inhibit microbial DNA replication, inhibit energy synthesis, and inhibit bacterial toxins to the host. In addition, these compounds may prevent antibacterial resistance as well as synergetics to antibiotics, which can ultimately kill pathogenic organisms. Based on these comprehensive antimicrobial mechanisms, the cultivation of traditional plant extracts and bioactive compounds offers a promising treatment for disease-causing infectious microbial pathogens. Hence, this mechanism constitutes an encouraging ally in the development of pharmacological agents required to combat the growing number of microbial strains that have become resistant to extant antibiotics in clinical practice.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

A. bohemicus	*Acinetobacter bohemicus*
A. flavus	*Aspergillus flavus*
A. fumigatus	*Aspergillus fumigatus*
A. niger	*Aspergillus niger*
A. solani	*Alternaria solani*
B. agri	*Brevibacillus agri*
B. brevis	*Brevibacillus brevis*
B. cereus	*Bacillus cereus*
B. megaterium	*Bacillus megaterium*
B. pumilus	*Bacillus pumilus*
B. subtilis	*Bacillus subtilis*
C. albicans	*Candida albicans*
C. Dipthieriae	*Corynebacterium Dipthieriae*
C. dubliniensis	*Candida dubliniensis*
C. glabrata	*Candida glabrata*
C. graminicola	*Colletotrichum graminicola*
C. jejuni	*Campylobacter jejuni*
C. krusei	*Candida krusei*
C. lunat	*Candida lunat*
C. lunatus	*Cochliobolus lunatus*
C. macrocarpum	*Cladosporium macrocarpum*
C. neoformans	*Cryptococcus neoformans*
C. parapsilosis	*Candida parapsilosis*
C. sphaerospermum	*Cladosporium sphaerospermum*
C. tropicalis	*Candida tropicalis*
C. maydis	*Cercospora zeae-maydis*
D. turcica	*Drechslera turcica*

E. aerogenes	*Enterobacter aerogenes*
E. cloacae	*Enterobacter cloacae*
E. coli	*Escherichia coli*
E. faecalis	*Enterococcus faecalis*
E. ficariae	*Entyloma ficariae*
E. floccosum	*Epidermophyton floccosum*
F. nucleatum	*Fusobacterium nucleatum*
F. oxysporum	*Fusarium oxysporum*
F. verticillioides	*Fusarium verticillioides*
H. carbonum	*Helminthosporium carbonum*
H. pylori	*Helicobacter pylori*
K. aerogenes	*Klebsiella aerogenes*
K. kristinae	*Kocuria kristinae*
K. pneumonia	*Klebsiella pneumonia*
L. acidophilus	*Lactobacillus acidophilus*
L. casei	*Lactobacillus casei*
L. innocua	*Listeria innocua*
L. monocytogenes	*Listeria monocytogenes*
L. sporogenes	*Lactobacillus sporogenes*
M. canis	*Microsporum canis*
M. luteus	*Micrococcus luteus*
M. morganii	*Morganella morganii*
M. ruber	*Monascus ruber*
M. smegmatis	*Mycobacterium smegmatis*
M. tuberculosis	*Mycobacterium tuberculosis*
M. verticillata	*Mortierella verticillata*
P. acnes	*Propionibacterium acnes*
P. aeruginosa	*Pseudomonas aeruginosa*
P. brasiliensis	*Paracoccidioides brasiliensis*
P. fluorescens	*Pseudomonas fluorescens*
P. gingivalis	*Porphrymonas gingivalis*
P. herbarum	*Pleospora herbarum*
P. innundatus	*Protomyces innundatus*
P. intermedia	*Prevotella intermedia*
P. lilacinum	*Purpureocillium lilacinum*
P. mirabilis	*Proteus mirabilis*
P. sojae	*Phytophthora sojae*
P. vulgaris	*Proteus vulgaris*
R. rubrum	*Rhodospirillum rubrum*
R. solanacearum	*Ralstonia solanacearum*
R. solani	*Rhizoctonia solani*
R. stolonifera	*Rhizopus stolonifera*
S. agalactiae	*Streptococcus agalactiae*
S. anginosus	*Streptococcus anginosus*
S. aureus	*Staphylococcus aureus*
S. auricularis	*Staphylococcus auricularis*
S. boydii	*Shigella boydii*
S. dysenteriae	*shigella dysenteriae*
S. epidermidis	*Staphylococcus epidermidis*
S. fecalis	*Streptococcus fecalis*
S. flexneri	*Shigella flexneri*
S. gordonii	*Streptococcus gordonii*
S. haemolyticus	*Staphylococcus haemolyticus*

S. heidelberg	*Salmonella heidelberg*
S. hominis	*Staphylococcus hominis*
S. japonicas	*Schizosaccharomyces japonicas*
S. kneipii	*Spizellomyces kneipii*
S. lutea	*Sarcina lutea*
S. marcescens	*Serratia marcescens*
S. mutans	*Streptococcus mutans*
S. para typhi	*Salmonella para typhi*
S. pneumoniae	*Streptococcus pneumoniae*
S. pseudodichotomus	*Spizellomyces pseudodichotomus*
S. pyogenes	*Streptococcus pyogenes*
S. sanguis	*Streptococcus sanguis*
S. saprophyticus	*Staphylococcus saprophyticus*
S. shiga	*Shigella shiga*
S. typhi	*Salmonella typhi*
T. deformans	*Taphrina deformans*
T. mentagraphytes	*Trichophyton mentagraphytes*
T. rubrum	*Trichophyton rubrum*
T. tonsurans	*Trichophyton tonsurans*
T. urans	*Trichophytontonsurans*
V. cholerae	*Vibrio cholerae*
V. fischeri	*Vibrio fischeri*
X. axonopodis Pv. malvacearum	*Xanthomonas axonopodis pv. Malvacearum*
X. vesicatoria	*Xanthomonas vesicatoria*
Y. enterocolitica	*Yersinia enterocolitica*

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