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Plants-derived bioactives: Novel utilization as antimicrobial, antioxidant and phytoreducing agents for the biosynthesis of metallic nanoparticles

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ABSTRACT

Medicinal and aromatic higher plants are sustainable resources for natural product compounds, including essential oils, phenolics, flavonoids, alkaloids, glycosides, and saponins. Extractives and essential oils as well as their bioactive compounds have many uses due to their antimicrobial, anticancer, and antioxidant properties as well as application in food preservation. These natural compounds have been reported in many works, for instance biofungicide with phenolic and flavonoid compounds being effective against mold that causes discoloration of wood. Additionally, the natural extracts from higher plants can be used to mediate the synthesis of nanoparticle materials. Therefore, in this review, we aim to promote and declare the use of natural products as environmentally eco-friendly bio-agents against certain pathogenic microbes and make recommendations to overcome the extensive uses of conventional pesticides and other preservatives.

1. Introduction

The search for new sources of bioactive compounds for use as natural biocide agents against microbes has been widely reported in several studies [1–6]. However, conventional pesticides are highly toxic to pathogens; however, they have a potential risk for public health, and consequently the phytochemical compounds isolated and identified from medicinal plants are recommended as bioactive ingredients in commercial bio-agent formulations to treat several diseases in humans, plants, and animals [7–9].

Forestry trees and shrubs are a primary source for secondary metabolites, which include several bioactive chemical compounds, such as phenolics, glycosides, lignans, flavonoids, saponins, alkaloids, essential oils (EOs), fixed oils (FOs), fatty acids, organic acids, and others. These natural products are not essential for the survival of the plant, and they play vital roles in the ethno-pharmacology industry as wood biopreservatives against attacks by fungi and insects and as antimicrobial agents against plant, animal, and human pathogens [4–6,10,11]. They are defensive compounds against competitors, insects, and pathogens [12].

Different plant EOs and extracts were evaluated and recommended for their bioactivities against certain human bacterial pathogens [13]. In the animal nutrition field, EOs and extracts were found to have great effects on improving the growth performance, nutrient digestibility, ruminal fermentation, anthelmintic agent and control of methane and carbon dioxide mitigation of ruminants [12,14,15].

Conventional chemical preservative-treated wood and wood-based panels, such as chromated copper arsenate (CCA) and acid copper chromate (ACC) have been observed to be acutely toxic to predators that attack them, such as fungi, insects, bacteria, marine borers, and others; however, researchers observed toxic effects on the environment and public health [16,17]. Recently, several studies have observed the benefits of using extracts and EOs as wood or papersheets biofungicide agents and recommended them as alternatives to conventional pesticides [3,4,18–25]. *Melia azedarach* wood treated at 2 % and 3 % with *Withania somnifera* fruit extract show no growth of *Agrobacterium*

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Table 1
Some famous bioactive chemical compounds and their antimicrobial and antioxidant activities.

Chemical compound	Bioactivity	References
Caffeic acid	Potent antibacterial activity (AA) against clinical strains of *Staphylococcus aureus*, with MIC ranged from 256 μg/mL to 1024 μg/mL.	[31]
Quinone	Derivatives of quinone such as - des-F (6)-quinolone showed highly active against *Haemophilus influenzae*, *Moraxella catarrhalis*, and *Legionella* sp., with MIC ranged from 0.0125 to 0.1 μg/mL.	[32]
	N-aminoquinoline-2-one 1, 1-((4-hydroxy-6-methyl-2-oxo-2H-pyran-3-yl)methyleneamino) quinolin-2(1H)-one and 1,1′-(1E,1′E)-(1,4-phenylenebis(methan-1-yl-1-ylidene))bis(azan-1-yl-1-ylidene)diquinolin-2(1H)-one showed good anticancer activity against HEp-2 cell line and microbes.	[33]
Catechol	Antimicrobial activity against *Pseudomonas putida*, *P. pyocyanea*, *Corynebacterium xerosis*, *Fusarium oxysporum*, and *Penicillium italicum*.	[34]
Catechin	AA against *E. coli* and *Salmonella* with MIC of 6–50 mg/mL.	[35]
	Potential activity against *Listeria monocytogenes* isolated from red meat.	[36]
Hypericin	Potential efficiently to kill *S. aureus*, methicillin-resistant *S. aureus* (MRSA), and *Candida albicans*.	[37]
	Without light, hypericin inhibited the growth of *S. aureus* and *S. epidermidis*.	[38]
Eugenol	Excellent and broadly antimicrobial activities against a wide range of bacteria and fungi.	[39]
Coumarin	Coumarin and its derivatives have been observed good antimicrobial and antioxidant properties.	[40–44]
Gallic acid	Potential antioxidant activity in terms of radical scavenging activity and ability to inhibit lipid peroxidation.	[45]
kaempferol	Gear ability to inhibit reactive oxygen species (ROS)-generating enzymes and increases the expression of antioxidant enzymes.	[46,47]
Quercetin	Potential effects on glutathione (GSH), signal transduction pathways, enzymatic activity, and ROS caused by environmental and toxicological factors.	[48]
Apigenin	antioxidant properties, anti-hyperglycemic, anti-inflammatory, and (in myocardial ischemia) anti-apoptotic effects.	[49–51]
Taxol	Taxol (Paclitaxel), the alkaloid compound found in *Taxus brevifolia* wood with antileukemic, anticancer and antitumor agent.	[52–55]

tumefaciens, *Erwinia amylovora* and *Pseudomonas cichorii*, while the extract at 3 % inhibited *Fusarium culmorum* and *Rhizoctonia solani* growth by 84.07 % and 67.03 %, respectively [4]. Papersheets manufactured from pulp treated with *Pinus rigida* heartwood extract (PRWE) at 2 % or 4 % and with 4 % *Eucalyptus camaldulensis* var. *obtusa* aerial parts (ECL) suppressed *Aspergillus niger* growth on the paper disc; pulp treated with 2 % or 4 % PRWE, 4 % ECL and with 2 % or 4 % *Eucalyptus* flower buds (ECF) were completely suppressed *A. terreus* growth [24], also, inhibition of *A. terreus* growth was achieved as papesheets produced from *E. camaldulensis* wood-branch pulp paper and *Meryta sinclairii* wood pulp treated with hexane extracts rom of *Melia azedarach*, *Sinapis alba*, and *Magnolia grandiflora* at 3 % and 5 % [26].

Natural extracts have been extensively used for the synthesis of metal nanoparticles (NPs), e.g., Ag, Au, Ag–Au, and TiO_2NPs with promising applications such as antioxidant, antimicrobial, anticancer, thrombolytic, antidiabetic, anticoagulant, anti-inflammatory, and larvicidal properties. AgNPs synthesized using cocoa pod extract showed enhancing in *Corchorus olitorius* plants in terms of physiological tolerance indices, hepatoprotective potentials and antioxidant activity and strengthening its controlling soil phytopathogens [27]. Avocado (*Persea americana*) fruit peel aqueous extracts was used to synthesize AgNPs AuNPs, and Ag–AuNPs, which effectively inhibited the growth of the tested bacteria in the following order Ag–AuNPs > AgNPs > AuNPs [28]. Phytosynthesis of AgNPs was achieved by leaf extract of *Petiveria alliacea*, where with 100 % inhibition, AgNPs was active against bacteria (*E. coli*, *K. pneumoniae*, and *S. aureus*), and fungi (*A. fumigatus* and *A. flavus*) [29]. AgNPs synthesized using aqueous extract of wonderful kola (*Buchholzia coriacea*) showed potent antifungal activity against *A. niger*, *A. flavus*, and *A. fumigatus* and antibacterial activity against *P. aeruginosa*, *S. aureus*, *E. coli* and *S. typhi* [30].

Plant extracts, and their derivative compounds, such as alkaloids, saponins, phenolic compounds, flavonoid compounds, and other compounds (Table 1), are known to be active against a wide variety of microorganisms and as antioxidants.

The increase in the development of new antimicrobial agents against microorganism (bacterial and fungal) infections of humans, plants, and animals has become a major challenge in past years [56–58]. Different botanical parts from medicinal and aromatic shrubs and trees, such as the leaves, fruits, wood, branches, seeds, roots, and bark, are a great source for natural products with potential antibacterial, antifungal, anticancer, antioxidant, and biopesticide properties [59–62]. Many works have documented the bioactivity and chemical composition of natural products from trees and shrubs; for example, extracts from the bark, fruits, leaves, roots, latex, and seeds of *Ficus* species (Family Moraceae) have been studied for their biochemical properties and bioactivities [63] as well as from *Callistemon viminalis* [64].

2. Bioactivity of natural products

2.1. Bioactivities of natural products from coniferous trees

The chemical byproducts from Coniferous trees have broad-spectrum uses in different applications, such as antimicrobials and in pharmaceutical industries, for example pinosylvin from pine [65] and Rosins (resins) from Norway spruce (*Picea abies*) [66]. Resins are natural products of coniferous trees, and the purified rosin from the trunk of Norway spruce required a minimum concentration of 10 % (w/w) to prevent the preservation of microbes in rosin-salve media [66]. In the rosin of *Pinus* species, the presence of an hdyroperoxide, 15-hydroperoxydehydroabietic acid, with contact allergenic properties was detected [67].

Resin acids with different functional groups, such as hydroxyls, aldehydes, and ketones, and *cis* or *trans* configurations, like *cis*-7-oxodeisopropyldehydroabietate, cover a spectrum of antimicrobial activities against several microorganisms, such as the fungi *Botrytis cinerea* and *Lophodermium seditiosum* [68]. The oils from the leaves of fir species were found to have sesquiterpenes, triterpenes, organic acid diterpenes, flavonoids, condensed tannins, lignans, and waxes [69]. *Cedrus libani* produces a kind of tar from its resinous roots and stemwood and is used for treating the skin complaints of animals and for killing parasites, e.g., aphids, insects, and ticks [70].

Pinosylvin (3,5-dihydroxy-trans-stilbene), a constituent identified in the extracts of pine, exhibited more potent growth inhibitory activity against *Candida albicans* and *Saccharomyces cerevisiae* compared with resveratrol (3,5,4′-trihydroxy-trans-stilbene) [65]. Several species of *Juniperus,* such as *J. foetidissime,* were used as a urine increaser, sweating antiseptic, in the treatment of certain skin ailments, or as a tar resource, as they contain triterpene etheric oils (resin cadinene) and phenols (guaiacol and creosol derivatives) [70]. The leaves of certain pine species (*Pinus nigra, P. sylvestris, P. brutia, P. pinae,* and *P. halepensis*) can be used as a mucus remover and as an antiseptic. *P. brutia* and *P. nigra* species contain compounds, such as α-pinene, β-pinene, β-caryophyllene, and gemacrene [71].

P. resinosa and *P. ponderosa* in comparison to *P. strobus* have been characterized by the higher content of β-pinene (42.4 % and 45.7 % vs. 7.9 %, respectively), while, α-pinene (17.7 %) and germacrene D (12.2 %) were found to be the dominant compounds of *P. strobus* [72], and

Table 2
Some extracted bioactive chemical compounds and their antimicrobial activities from coniferous trees.

Coniferous Tree/s	Part used	Extract/compound	Test method	Bioactivity	Reference
Picea abies	Trunk.	Rosins (resins).	DDM.	Reduced the colonization of *S. aureus*, and methicillin-resistant *S. aureus* (MRSA), within 24 h and *E. coli*, *P. aeruginosa*, *B. subtilis*, and *C. albicans* within 4 days.	[66]
Picea abies	Trunk.	Acetone extract from resins with coumaric acid, resin acids (abietic acid, pimaric acid, neoabietic acid, palustric acid, levopimaric acid, and their hydroxy derivatives); and lignans (matairesinol, isolariciresinol, pinoresinol, lariciresinol, and isolariciresinol).	DDM.	Potential activity against Candida yeasts and *Trichophyton mentagrophytes*.	[77]
Pinus brutia, *Juniperus oxycedrus*, *Abies cilicia*, *Cedrus libani* and *P. nigra*	Leaves, resins, barks, cones and fruits.	Chloroform, acetone and methanol extracts.	DDM.	All the plant extracts inhibited *B. megaterium*, *B. subtilis*, *B. cereus*, *E. coli*, *Klebsiella pneumoniae*, *Enterobacter aerogenes*, *S. aureus*, *Mycobacterium smegmatis*, *Proteus vulgaris*, *Listeria monocytogenes*, *P. aeruginosa*, *C. albicans*, *Candida tropicalis,* and *Penicillium italicum*.	[78]
P. roxburghii	Wood, bark, and needles.	The main compounds of EOs from wood were caryophyllene, thunbergol, 3-carene, cembrene, α-thujene, and terpinolen, from bark were α-pinene and 3-carene, and in needles were *α*-pinene and 3-carene.	DDM.	All EOs were active against *B. subtilis*, *Sarcina lutea*, *S. aureus*, *E. coli*, *Ralstonia solanacearum, Erwinia amylovora*, and *Pectobacterium carotovorum* subsp. *Carotovorum*.	[79]
P. roxburghii	Stem, leaves, bark, female cone, and male cone	Aqueous and alcoholic extracts.	DDM.	Inhibitory activity against *A. tumefaciens*, while all the extracts except the stem extract showed inhibitory activity against *E. coli*.	[80]
P roxburghii	Wood.	EOs, methanol, and chloroform extracts.	DDM.	Significant biological activities against *P. aeruginosa*, *E. coli*, *S. aureus*, *S. pyogenes*, *B. subtilis*, *C, albicans*, *A. niger*, and *A. clavatus* for EOs rather than the methanolic and chloroform extracts.	[81]
P. roxburghii	Trunk.	Pine rosin (*cis*-7-oxodeisopropyldehydroabietate and methyl *trans*-7-oxo-deisopropyldehydroabietate were the major compounds).	Solid medium in Multi-well plates.	Completely or partially inhibited spore germination of *Mucor racemosus*, *Syncephalastrum racemosum*, *Rhizopus stolonifera,* and *R. arrhizus* and growth of bacteria *S. aureus* and *E. faecalis* was found.	[82]
P. roxburghaii	Stem.	EOs (α- pinene followed by 3-carene, caryophyllene, *p*-cymene, terpinenol, and limonene were the most abundant compounds.	Well diffusion method.	AA against *S. aureus* and *B. subtilis*, while no activity against *E. coli* and *E. aerogenes*. Antifungal activity against *A. terrus*, *A. flavus*, *A. candidus*, *A. vessicolor*, *A. niger,* and *Trichoderma viride*.	[83]
P. roxburghaii	Needles.	EOs (α-pinene, caryophyllene, 3-carene, α-terpineol, caryophyllene oxide, and borneol acetate as major compounds).	Well/cup plate method.	Maximum activity against *S. aureus* and *B. subtilis*, while no activity was observed against *E.coli*, *Salmonella typhi,* and *E. aerogenes*.	[84]
Juniperus communis	Needles.	EOs (α-pinene and sabinene as major compounds).	DDM.	EOs inhibited the growth of all bacteria (*B. cereus*, *E. coli*, *Listeria monocytogenes*, *Corynebacterium* sp., *P. aeruginosa*, and *S. aureus*), yeast (*C. albicans*), and fungi (*Alternaria* sp., *A. nidulans*, and *A. niger*).	[85]
P. ponderos, P. resinosa and *P. strobus*	Needles.	EOs.	Growth inhibition.	The strongest activity was observed for the EOs from *P. ponderosa*, which fully inhibited the growth of *Fusarium culmorum*, *F. solani* at 2 %, and *F. poae* at 5 %.	[72]
Pinus nigra (*ssp. nigra, ssp. pallasian, andvar. banatica*)	Needles.	EOs.	DPPH and ABTS scavenging assays and MIC.	Weak antioxidative properties. Good activity against *A. niger*, *S. aureus,* and *Bacillus cereus*.	[73]
P. patula	Needles.	The EOs major compounds were *β*-phellandrene, *α*-pinene, bornyl acetate, *β*-caryophyllene, and limonene.	Broth macrodilution and DDM.	Strong activity against *S. pyogenis*, *P. solanacearum*, *S. aureus*, and *Pycularia oryzae*, with the exception of *Colletotrichum coffeanum*.	[86]
P. densiflora, Pinus koraiensis, and *Chamaecyparis obtusa*	Needles.	The major compounds of EOs were β-thujene in *P. densiflora*; α-pinene in *P. koraiensis*; bornyl acetate in *C. obtusa*).	DDM.	*P. densiflora* and *C. obtusa* EOs have AA, whereas EOs from *P. koraiensis* and *C. obtusa* have antifungal effects.	[87]
P. densiflora, Cryptomeria japonica,		The EOs major compounds were *β*-phellandrene and *α*-pinene in *P. densiflora*; kaur-16-ene and sabinene in	DDM.	*C. obtusa* EOs at 2.2 μg inhibited *E. coli* and *K. oxytoca*, whereas the *C. japonica* EOs gave weak AA. *P. densiflora* oil	[88]

(*continued on next page*)

Table 2 (*continued*)

Coniferous Tree/s	Part used	Extract/compound	Test method	Bioactivity	Reference
and *Chamaecyparis obtusa*		*C. japonica*; and bicyclo [1,2,2] heptan-2-ol and 2-carene in *Ch. Obtusa*).		showed the most effective antifungal activity. MIC values for *Cryptococcus neoformans* and *C. glabrata* were as low as 0.54 and 2.18 mg/mL, respectively.	
P. halepensis	Cones.	EOs (caryophyllene, α-pinene, and caryophyllene oxide and n-butanol extract (3,4-dimethyldihydrofuran-2,5-dione, and 2-methylenecholestan-3-ol.	DDM.	Moderate AA against *D. solani*, *P. atrosepticum*, *R. solanacearum*, *A. tumefaciens*, *B. subtilis*, *Sarcina lutea*, *E. coli*, and *S. aureus*.	[58]
P. peuce	- Twigs with needles (T+N). - Twigs without needles (T-N).	The major components of EOs in T+N and T-N were: α-pinene, camphene, *β*-pinene, myrcene, limonene+*β*-phellandrene, bornyl acetate, *trans-(E)*-caryophyllene, germacrene D, and *δ*-cadinene.	DDM and broth dilution method.	T-N EOs showed antimicrobial activity against *S. pneumoniae*, *S. aureus*, *S. epidermidis*, *C. albicans*, *S. agalactiae*, *Acinetobacter* spp., and *Haemophilus influenzae*. T+N EOs showed the greatest activity against *S. agalactiae*, *S. pyogenes*, *Enterococcus,* and *C. albicans*, followed by *H. influenzae*, *Acinetobacter* spp., *E. coli*, *S. enteritidis*, *S. aureus,* and *S. Epidermidis* (Karapandzova et al., 2014).	[89]
P. wallichiana	Leaves.	*n*-Hexane, ethyl acetate, chloroform, aqueous and residue.	DDM and MIC. % Mortality of insects.	*n*-hexane showed MIC at 25 μg/mL against *Microsporum canis*, ethyl acetate against *Tribolium castaneum*, *Rhyzopertha dominica,* and *Callosobruchus analis*. The other fraction showed activities against *R. dominica*, *T. castaneum,* and *C. analis*.	[90]
P. pinea	Nuts.	*n*-Hexane oils.	MIC.	Good activity against *E. coli*, *P. aeruginosa*, *P. mirabilis*, *K. pneumoniae*, *A. baumannii*, *S. aureus,* and *E. faecalis*.	[91]

EOs: Essential oils; DDM: Disc diffusion method; DPPH: 2,2-diphenyl-1-picrylhydrazyl; ABTS: 2,2′-azinobis(3-ethylbenzothiaziline-6-sulfonate); MIC.

P. resinosa was richer in myrcene at 15.9 %. α-Pinene was observed at the percentages of 45.93 %, 42.33 %, and 50.83 % in the essential oils (EOs) from *P. nigra* taxa of the ssp. *nigra,* ssp. *pallasiana,* and var. *banatica*, respectively [73]. In addition, researchers reported α-pinene to be fungicidal, insecticidal, and antibacterial ([74,75]. Table 2 summarizes the bioactivity of extracts and EOs from the coniferous wood and bark oil extracts of *P. sylvestris*, *Abies alba*, *Picea abies*, and *Larix decidua,* which showed the presence of monoterpenes, sesquiterpenes, diterpenoids, and resin acids [76].

2.2. Bioactivity of leaf extracts and essential oils

The leaves of trees and shrubs contain a greater number of secondary metabolites; e.g., steroids, tannin, anthocyanin, flavonoids, diterpenes, physterols, and phlobatannins were identified in the leaf extracts of teak [92]. Teak extracts showed great bioactivity against pathogenic fungi and insect pests [93–95]. Furthermore, teak leaf extract did not cause any apparent in vivo toxicity in an animal model [96].

Syzygium cumini leaves EOs found to have *α*-pinene, *α*-terpineol, alloocimene, *α*-bornyl acetate, 2-*β*-pinene, and caryophyllene as the main compounds [97], while other compounds, such as *α*-pinene, *cis*-ocimin, *trans*-ocimine, and 2-*β*-pinene, were also identified [98].

Cupressus sempervirens EOs showed cedrol, phenanthrene, Δ3-carene, *α*-terpineolene, camphene, *α*-pinene, 2-*β*-pinene, limonene, and *α*-terpineol as the main compounds [97]. Some of these components were found in plants of the same species [99] with a lower percentage of cedrol, while sabinene and *α*-pinene were higher. Turkish cultivars were found to have camphene as a chemotaxonomic value [100].

Leucaena leucocephala leaf extract was identified with compounds of pentadecanoic acid-14-methyl-methyl ester, 2(H)-benzofuranone-5,6,7,7a-tetrahydro-4,4,7a-trimethyl, and 6,10,14-trimethyl-2-pentadecanone [101]. Extracts from leaves of *L. leucocephala* were shown to have quercetin [102]. Mimosine (leucenol), a non-protein amino acid, was isolated from the seeds of *L. leucocephala*, which is known to be toxic to ruminants [103]. From whole plants of *L. leucocephala*, squalene, ficaprenol-11 (polyprenol), coumaric acid, lupeol, *trans-cis*-coumaric acid, and *β*-sitostenone, were isolated [104].

Salicin, a salicylate compound, and phenolic glycosides were isolated from *Salix babylonica* extracts [105]. Salicin, benzyl ester of gentisic acid, luteolin-4′-Oglucoside, trichocarpin, apigenin/kaempferol-7-*O*-galactoside, and esters of terephthalic acid have been isolated the leaves [106]. Additionally, fatty acid esters of octadecenoic acid-1,2,3-propanetriyl ester, tritetracontane, and hexadecanoics were identified from leaf extracts [101].

Tecoma stans leaf extracts showed potential antibacterial activity [107]. Different groups of chemical compounds, such as EOs, saponins, resins, alkaloids, steroids, flavonoids, phenols, and anthraquinones, have been isolated from *T. stans* extracts [95,108,109], with antioxidant, antifungal, and antimicrobial activities [109,110]. The bioactive compounds iridoid glucoside and 5-deoxystansioside [111] as well as hyperoside, chrysoeriol, and luteolin [111] have been found in the leaf extracts.

The compounds of *α*-pinene, *cis*-ocimene, *α*-phellandrene, sabinene, adamantane, calarene, *cis*-caryophyllene, *β*-selinene, *α*-muurolene, (+)-cycloisosativene, valencene, *β*-cubebene, *α*-selinene, Δ-cadinene, and *γ*-selinene were identified in *Schinus molle* leaf EOs of plants grown in Egypt with moderate antioxidant activity [112]. *α*-Phellandrene, *β*-phellandrene, limonene, *β*-myrcene, and elemol were the main compounds in *S. molle* plants grown Southeast Portugal [113]. *α*- and *β*-phellandrene and limonene were found in leaf EOs of *S. molle* grown in Italy [114]. *α*-Pinene and *β*-pinene were found in the EOs of *S. molle* grown in Costa Rica [115]. *p*-Cymene with high efficacy against two stored product insects (*Tribolium castaneum* and *Trogoderma granarium*) was reported [116]. In Tunisian plants, *α*-phellandrene followed by *β*-phellandrene were reported as the main constituents [117].

Callistemon viminalis leaf EOs showed that 1,8-cineole and *α*-pinene, as the main compounds, had high antioxidant and antibacterial activities [118]. Additionally, the bioactivities of EOs from *C. viminalis* are summarized in a previous work [64].

The unsaponified terpene-rich extract of *Lantana camara* leaves showed considerable antioxidant activity [119]. Sabinene, (*Z*)-citral, *α*-pinene, 1,8-cineole, *γ*-terpinene, (*E*)-citral, *trans*-caryophyllene, bicyclogermacrene, *α*-humulene, *β*-caryophyllene, α-curcumene, and germacrene D were the most prominent EOs compounds in the leaves [97,120], with good antibacterial activity against some human and plant bacterial pathogens. Lantadene A, lantadene B, lantadene C,

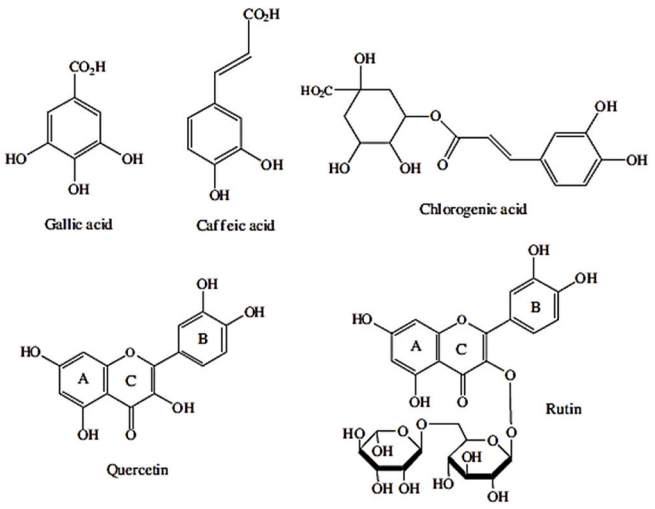

Fig. 1. Phenolic compounds structures detected in ethanolic extracts of *L. camara* and *L. montevidensis* of leaves and roots [126].

β,β-dimethylacryloyl ester of lantanilic acid, lantadene D, icterogenin, camarinic acid, lancamarolide, camaric acid, 3-methoxy quercetin, *β*-resorcylic acid, salicylic acid, gentisic acid, coumarin, ferulic acid, *p*-hydroxybenzoic acid, and 6-methyl coumarin were also found [121–125]. Fig. 1 presents the chemical structures of the phenolic compounds detected in the ethanolic extracts of leaves and roots from *L. montevidensis* and *L. camara* with good antioxidant activity [126].

The aqueous extracts from *Feronia limonia*, *Bauhinia racemosa*, *Pongamia pinnata*, *Dalbeagia sissoo*, *Terminalia arjuna, Ailanthus excelsa, Morinda tinctoria, Moringa oleifera,* and *Cordia dichotoma* demonstrated activity against *S. typhimurium*, *B. megaterium, P. aeruginosa, Staphylococcus aureus, Proteus vulgaris,* and *Aspergillus niger* [127]. Hydromethanolic extracts of *Cistus monspeliensis*, *Berberis vulgaris*, *Punica granatum*, *Cassia angustifolia*, *Withania frutescens, Cinnamomum cassia*, *Nigella sativa*, *Rhus tripartata*, and *Zingiber officinale* showed good activity against *S. aureus*, *E. faecalis*, *E. coli*, *E. cloacae*, *Klebsiella pneumoniae,* and *P. aeruginosa* [128].

2.3. Bioactivity of essential oils and extracts from bark

The extracts and essential oils from bark of the genus *Cinnamomum* are commonly used for their antibacterial, antioxidant, antifungal, antidiabetic, anti-inflammatory, nematicidal, insecticidal, and anticancer effects [129–132]. These compounds include cinnamaldehyde, cinnamate, and cinnamic acid [133]. *trans*-Cinnamaldehyde, eugenol, camphor, *β*-caryophyllene, L-borneol, cinnamyl acetate, and other compounds have also been identified [134,135]. The chemical structures of the most commonly identified compounds in extracts and essential oils from *Cinnamomum* bark are shown in Fig. 2.

The methanolic extract of stem bark from *Schinus terebinthifolius* showed moderate antibacterial activity [136], which was reported to be rich in tannins, phenols, anthraquinones, and triterpenes [137]. *Terminalia brownie* stem bark and wood extracts showed the presence of a quercetin-7-*O*-diglucoside isolate, which possessed significant activity against *Aspergillus* and *Fusarium* strains [138].

Stem bark methanoilc extracts of *Delonix regia* and *Erythrina humeana* were observed to have moderate to weak activity against *D. dianthicola*, *P. carotovorum* subsp. *wasabiae*, *P. carotovorum* subsp. *carotovorum*, *P. carotovorum* subsp. *Atrosepticum,* and *D. chrysanthemi* [139]. Compounds of *p*-methoxybenzaldehyde, *β*-sitosterol, lupeol, epilupeol, and stigmasterol were isolated from stem bark extract of *D. regia* [140]. *D. regia* bark contains carotene, *β*-sitosterol, and alkaloids, along with other compounds [141,142].

The bark EOs of *P. roxburghii* showed *α*-pinene, 3-carene, cembrene, longifolene, thunbergol, *β*-pinene, sylvestrene, terpineol, and terpinolen as the main compounds [79], with good activity against *E. coli* and *R. solanacearum*. From the methanolic extract of the bark of *P. roxburghii*, 1,5-dihydroxy-3,6,7-trimethoxy-8-dimethylallyloxy-xanthone and 1-hydroxy-3,6-dimethoxy-2-*β*-dglucopyranoxanthone were isolated as xanthone compounds [143]. Ferulic acid, *p*-coumaric acid, and pinoresinol were also isolated [144].

Ferulic acid and catechin were detected in *Catalpa speciosa* bark

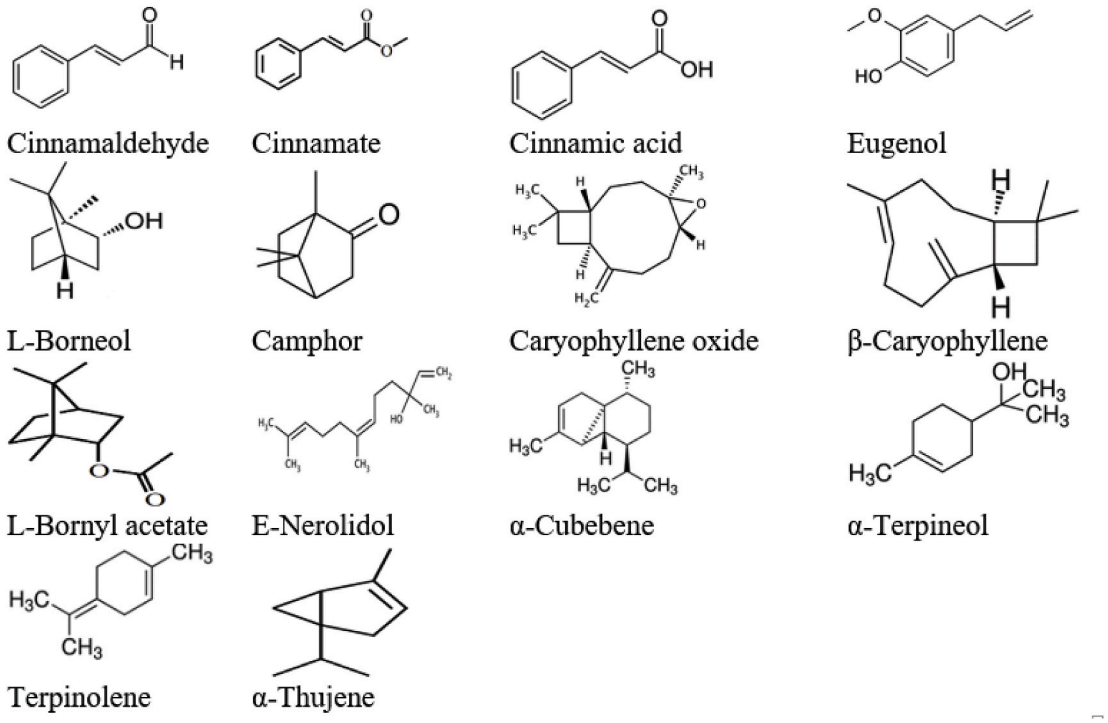

Fig. 2. Extracts and essential oils compounds from *Cinnamomum* bark.

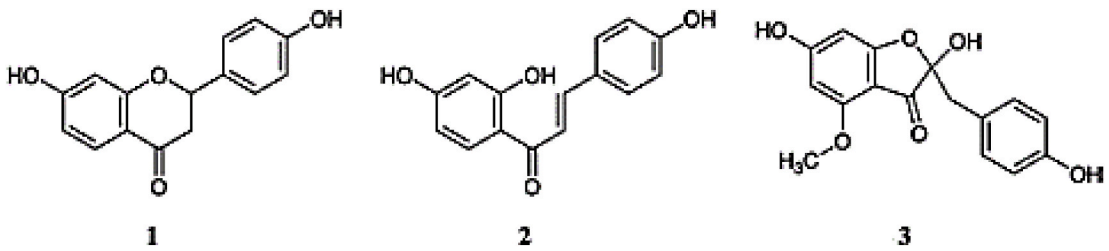

Fig. 3. Chemical structures of liquiritigenin (1), isoliquiritigenin (2), and marsupsin (3) isolated from *Pterocarpus marsupium* heartwood [151].

extract, while hydroxycaffeic and protocatechuic acids were found in *Taxus cuspidate,* and catechin was found in *Magnolia acuminate* [145]. The three species exerted clear anticancer activity especially from the phenolic compounds from *M. acuminate* [145]. In addition, the barks of *Quercus robur* (ellagic acid), *Q. macrocarpa* (caffeic acid), and *Q. acutissima* (ellagic acid) were identified to have potential antibacterial activity [146]. *Eucaluptus camaldulensis* bark extract with its main polyphenolic compounds benzoic acid, quinol, salicylic acid, myricetin, and rutin by demonstrated using HPLC was observed as a good antiviral against *Tobacco mosaic virus* (TMV) MG264, as an antifungal against *Fusarium culmorum*, *Rhizoctonia solani*, and *Botrytis cinerea* colonized wood blocks of chinaberry, and as an insecticide against *Tribolium castaneum* (Herbst) and *Sitophilus oryzae* [147]. The stem-bark of *Dalbergia sissoo* stem bark showed the presence of compounds dalbergenone, dalbergin and methyl dalbergin, and dalbergichromene [148].

2.4. Bioactivity of extracts and essential oils from wood

Extracts dissolved in methanol, ethyl acetate, and chloroform from *Brachychiton diversifolius* wood branches had antibacterial activity against certain human or plant pathogens [149,150]. The bioactive compounds marsupsin, liquiritigenin, and isoliquiritigenin (Fig. 3) were isolated from *Pterocarpus marsupium* heartwood [151]. Flavone nor-artocarpotin, and β-amyrin, β-sitosterol and stigmasterol were isolated from the green branches of *D. sissoo* Roxb [152], and neoflavonoid dalbergiphenol from heartwood of *D. sissoo* [148].

Schinol and biphenyl 4′-ethyl-4-methyl-2,2′,6,6′-tetrahydroxy[1,1′-biphenyl]-4,4′-dicarboxylate were isolated from *Schinus terebinthifolius* stems with good antifungal activity [140]. EOs from the fruits showed the presence of bioactive compounds, such as caryophyllene, thunbergol, α-caryophyllene, verticiol, 3-carene, cembrene, α-thujene, terpinolen, and α-pinene [153]. In the stems, 3-carene, α-pinene, and caryophyllene [83] were found to have good antibacterial activity.

Morin, 1,3,6,7-tetrahydroxyxanthone, and oxyresveratrol were isolated from *Maclura pomifera* wood extract with remarkable fungicidal and termiticidal agents [154]. 3,4′,5-trihydroxystilbene and 2,4,3′,5′-tetrahydroxystilbene were isolated from *Maclura pomifera* wood [155]. In addition, heartwood has been reported to have nontoxic antibiotic effects making it useful as a food preservative and antifungal agent [154]. Research reported that the 5,7,4′,20-tetrahydoxy-6-[30-methyl-but-30-enyl]-flavone, 5,4′-dihydroxy-20-(1-hydroxy-1-methylethyl)-30-methoxyfurano(40,50(6,7) isoflavone, and 5,4′-dihydroxy-20-(1-hydroxy-1-methylethyl)-30-methoxyfurano(40,50(6,7) flavone isolated from stem and leaf extracts had antibacterial activity [156].

D. regia wood essential oil showed effective activity against *B. subtilis*, *S. lutea*, and *S. aureus* [157], with the presence of 1,6,7-trimethyl-naphthalene, 1,7-dimethyl-naphthalene, heptadecane, heneicosane, hexadecane, octadecane, pentadecane, and eicosane in EOs compounds.

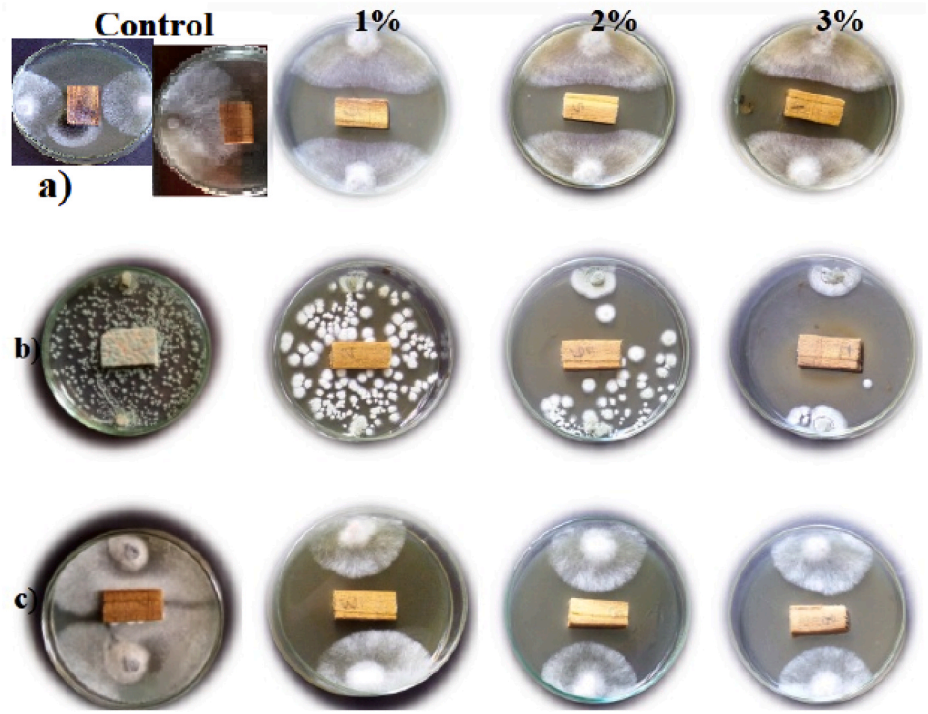

Fig. 4. Bioactivity of treated wood with *A. saligna* flower water extracts at the concentrations of 1, 2, and 3 % against three fungi: (a) *R. solani*; (b) *P. chrysogenum*; and (c) *F. culmorum* (Adapted from Al-Huqail et al. [173].

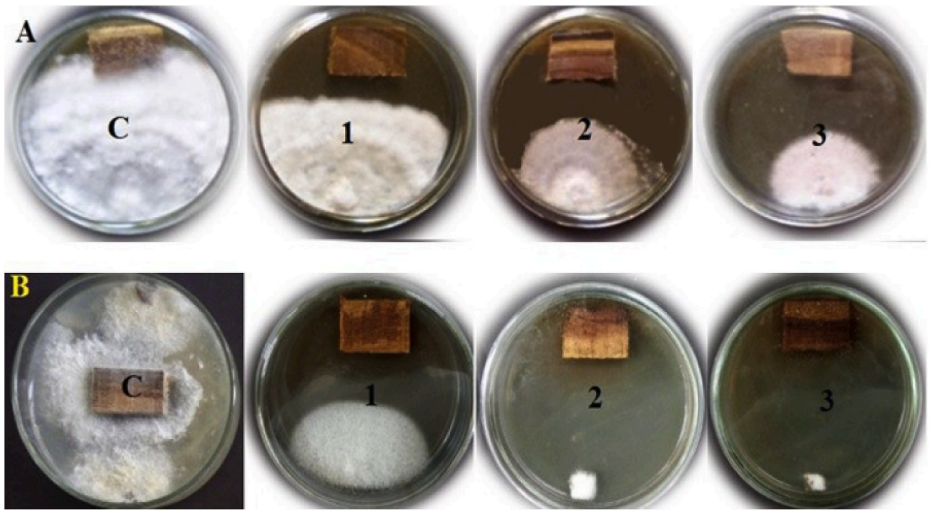

Fig. 5. Wood treated with the methanolic extract of *M. paradisiaca* peels. A: *F. culmorum*, and (B) *R. solani* (Adapted from Behiry et al. [21]). C: Control, where wood block received 100 μL of 10 % DMSO; 1: extract concentration 1 %; 2: extract concentration 2 %; 3: extract concentration 3 %.

3. Role of natural products as wood biopreservatives

Some fungi are able to produce hydrolyzing enzymes, such as xylanase and *b*-xylosidases, and colonizing wood causes colored spores leading to the discoloration of different woods and wood-based products in humid conditions [158–161]. Although, fungal production of xylanases from *Aspergillus fumigatus A. flavus*, *A. fumigatus*, *Fusarium solani*, *A. niger*, *Trichoderma longibrachiatum*, and *Botryodiplodia* sp. has biotechnological relevance [162,163], or for the biofabrication of metal nanoparticles by using of agro-wastes, enzymes and pigments with potent biomedical antimicrobial, antioxidant, anticoagulant and catalytic activities [164–166], the presence of xylanolytic fungi on wood promotes deterioration of wood.

Subsequently, natural products can be used against the infestation of molds in wood through surface applications [25,167–169]. *Myrtus communis* hydro-alcoholic extract and *Cinnamomun zeylanicum* water extract showed good activity against *S. aureus*, *E. coli*, *P. aeruginosa,* and *S. enteri* [170]. Extracts from *Capparis decidua, Ficus carica, Syzygium cumini,* and *Ziziphus jujuba* showed potential antibacterial activity against *E. coli*, *P. aeruginosa*, and *S. typhi* and the fungi *Trichophyton longifusus* and *Candida albicans* [171].

In recent years, natural extracts have been used as wood preservatives not only because of the potential utility of decay-resistant wood sources but also because of the need for decay protection, especially for commercial antifungal products [4,172]. Wood samples of *Melia azedarach* treated with water extracts of the *Acacia saligna* flower (phenolic compounds of benzoic acid, caffeine, *o*-coumaric acid, naringenin, quercetin, and kaempferol were found) showed good antifungal activity against certain molds as shown in Fig. 4 [173], where with increase the extract concentration from 1 % to 3 %, the mycelial fungal

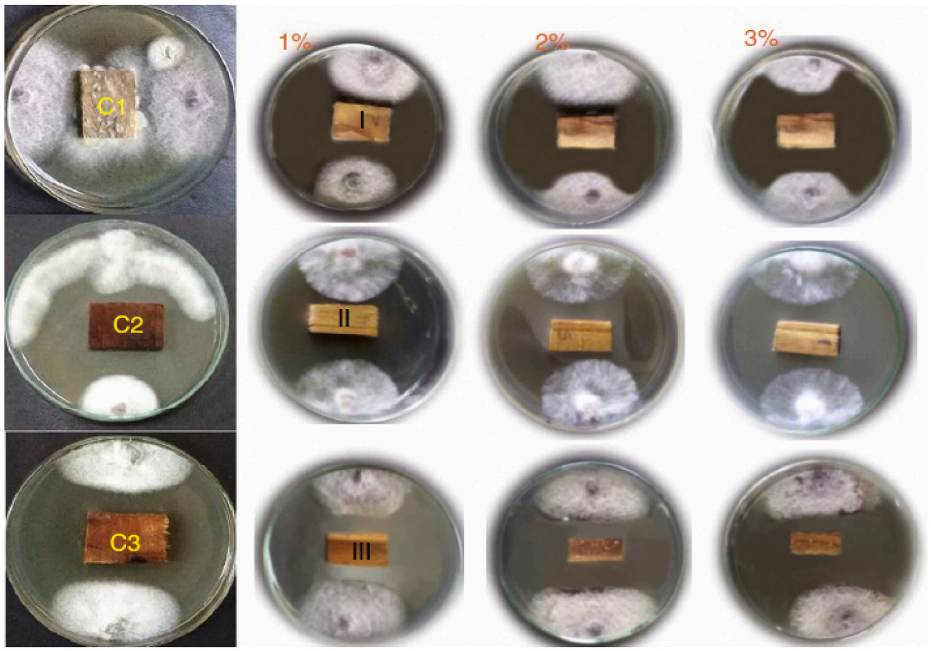

Fig. 6. Antifungal activities of wood treated with oils against *F. culmorum*. (C1) Wood treated with 10 % DMSO); (C2) wood treated with clotrimazole 1000 ppm; (C3) wood treated with thiophanate-methyl 1500 ppm; (I) wood treated with *E. camaldulensis* oil at 1, 2, and 3 %; (II) wood treated with *M. chamomilla* oil at 1, 2, and 3 %; and (III) wood treated with *V. agenus-castus* oil at 1, 2, and 3 % (Adapted from Salem et al. [19]).

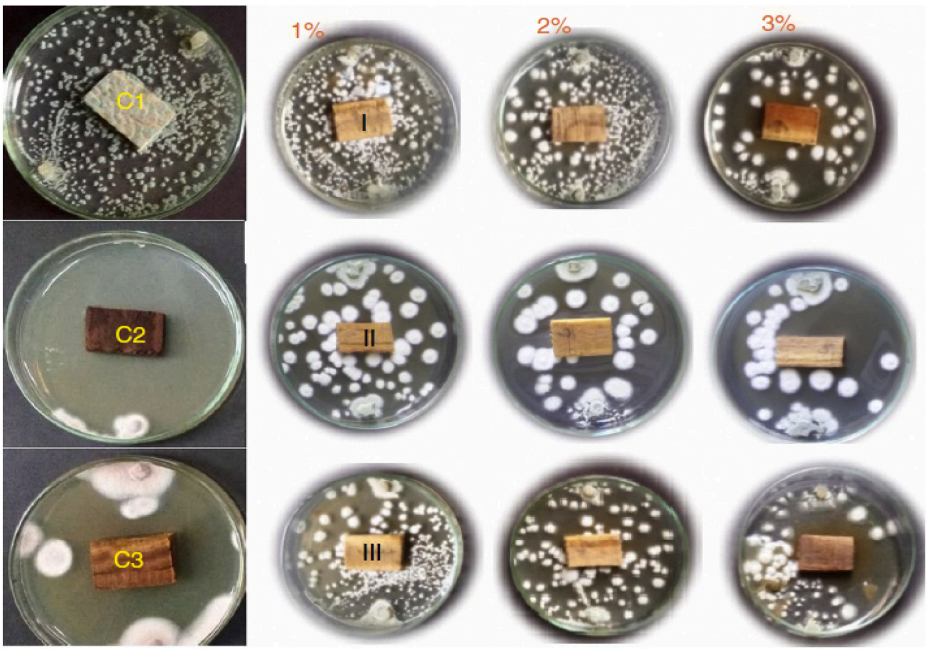

Fig. 7. Antifungal activities of wood treated with oils against the growth of *P. chrysogenum* (Adapted from Salem et al. [19]), for the legend, see Fig. 6.

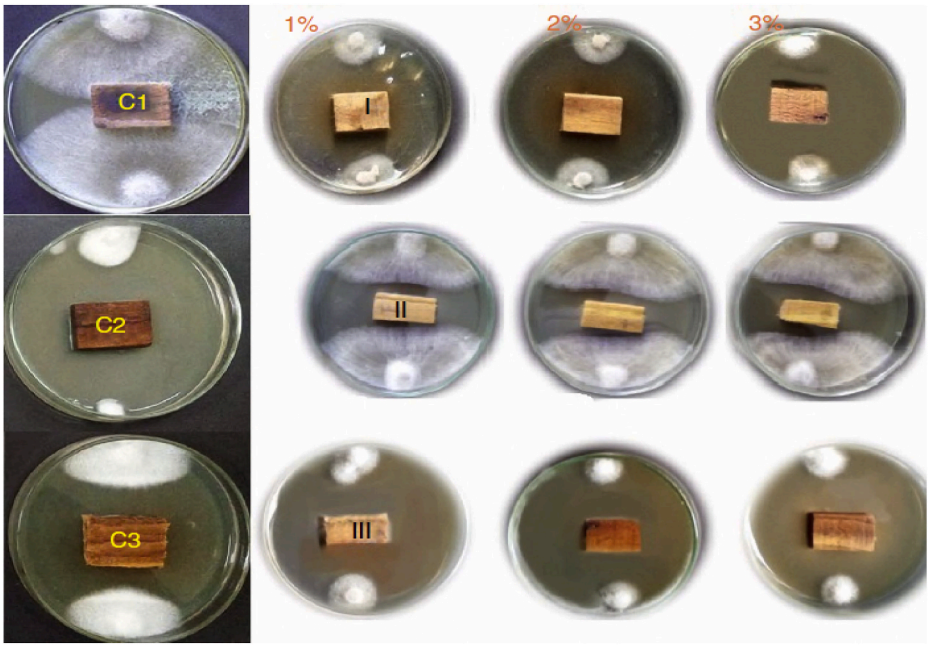

Fig. 8. The antifungal activity of wood treated with oils against the growth of *R. solani*. For the legend, see Fig. 6.

growth inhibition was increased.

The methanol extract of *Callistemon viminalis* bark was effective against *F. culmorum*, as were *Magnolia grandiflora* leaves against *A. tenuissima,* and, after three months, no fungal growth was found on the *Acacia saligna* wood surface treated with *M. pomifera* bark methanol extract [174]. Fig. 5 shows that the linear fungal growth of *F. culmorum* and *R. solani* was decreased with increased concentrations of the extract of *Musa paradisiaca*-peel-treated wood from 1 % to 3 % [21].

Oils extracted with *n*-hexane from *Eucalyptus camaldulensis* and *Vitex agenus-castus* and the treated wood of *M. azedarach* (Figs. 6–8) showed promising antifungal activities, while the oil extracted from *Matricaria chamomilla* was observed to have the lowest activity [19]. In these Figures, each wood block had received 100 μL from the prepared extracts at the concentrations of 1, 2, and 3 %, and compared with the control wood block that received 100 μL of 10 % dimethyl sulfoxide (DMSO). Also, it can been seen that, wood treated with oils from *E. camaldulensis*, *M. chamomilla* and *V. agenus-castus* showed potential antifungal activity against *F. culmorum* compared to the positive controls used (Fig. 6). Wood-treated with the studied oils showed weak antifungal activity against the growth of *P. chrysogenum* compared to the positive controls (Fig. 7), while those oils showed good antifungal activity against the growth of *R. solani* (Fig. 8).

L. leucocephala wood treated with a combination of extracts from *Acer saccharum* var. *saccharum* inner bark 0.25 %, outer bark 0.25 %, and citric acid 0.25 % produced the highest antifungal effects against the growth of *T. viride* [20]. *A. saligna* wood treated with Paraloid B-72 and

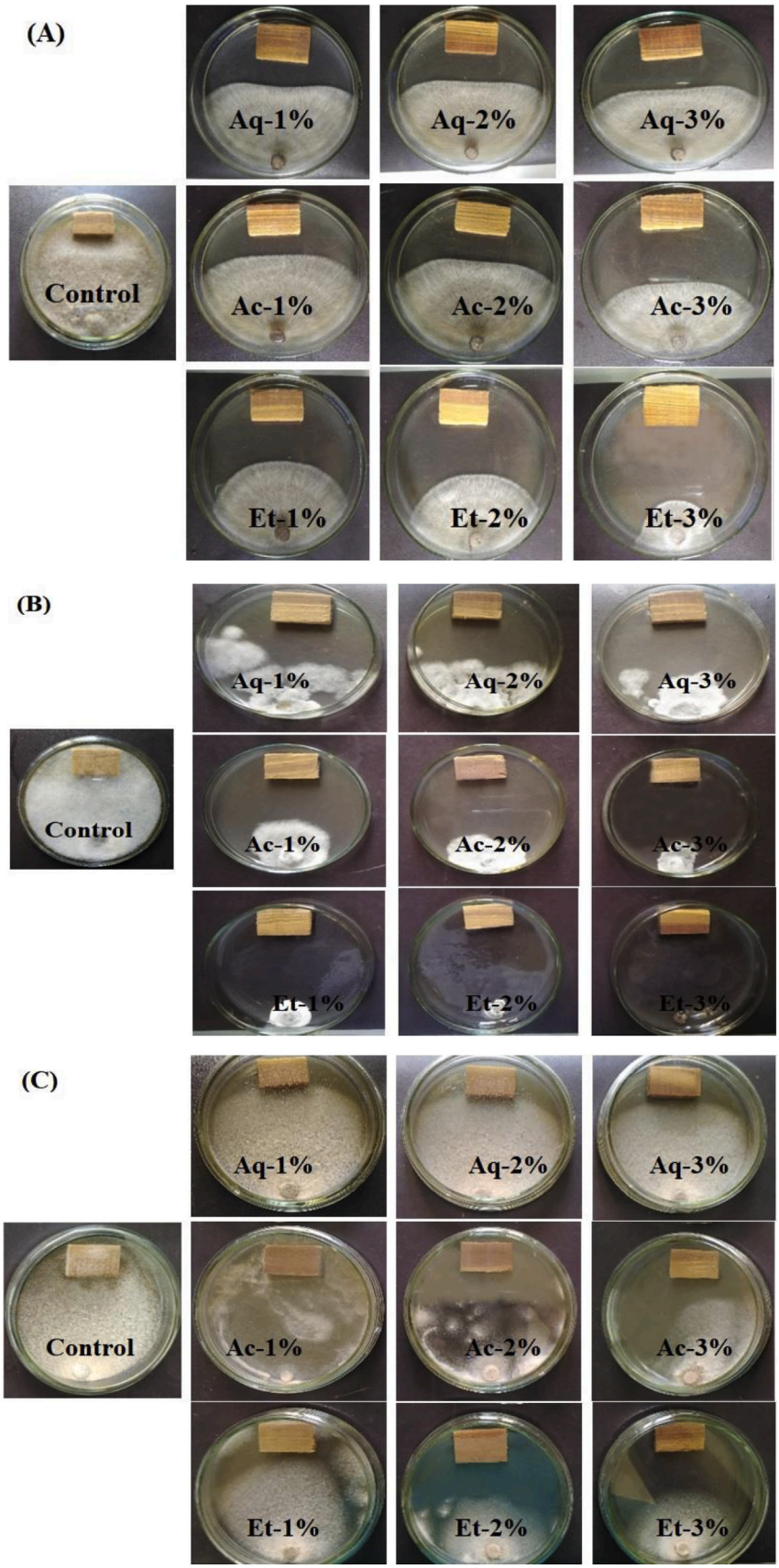

Fig. 9. Antifungal activities of wood treated with aqueous (Aq), acetone (Ac), and ethanol (Et) *C. uvifera* leaf extracts vs. *Rhizoctonia solani* (A), *Botrytis cinerea* (B), and *Fusarium culmorum* (C). (Adapted from Ashmawy et al. [2]).

Table 3
Green methods for the production of metal nanoparticles using natural extracts.

Plant species	Part and solvent extract	Synthesized nanoparticle/ biological activity	References
Acacia farnesiana	SAE.	AgNPs demonstrated high inhibitory action against *E. coli*, *S. aureus*, *B. subtilis*, and *P. aeruginosa* and good AoA.	[192]
Annona muricata	ALE.	AgNPs with strong AoA as measured by DPPH, ABTS, α-amylase and α-glucosidase.	[56]
Artocarpus heterophyllus	Seed powder extract.	AgNPs showed potent AA toward *B. cereus*, *B. subtilis*, *S. aureus*, and *P. aeruginosa*.	[193]
A. hirsutus	SAE.	AgNPs showed better AA against *Enterobacter aerogenes* with a maximum zone of inhibition than on *Listeria monocytogenes*. .	[194]
Avicennia marina	SAE.	AgNPs observed potential AA against *E. coli*, *K. pneumoniae*, *S. aureus*, *E. faecalis*, and *P. aeruginosa*.	[195]
Azadirachta indica	ALE.	AgNPs with some AAs against *S. aureus* and *E. coli*.	[196]
Berberis vulgaris	ALE and root extract.	AgNPs with some AA against *E. coli* and *S. aureus*.	[197]
Brucea javanica	ALE.	AgNPs.	[198]
Chasmanthera dependens	Stem aqueous extract.	AgNPs displayed potent activity against *Klebsiella pneumoniae*, scavenging activity of DPPH, high anticoagulant efficacy and larvicidal agents.	[59]
Cassia fistula	ALE.	ZnONPs showed excellent AA against *K. aerogenes*, *E. coli*, *Plasmodium desmolyticum* and *S. aureus* with significant AoA.	[199]
C. auriculata	ALE.	AuNPs with potential antidiabetic properties.	[200]
Caesalpinia coriaria	ALE.	AgNPs with potential AA against *E. coli*, *P. aeruginosa* and *K. pneumoniae*, and a clinically isolated human pathogens *S. aureus*.	[201]
Caesalpinia pulcherrima	ALE.	AgNPs with good AA.	[202]
Callistemon viminalis	ALE.	AuNPs.	[203]
		AuNPs with potent AA against *E. coli*, *S. aureus*, *Klebsiella pneumoniae* and *Salmonella typhimurium*.	[204]
C. viminalis	AFE.	Sm_2O_3NPs.	[205]
C. viminalis	AFE (rich in flavonoids, saponins, steroids, alkaloids and triterpenoids).	α-Cr2O3NPs.	[206]
Ceratonia siliqua	ALE.	AgNPs with AA toward *E. coli*.	[207]
Cinnamomum camphora	ALE.	AgNPs with low AA against *E. coli*.	[208]
Cocos nucifera	Mesocarp layer aqueous extract.	AgNPs with anti-larvicidal agent against *Anopheles stephensi* and *Culex quinquefasciatus*.	[209]
C. nucifera	Oil cake extract.	AgNPs with reduction the growth rate of multi-antibiotic-resistant bacteria such as *Aeromonas* sp., *Acinetobacter* sp. and *Citrobacter* sp. isolated from livestock wastewater.	[210]
Eucalyptus urophylla, *E. citriodora* and *E. robusta*	ALE.	AgNPs.	[211]
E. globulus	ALE.	AgNPs.	[212]
Eucalyptus	ALE.	FeNPs showed in situ remediation of eutrophic wastewater.	[213]
E. chapmaniana	ALE.	AgNPs inhibited various pathogenic microbes and reduced the viability of the HL-60 cells.	[214]
Excoecaria agallocha	ALE.	AgNPs exhibited an excellent cytotoxic effect against human breast carcinoma cell lines (MCF-7), with good AA against *S. typhi*, *P. aeruginosa*, *S. aureus* and *B. cereus*.	[215]
Ficus benghalensis	ALE.	AgNPs with effective AA toward *E. coli*.	[216]
Fraxinus excelsior	ALE.	AgNPs with better AoA.	[217]
Jatropha curcas	SAE.	AgNPs.	[218]
J. curcas	Latex.	AgNPs.	[219]
J. curcas	Seed cake extract (carbohydrates, proteins, alkaloids, flavonoids, saponins, tannins, phenols and terpenoids).	AgNPs with bacteriostatic effects against *B. subtilis*, *E. coli*, and P. *aeruginosa*.	[220]
Musa paradisiaca	Peels boiled distilled water extract.	AgNPs with good AA against *B. subtilis*, *S. aureus*, *P. aeruginosa*, *E. coli* and *Candida albicans*.	[221]
Nyctanthes arbor-tristis	AFE.	ZnONPs with antifungal potential against *Alternaria alternata*, *Aspergillus niger*, *Botrytis cinerea*, *Fusarium oxysporum* and *Penicillium expansum*.	[222]
Olea europaea	ALE.	AgNPs with significant AA against *S. aureus*, *P. aeruginosa*, and *E. coli*.	[223]
O. europaea	SAE.	AgNPs.	[224]
Opuntia ficus-indica	Spines aqueous extract.	Ag, Au and Ag-AuNPs with potential AA and AoA.	[225]
	ASE.		[226]

(*continued on next page*)

Table 3 (*continued*)

Plant species	Part and solvent extract	Synthesized nanoparticle/ biological activity	References
Pedilanthus tithymaloides		AgNPs with controlling of mosquito vector *Aedes aegypti*.	
Phoenix dactylifera	SAE.	AgNPs with AA against MRSA.	[227]
Pistacia atlantica	SAE.	AgNPs with AA against *S. aureus*.	[228]
Protorhus longifolia	SAE.	AgNPs and AuNPs.	[229]
Prunus persica	ALE (alkaloids, flavonoids, saponins, and steroid compounds).	AgNPs with AA against *E. coli*, and *V. cholera*.	[230]
Psidium guajava	ALE.	AgNPs.	[231]
Prunus japonica	ALE.	AgNPs with AA against *E. coli*, *Proteus vulgaris*, *S. aureus*, and *B. cereus*.	[232]
Pulicha Indeca	ASE.	AgNPs showed positive AA against *S. aureus*, *K. pneumoniae*, *B. subtilis* and negative against *P. mirabilis*.	[233]
Pterocarpus santalinus	ALE (steroids, saponins, tannins, phenols, triterpenoids, flavonoids, glycosides, and glycerides).	AgNPs with good AA against gram-positive and G^- bacterial strains.	[234]
Tectona grandis	SAE.	AgNPs observed AA against *S. aureus*, *B. cereus*, and *E. coli*.	[235]
Terminalia arjuna	ALE.	AgNPs with AA against *S. aureus* and *E. coli*.	[236]
Theobroma cacao	Pod husk extract.	AgNPs inhibited *K. pneumonia, E. coli, S. pyogenes, S. aureus, P. aeruginosa, A. flavus, A. fumigatus*, and *A. niger*.	[237]

AA; antibacterial activity; ALE; aqueous leaf extract; AFE; aqueous red flowers extract; AoA: Antioxidant activity; ASE; aqueous stem extract; SAE; seed aqueous extract.

Cupressus sempervirens wood methanolic extract as a combination treatment showed potent biocide activity against *T. harzianum* [175].

More recently, *P. roxburghii* wood blocks treated with ethanol extract from *Coccoloba uvifera* leaf extracts at 3 % showed the highest inhibition of *R. solani* (64.4 %), *B. cinerea* (100 %), and *F. culmorum* (38.5 %) over the acetone and water extracts as shown in Fig. 9. In addition, moderate growth inhibition was found against the plant pathogenic bacteria *Agrobacterium tumefaciens*, *Pectobacterium carotovorum* subsp. *carotovorum*, *Erwinia amylovora*, *Ralstonia solanacearum*, *Pectobacterium atrosepticum*, and *Dickeya solani* [2]. This bioactivity was related to phenolic acid compounds (benzoic, ellagic, gallic, and *o*-coumaric) or regarding flavonoids (rutin, myricetin, and quercetin).

4. Natural extracts from trees and shrubs in the green synthesis of nanoparticles

Several plant materials have been used as sources of bioreducing, capping and stabilization agents in the phytofabrication of metallic nanoparticles under ambient conditions as shown in Table 3. *Moringa oleifera* flower aqueous extract has been used in the green synthesis of gold (Au) nanoparticles (NPs). The particles exhibited a distribution of sizes in the range 3–5 nm with large gold NPs [176]. The Scanning electron microscope confirmed the AuNPs and nano size crystalline nature using the EDX pattern. *M. oleifera* leaf, flower, fruit, and bark extracts with their phytochemical compounds, such as the amino acids, carotenoids, minerals, vitamins, sterols, glycosides, flavonoids, alkaloids, and phenolics [177], were able to aid in the biosynthesis of NPs. CaNPs amended soil showed significant declines in the concentrations of some minerals in *M. oleifera* planted on it, but CaNPs the free radical scavenging ability, phenolic contents and flavonoid contents significantly improved, also reduction in oxidative stress biomarker was also recorded [178]. Silver nanoparticles (AgNPs), e.g., were synthesized by *L. camara* leaf extract with good antibacterial activity against *E. coli, Pseudomonas* sp, *Bacillus* spp., and *Staphylococcus* sp. [179]. Table 3 presents extracts from trees and shrubs that have been used for the green synthesis of metal NPs.

Other plants that have been used for the synthesis of metal nanoparticles (Ag, Au, Ag–Au, TiO_2 and CaNPs) with novel applications (antimicrobial, antioxidant, anticancer, anticoagulant, thrombolytic, antidiabetic, anti-inflammatory, larvicidal etc) were also reported. Leaf extract from *Annona muricata* was used for bio-fabrication of AgNPs, where it showed strong antioxidant activity with other biological activities such as anti-diabetic, antimicrobial, and cytotoxic [56]. The AgNPs synthesized with the application of stem extract from *Chasmanthera dependens* showed promising several biological activities [59].

Ehretia cymosa-AgNPs cream showed significant anti-inflammatory activity within 6 h as different extracts of the plant used in the following order; ethylacetate > methanol > *n*-hexane [180]. Phytosynthesized AuNPs from aqueous extract of *Datura stramonium* seed was achieved was scavenging properties against 2,2-diphenyl-1-picrylhydrazyl and nitric oxide, also, prevention of blood coagulation and thrombolytic potential by causing lysis of blood clot were found by the AuNPs [181], as well as with antidiabetic properties [182], which led to showing potential for biomedical applications [181]. AgNPs synthesized by *Carica papaya* seed extract observed LC_{50} and LC_{90} lethal concentration on the *Aedes aegypti* larva at 14.56 and 33.89 μg/mL respectively after 12 h of exposure and zones of inhibition between 10 and 24 mm, against selected microorganisms [183]. Aqueous leaf extract of *Hyptis suaveolens* was used to synthesis AgNPs, which presented potent inhibition against multidrug resistant bacteria, and fungal growth with scavenged DPPH and H_2O_2 and was effectively inhibited coagulation of blood [184].

Phytosynthesis TiO_2NPs was achieved by using the leaf, pod, seed and seed shell extracts of kola nut tree (*Cola nitida*), which inhibited MDR bacteria and toxigenic fungi with good antioxidant activity [185]. AgNPs synthesized by seed and seed shell extracts of *C. nitida* showed antibacterial activity [186], while by the pod extract it showed Antibacterial/antioxidant activities with applicative as a paint additive [187]. AgNPs synthesized by pod extract of *C. nitida* enhanced the antioxidant activity and phenolic/flavonoid contents of *Amaranthus caudatus* plants [188]. Also, the hyprid Ag-AuNPs produced with using Kolanut (*C. nitida*) extract showed some applications such as antifungal, catalytic, larvicidal and thrombolytic [189]. Cocoa bean extract was used to synthesize AgNPs, with pronounced antimicrobial activities [190]. Phytosynthesis of AgNPs mediated by *Synsepalum dulcificum* leaf and seed extracts inhibited the growth of *P. aeruginosa* and *K. granulomatis* with zone of inhibition of 11–24 mm and completely inhibited the growth of *A. flavus* and *A. niger* [191].

5. Antioxidant properties of extracts from trees and shrubs

Researchers have studied the antioxidant of extracts and their bioavailability, which include phenolic and flavonoid compounds, such as quercetin, rutin, benzoic acid, quercetin, *p*-hydroxy benzoic acid, ellagic acid, myricetin, *o*-coumaric acid, *p*-coumaric acid, gallic acid, syringic acid, vanillin, ferulic acid, salicylic acid, rosmarinic acid kaempferol, cinnamic acid, naringenin, caffeic acid, vanillic acid, and

Table 4
The antioxidant activity (AoA) of extracts and bioactive compounds from trees and shrubs.

Plant	Part used for Extraction	Method used	Bioactivity	References
Azadirachta indica, and *A. Juss* var. *siamensis* Valeto	Leaves, fruits, flowers and stem bark.	DPPH.	ALE, flower, and stem bark (ethanol extracts) exhibited higher free AoA..	[242]
		TBARS.	The ethanol flower extract and ALE decreased MDA levels (46.0 and 50.6 %, respectively) at 100 μg/mL.	[242]
Acacia nilotica	Leaves, pods and bark extracts (High TPC, TVC and proteins).	DPPH.	Potential AoA.	[245]
Castanea sativa	Shell.	FRAP.	TPC, 50.7 g GAE/100 g extract), with AoA = 3808 nmol AAE/mg extract.	[246]
Eucalyptus globulus	Bark.	FRAP	Total phenols 20.1 g GAE/100 g extract with AoA = 2199 nmol AAE/mg extract.	[246]
E. grandis, *E. urograndis* (*E. grandis* × *E. urophylla*), and *E. maidenii*	Bark extract- Epicatechin and quercetin-glucuronide in *E. grandis* and *E. urograndis*. ellagic acid-rhamnoside and ellagic acid in *E. grandis*. galloyl-bis-hexahydroxydiphenoyl (HHDP)-glucose and gallic acid in *E. urograndis*. Catechin, chlorogenic acid and methyl-ellagic acid-pentose in *E. maidenii* bark.	DPPH.	TPC of the three extracts demonstrated positive correlation with their AoA, evaluated by DPPH with values between the obtained from ascorbic acid and BHT.	[247]
E. camaldulensis var. *brevirostris*	Fruit EO (aromadendrene (17.99 %), α-pinene (12.68 %), cubenol (9.23 %), α-gurjunene (6.65 %), and p-cymenene (5.39 %). ethanol extract (ellagic acid).	LAO.	Ethanol extract showed considerable AoA compared with BHA and TBHQ.	[248]
Azadirachta indica, *Terminalia arjuna*, *Acacia nilotica*, and *Eugenia jambolana*	Bark.	LAO and DPPH.	The extracts exhibited TPC of 7.8–16.5 GAE and TV, 1.59–4.93 CAE. Reducing power at 10 mg/mL extract concentration ranged from 1.34 to 1.87. Extracts inhibited LAO by 44–90 %. DPPH radical scavenging activity ranged from 49 % to 87 %.	[244]
Camellia sinensis, *Ficus bengalensis* and *F. racemosa*	Methanol and 70 % acetone stem bark and fruit extracts.	Reducing power assay, DPPH, ABTS, OH radical scavenging capacities, LAO, antihemolytic assay by a hydrogen peroxide-induced method, and metal ion chelating ability.	Methanol extracts of *C. sinensis* and *F. bengalensis* and 70 % acetone extract of *F. racemosa* contained higher TPC with high AoA.	[249]
Cassia fistula	70 % Methanol extract from bark, stem, leaf, and root.	DPPH.	Bark extract demonstrated high TPC, TTC, and AA with IC50 values of 0.04 g/mL.	[250]
Garcinia atroviridis	Methanol extracts of leaves, fruits, roots, stems, and trunk bark.	FTC. TBARS.	The root, leaf, trunk, and stem bark extracts demonstrated strong antioxidant activity more than α-tocopherol.	[251]
Maclura tinctoria	Wood and bark.	DPPH	The AoA of wood extract (IC_{50} = 18.7 μg/mL) was more effective than bark extract (IC_{50} = 20.9 μg/mL).	[252]
Morinda citrifolia	Methanol and ethyl acetate extracts from leaf, fruit, and root.	FTC TBARS	The methanol extract of root exhibited high AoA compared to α-tocopherol or BHT.	[253]
Moringa oleifera seeds, *Cassia fistula* fruits and *Ceratonia siliqua* fruits	Oils from fruits and seeds.	DPPH	Moderate AoA.	[177]
M. oleifera	Extracts of freeze-dried leaves (water, aqueous methanol, and aqueous ethanol). Quercetin and Kaempferol as the main compounds.	DPPH and β-carotene−linoleic acid.	Methanol and ethanol extracts showed good AoA with 65.1 % and 66.8 %, respectively.	[254]
Pinus pinaster and *P. radiata*	Procyanidins from the bark. *P. radiata* bark was richer procyanidins and catechin, while epicatechin was richer in *P. pinaster*.	DPPH.	Both extracts had specific antiradical activity.	[255]
P. pinaster subsp. *atlantica*	Water, water/ethanol (1/1), and just ethanol, bark extracts.	DPPH.	High AoA as follows; water/ethanol> ethanol> water.	[256]
Quercus robur, *Q. macrocarpa,* and *Q. acutissima*	Bark extracts.	DPPH, β-carotene−linoleic acid and FRAP.	High AoA in *Q. robur* (ellagic acid) (Elansary et al., 2019b).	[257]

ALE: aqueous leaf extract; AoA: Antioxidant activity; TPC: total phenolic content, TTC: total tannin content; BHT: butylated hydroxytoluene; TBHQ: tertiary butylated hydroquinone; LAO: Linoleic acid oxidation: FTC: Ferric thiocyanate; DPPH: 1,1-diphenyl-2-picryl hydrazyl; TBARS: Thiobarbituric acid reactive substances; and MDA: malondialdehyde.

quercetin [1,2,4,61].

Ethanol and aqueous Bark extract from *P. halepensis*, rich in phenolic compounds, showed a significant reducing power towards the radicals tested by DPPH and ABTS radical scavenging capacity, and FRAP [238]. Willow bark, pine bark and cork, spruce needles, willow herb, meadowsweet and birch phloem with their rich in phenolic content were observed potential antioxidant activity [239]. Methanol and ethylacetate extracts from root bark Chionanthus virginicus L. were observed good antioxidant activity as measured by ABTS, DPPH, and superoxide anion (O2 •-) radical scavenging, where both extract shoed 69.4, 79.3, 72.3 and 83.7 % inhibition on lipid peroxidation of linoleic acid emulsion, respectively, at the 10 and 20 μg/mL concentrations [240]. Chloroform/methanol extracted oils from tree nut possessed higher antioxidant activities than hexane extracted counterparts as

measured by ABTS, DPPH, β-carotene bleaching test, oxygen radical absorbance capacity (ORAC) and photochemiluminescence inhibition assays [241]. Aqueous extract from leaves, and ethanol extracts from flowers and stem bark of neem tree were exhibited higher free radical scavenging effect on the DPPH assay IC_{50} at 26.5, 27.9 and 30.6 μg/mL, respectively [242]. Knotwood extracts from commercially important wood species had a high antioxidative potency and radical scavenging that were related to the pure wood-derived lignans and taxifolin [243]. Bark extracts from *Eugenia jambolana*, *Azadirachta indica*, *Terminalia arjuna*, and *Acacia nilotica* trees exhibited wide range of total phenolic, 7.8–16.5 GAE and total flavonoid contents, 1.59–4.93 CAE, and inhibited oxidation of linoleic acid by 44–90 % while DPPH ranged from 49 % to 87 % [244]. In this regards, Table 4 presents the antioxidant activity of different extracts from trees and shrubs using different analytical methods.

6. Conclusions

The potential uses of natural chemical compounds identified in different botanical parts from trees and shrubs were summarized in this review. These bioactive compounds have demonstrated several activities, such as antimicrobial, anticancer, and antioxidant properties and as biofungicides as well as in the mediation for the production of nanoparticles. The current work highlights the potential of tropical plants with antifungal activity to control a number of plant fungal diseases and identifies the compounds responsible for such antifungal activity. In addition, we indicate the extracts with good results in the biosynthesis of metallic nanoparticles for potential antimicrobials and antioxidants.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] N.A. Ashmawy, S.I. Behiry, A.A. Al-Huqail, H.M. Ali, M.Z.M. Salem, Bioactivity of selected phenolic acids and hexane extracts from *Bougainvilla spectabilis* and *Citharexylum spinosum* on the growth of *Pectobacterium carotovorum* and *Dickeya solani* bacteria: an opportunity to save the environment, Processes 8 (4) (2020) 482.

[2] N.A. Ashmawy, M.Z.M. Salem, N. El Shanhorey, A. Al-Huqail, H.M. Ali, S. I. Behiry, Eco-friendly wood-biofungicidal and antibacterial activities of various *Coccoloba uvifera* L. leaf extracts: HPLC analysis of phenolic and flavonoid compounds, BioResources 15 (2) (2020) 4165–4187.

[3] S.I. Behiry, R.A. Nasser, M.S.M. Abd El-Kareem, H.M. Ali, M.Z.M. Salem, Mass spectroscopic analysis, MNDO quantum chemical studies and antifungal activity of essential and recovered oil constituents of lemon-scented gum against three common molds, Processes 8 (3) (2020) 275.

[4] M. El-Hefny, M.Z.M. Salem, S.I. Behiry, H.M. Ali, The potential antibacterial and antifungal activities of wood treated with *Withania somnifera* fruit extract, and the phenolic, caffeine, and flavonoid composition of the extract according to HPLC, Processes 8 (1) (2020) 113.

[5] A. Hassan, S.H. Abu Hafsa, M.M.Y. Elghandour, P.R. Kanth Reddy, M.Z.M. Salem, U.Y. Anele, P.P. Ranga Reddy, A.Z.M. Salem, Influence of *Corymbia citriodora* leaf extract on growth performance, ruminal fermentation, nutrient digestibility, plasma antioxidant activity and faecal bacteria in young calves, Anim. Feed Sci. Technol. 261 (2020) 114394.

[6] A.A. Mohamed, S.I. Behiry, H.M. Ali, M. El-Hefny, M.Z.M. Salem, N.A. Ashmawy, Phytochemical compounds of branches from *P. halepensis* oily liquid extract and *S. terebinthifolius* essential oil and their potential antifungal activity, Processes 8 (3) (2020) 330.

[7] N.A. Ashmawy, S.I. Behiry, H.M. Ali, M.Z.M. Salem, Evaluation of *Tecoma stans* and *Callistemon viminalis* extracts against potato soft rot bacteria in vitro, J. Pure Appl. Microbiol. 8 (2014) 667–673.

[8] M. El-Hefny, N.A. Ashmawy, M.Z.M. Salem, A.Z.M. Salem, Antibacterial activities of the phytochemicals-characterized extracts of *Callistemon viminalis, Eucalyptus camaldulensis* and *Conyza dioscoridis* against the growth of some phytopathogenic bacteria, Microb. Pathog. 113 (2017) 348–356.

[9] M. El-Hefny, H.M. Ali, N.A. Ashmawy, M.Z.M. Salem, Chemical composition and bioactivity of *Salvadora persica* extracts against some potato bacterial pathogens, BioResources 12 (1) (2017) 1835–1849.

[10] M.L. Falcone Ferreyra, S. Rius, P. Casati, Flavonoids: biosynthesis, biological functions, and biotechnological applications, Front. Plant Sci. 3 (222) (2012).

[11] M.M.A. Mansour, M. El-Hefny, M.Z.M. Salem, H.M. Ali, The biofungicide activity of some plant essential oils for the cleaner production of model linen fibers similar to those used in ancient Egyptian mummification, Processes 8 (1) (2020) 79.

[12] T. Efferth, E. Koch, Complex interactions between phytochemicals. The multi-target therapeutic concept of phytotherapy, Curr. Drug Targets 12 (1) (2011) 122–132.

[13] K.A. Hammer, C.F. Carson, T.V. Riley, Antimicrobial activity of essential oils and other plant extracts, J. Appl. Microbiol. 86 (6) (1999) 985–990.

[14] J. Pedraza-Hernández, M.M.M.Y. Elghandour, A. Khusro, M.Z.M. Salem, L. M. Camacho-Diaz, A. Barbabosa-Pliego, A.Z.M. Salem, Assessment on bioactive role of Moringa oleifera leaves as anthelmintic agent and improved growth performance in goats, Trop. Anim. Health Prod. 53 (2) (2021) 318.

[15] M.M.Y. Elghandour, L.H. Vallejo, A.Z.M. Salem, M.Z.M. Salem, L.M. Camacho, G. Buendía R, N.E. Odongo, Effects of *Schizochytrium microalgae* and sunflower oil as sources of unsaturated fatty acids for the sustainable mitigation of ruminal biogases methane and carbon dioxide, J. Clean. Prod. 168 (2017) 1389–1397.

[16] S. Hadi, S.K. Hosseinihashemi, A.J. Latibari, M.Z.M. Salem, Effects of acid copper chromate preservative and hydrothermal treatment on the dimensional stability, hardness, and decay resistance of poplar wood, BioResources 11 (2) (2016) 4850–4864.

[17] L. Helsen, E. Van den Bulck, Review of disposal technologies for chromated copper arsenate (CCA) treated wood waste, with detailed analyses of thermochemical conversion processes, Environ. Pollut. 134 (2) (2005) 301–314.

[18] M.Z.M. Salem, S.A.E.-K.M. Hamed, M. Mansour, Assessment of efficacy and effectiveness of some extracted bio-chemicals as bio-fungicides on Wood, Drv. Ind.: Znanstveni časopis za pitanja drvne tehnologije 70 (4) (2019) 337–350.

[19] M.Z.M. Salem, S.I. Behiry, M. El-Hefny, Inhibition of *Fusarium culmorum, Penicillium chrysogenum* and *Rhizoctonia solani* by n-hexane extracts of three plant species as a wood-treated oil fungicide, J. Appl. Microbiol. 126 (6) (2019) 1683–1699.

[20] M.Z.M. Salem, M.M.A. Mansour, H.O. Elansary, Evaluation of the effect of inner and outer bark extracts of sugar maple (*Acer saccharum var. saccharum*) in combination with citric acid against the growth of three common molds, J. Wood Chem. Technol. 39 (2) (2019) 136–147.

[21] S.I. Behiry, M.K. Okla, S.A. Alamri, M. El-Hefny, M.Z.M. Salem, I.A. Alaraidh, H. M. Ali, S.M. Al-Ghtani, J.C. Monroy, A.Z.M. Salem, Antifungal and antibacterial activities of *Musa paradisiaca* L. Peel extract: HPLC analysis of phenolic and flavonoid contents, Processes 7 (4) (2019) 215.

[22] M.Z.M. Salem, Y.E. Zidan, N.M.N. El Hadidi, M.M.A. Mansour, W.A.A. Abo Elgat, Evaluation of usage three natural extracts applied to three commercial wood species against five common molds, Int. Biodeterior. Biodegrad. 110 (2016) 206–226.

[23] M.Z.M. Salem, Y.E. Zidan, M.M.A. Mansour, N.M.N. El Hadidi, W.A.A. Abo Elgat, Antifungal activities of two essential oils used in the treatment of three commercial woods deteriorated by five common mold fungi, Int. Biodeterior. Biodegrad. 106 (2016) 88–96.

[24] A.S. Taha, W.A. Elgat, Y.G. Fares, E.S. Dessoky, S.I. Behiry, M.Z. Salem, Using plant extractives as eco-friendly pulp additives: mechanical and antifungal properties of paper sheets made from linen fibers, BioResources 16 (2) (2021) 2589–2606.

[25] H.M. Ali, W.A.A.A. Elgat, M. EL-Hefny, M.Z.M. Salem, A.S. Taha, D.A. Al Farraj, M.S. Elshikh, A.A. Hatamleh, E.M. Abdel-Salam, New approach for using of mentha longifolia L. And citrus reticulata L. Essential oils as wood-biofungicides: GC-MS, SEM, and MNDO quantum chemical studies, Materials 14 (6) (2021) 1361.

[26] M.Z.M. Salem, W.A.A. Abo Elgat, A.S. Taha, Y.G.D. Fares, H.M. Ali, Impact of three natural oily extracts as pulp additives on the mechanical, optical, and antifungal properties of paper sheets made from *Eucalyptus camaldulensis* and *Meryta sinclairii* wood branches, Materials 13 (6) (2020) 1292.

[27] L. Azeez, A. Lateef, A.A. Wahab, M.A. Rufai, A.K. Salau, E.I.O. Ajayi, M. Ajayi, M. K. Adegbite, B. Adebisi, Phytomodulatory effects of silver nanoparticles on Corchorus olitorius: its antiphytopathogenic and hepatoprotective potentials, Plant Physiol. Biochem. 136 (2019) 109–117.

[28] A.E. Adebayo, A.M. Oke, A. Lateef, A.A. Oyatokun, O.D. Abisoye, I.P. Adiji, D. O. Fagbenro, T.V. Amusan, J.A. Badmus, T.B. Asafa, L.S. Beukes, E.B. Gueguim-Kana, S.H. Abbas, Biosynthesis of silver, gold and silver–gold alloy nanoparticles using *Persea americana* fruit peel aqueous extract for their biomedical properties, Nanotechnol. Environ. Eng. 4 (1) (2019) 13.

[29] A. Lateef, B.I. Folarin, S.M. Oladejo, P.O. Akinola, L.S. Beukes, E.B. Gueguim-Kana, Characterization, antimicrobial, antioxidant, and anticoagulant activities of silver nanoparticles synthesized from *Petiveria alliacea* L. leaf extract, Prep. Biochem. Biotechnol. 48 (7) (2018) 646–652.

[30] I.A. Adelere, A. Lateef, D.O. Aboyeji, R. Abdulsalam, N.U. Adabara, J.D. Bala, Biosynthesis of silver nanoparticles using aqueous extract of *Buchholzia coriacea* (wonderful kola) seeds and their antimicrobial activities, Ann. Food Sci. Technol. 18 (4) (2017) 671–679.

[31] M. Kępa, M. Miklasińska-Majdanik, R.D. Wojtyczka, D. Idzik, K. Korzeniowski, J. Smoleń-Dzirba, T.J. Wąsik, Antimicrobial potential of caffeic acid against *Staphylococcus aureus* clinical strains, BioMed Res. Int. 2018 (2018) 7413504.

[32] M. Takahata, J. Mitsuyama, Y. Yamashiro, M. Yonezawa, H. Araki, Y. Todo, S. Minami, Y. Watanabe, H. Narita, In vitro and in vivo antimicrobial activities of T-3811ME, a novel des-F(6)-quinolone, Antimicrob. Agents Chemother. 43 (5) (1999) 1077–1084.

[33] A.A. Al-Amiery, R.I.H. Al-Bayati, K.Y. Saour, M.F. Radi, Cytotoxicity, antioxidant, and antimicrobial activities of novel 2-quinolone derivatives derived from coumarin, Res. Chem. Intermed. 38 (2) (2012) 559–569.

[34] I. Kocaçalışkan, I. Talan, I. Terzi, Antimicrobial activity of catechol and pyrogallol as allelochemicals, Z. Naturforsch. C Biosci. 61 (9–10) (2006) 639–642.

[35] Y. Ma, S. Ding, Y. Fei, G. Liu, H. Jang, J. Fang, Antimicrobial activity of anthocyanins and catechins against foodborne pathogens *Escherichia coli* and *Salmonella*, Food Contr. 106 (2019) 106712.

[36] D. Rahardiyan, Antibacterial potential of catechin of tea (*Camellia sinensis*) and its applications, Food Res. 3 (1) (2019) 1–6.

[37] S.T. Alam, T.A. Le, J.-S. Park, H.C. Kwon, K. Kang, Antimicrobial biophotonic treatment of ampicillin-resistant *Pseudomonas aeruginosa* with hypericin and ampicillin cotreatment followed by orange light, Pharmaceutics 11 (12) (2019) 641.

[38] B. Feyzioğlu, M.E. Demircili, M. Doğan, M. Baykan, Antibacterial effect of hypericin, Afr. J. Microbiol. Res. 7 (11) (2013) 979–982.

[39] A. Marchese, R. Barbieri, E. Coppo, I.E. Orhan, M. Daglia, S.F. Nabavi, M. Izadi, M. Abdollahi, S.M. Nabavi, M. Ajami, Antimicrobial activity of eugenol and essential oils containing eugenol: a mechanistic viewpoint, Crit. Rev. Microbiol. 43 (6) (2017) 668–689.

[40] M. Kawase, B. Varu, A. Shah, N. Motohashi, S. Tani, S. Saito, S. Debnath, S. Mahapatra, S.G. Dastidar, A. Chakrabarty, Antimicrobial activity of new coumarin derivatives, Arzneimittelforschung 51 (1) (2001) 67–71.

[41] Y.K. Al-Majedy, A.A.H. Kadhum, A.A. Al-Amiery, A.B. Mohamad, Coumarins: the antimicrobial agents, Sys. Rev. Pharm. 8 (1) (2017) 62.

[42] G. Tataringa, A.M. Zbancioc, Coumarin Derivatives with Antimicrobial and Antioxidant Activities, Phytochemicals in Human Health, IntechOpen, 2019.

[43] G.B. Bubols, R. Vianna Dda, A. Medina-Remon, G. von Poser, R.M. Lamuela-Raventos, V.L. Eifler-Lima, S.C. Garcia, The antioxidant activity of coumarins and flavonoids, Mini Rev. Med. Chem. 13 (3) (2013) 318–334.

[44] Y.K. Al-Majedy, D.L. Al-Duhaidahawi, K.F. Al-Azawi, A.A. Al-Amiery, A.A. H. Kadhum, A.B. Mohamad, Coumarins as potential antioxidant agents complemented with suggested mechanisms and approved by molecular modeling studies, Molecules 21 (2) (2016) 135.

[45] B. Badhani, N. Sharma, R. Kakkar, Gallic acid: a versatile antioxidant with promising therapeutic and industrial applications, RSC Adv. 5 (35) (2015) 27540–27557.

[46] S. Hofer, S. Geisler, R. Lisandrelli, H. Nguyen Ngoc, M. Ganzera, H. Schennach, D. Fuchs, J.E. Fuchs, J.M. Gostner, K. Kurz, Pharmacological targets of kaempferol within inflammatory pathways—a hint towards the central role of tryptophan metabolism, Antioxidants 9 (2) (2020).

[47] L. Wang, Y.-C. Tu, T.-W. Lian, J.-T. Hung, J.-H. Yen, M.-J. Wu, Distinctive antioxidant and antiinflammatory effects of flavonols, J. Agric. Food Chem. 54 (26) (2006) 9798–9804.

[48] D. Xu, M.-J. Hu, Y.-Q. Wang, Y.-L. Cui, Antioxidant activities of quercetin and its complexes for medicinal application, Molecules 24 (6) (2019) 1123.

[49] B. Salehi, A. Venditti, M. Sharifi-Rad, D. Kręgiel, J. Sharifi-Rad, A. Durazzo, M. Lucarini, A. Santini, E.B. Souto, E. Novellino, H. Antolak, E. Azzini, W. N. Setzer, N. Martins, The therapeutic potential of apigenin, Int. J. Mol. Sci. 20 (6) (2019) 1305.

[50] Q.C. Fidelis, I. Faraone, D. Russo, F.E. Aragão Catunda Jr., L. Vignola, M.G. de Carvalho, N. de Tommasi, L. Milella, Chemical and Biological insights of Ouratea hexasperma (A. St.-Hil.) Baill.: a source of bioactive compounds with multifunctional properties, Nat. Prod. Res. 33 (10) (2019) 1500–1503.

[51] Z. Zhou, Y. Zhang, L. Lin, J. Zhou, Apigenin suppresses the apoptosis of H9C2 rat cardiomyocytes subjected to myocardial ischemia-reperfusion injury via upregulation of the PI3K/Akt pathway, Mol. Med. Rep. 18 (2) (2018) 1560–1570.

[52] W.J. Slichenmyer, D.D. Von Hoff, Taxol: a new and effective anti-cancer drug, Anti Canc. Drugs 2 (6) (1991) 519–530.

[53] H.J. Long, Paclitaxel (taxol): a novel anticancer chemotherapeutic drug, Mayo Clin. Proc. 69 (4) (1994) 341–345.

[54] S. Malik, R.M. Cusidó, M.H. Mirjalili, E. Moyano, J. Palazón, M. Bonfill, Production of the anticancer drug taxol in *Taxus baccata* suspension cultures: a review, Process Biochem. 46 (1) (2011) 23–34.

[55] M.C. Wani, H.L. Taylor, M.E. Wall, P. Coggon, A.T. McPhail, Plant antitumor agents. VI. Isolation and structure of taxol, a novel antileukemic and antitumor agent from Taxus brevifolia, J. Am. Chem. Soc. 93 (9) (1971) 2325–2327.

[56] J.A. Badmus, S.A. Oyemomi, O.T. Adedosu, T.A. Yekeen, M.A. Azeez, E. A. Adebayo, A. Lateef, U.M. Badeggi, S. Botha, A.A. Hussein, J.L. Marnewick, Photo-assisted bio-fabrication of silver nanoparticles using *Annona muricata* leaf extract: exploring the antioxidant, anti-diabetic, antimicrobial, and cytotoxic activities, Heliyon 6 (11) (2020), e05413.

[57] M.K. Okla, S.A. Alamri, M.Z.M. Salem, H.M. Ali, S.I. Behiry, R.A. Nasser, I. A. Alaraidh, S.M. Al-Ghtani, W. Soufan, Yield, phytochemical constituents, and antibacterial activity of essential oils from the leaves/twigs, branches, branch wood, and branch bark of sour orange (*Citrus aurantium* L.), Processes 7 (6) (2019) 363.

[58] N.A. Ashmawy, D.A. Al Farraj, M.Z.M. Salem, M.S. Elshikh, R. Al-Kufaidy, M. K. Alshammari, A.Z.M. Salem, Potential impacts of *Pinus halepensis* Miller trees as a source of phytochemical compounds: antibacterial activity of the cones essential oil and n-butanol extract, Agrofor. Syst. 94 (4) (2020) 1403–1413.

[59] D.A. Aina, O. Owolo, A. Lateef, F.O. Aina, A.S. Hakeem, M. Adeoye-Isijola, V. Okon, T.B. Asafa, J.A. Elegbede, O.D. Olukanni, Biomedical applications of *Chasmanthera dependens* stem extract mediated silver nanoparticles as antimicrobial, antioxidant, anticoagulant, thrombolytic, and larvicidal agents, Karbala Int. J. Modern Sci. 5 (2) (2019) 71–80.

[60] J. Dai, R.J. Mumper, Plant phenolics: extraction, analysis and their antioxidant and anticancer properties, Molecules 15 (10) (2010) 7313–7352.

[61] C. Wu, R. Chen, X.S. Wang, B. Shen, W. Yue, Q. Wu, Antioxidant and anti-fatigue activities of phenolic extract from the seed coat of *Euryale ferox* salisb. And identification of three phenolic compounds by LC-ESI-MS/MS, Molecules 18 (9) (2013) 11003–11021.

[62] H.I.A. Boy, A.J.H. Rutilla, K.A. Santos, A.M.T. Ty, A.I. Yu, T. Mahboob, J. Tangpoong, V. Nissapatorn, Recommended medicinal plants as source of natural products: a review, Digital Chin. Med. 1 (2) (2018) 131–142.

[63] M.Z.M. Salem, A.Z.M. Salem, L. Camacho, H.M. Ali, Antimicrobial activities and phytochemical composition of extracts of *Ficus* species: an over view, Afr. J. Microbiol. Res. 7 (33) (2013) 4207–4219.

[64] M.Z.M. Salem, M. El-Hefny, R.A. Nasser, H.M. Ali, N.A. El-Shanhorey, H. O. Elansary, Medicinal and biological values of *Callistemon viminalis* extracts: history, current situation and prospects, Asian Pac. J. Trop. Med. 10 (3) (2017) 229–237.

[65] S.K. Lee, H.J. Lee, H.Y. Min, E.J. Park, K.M. Lee, Y.H. Ahn, Y.J. Cho, J.H. Pyee, Antibacterial and antifungal activity of pinosylvin, a constituent of pine, Fitoterapia 76 (2) (2005) 258–260.

[66] A. Sipponen, K. Laitinen, Antimicrobial properties of natural coniferous rosin in the European Pharmacopoeia challenge test, APMIS 119 (10) (2011) 720–724.

[67] L.P. Shao, E. Gäfvert, U. Nilsson, A.-T. Karlberg, J.L.G. Nilsson, 15-hydroperoxydehydroabietic acid—a contact allergen in colophony from Pinus species, Phytochemistry 38 (4) (1995) 853–857.

[68] S. Savluchinske-Feio, M.J.M. Curto, B. Gigante, J.C. Roseiro, Antimicrobial activity of resin acid derivatives, Appl. Microbiol. Biotechnol. 72 (3) (2006) 430–436.

[69] M.E. Coşkun, Xi. Bitkisel İlaç Hammaddeleri Toplantısı: Ankara Üniversitesi Eczacılık Fakültesi Ankara, 22-24 Mayıs 1996: Bildiri Kitabı= Proceedingsof the Xıth Symposium on Plant Originated Crude Drugs Ankara, May 2, Ankara: Ankara Üniversitesi Eczacılık Fakültesi.

[70] M. Ozturk, E. Altundağ, S. Gücel, Medicinal and Aromatic Plants (Turkey). Ethnopharmacology, Encyclopedia of Life Support Systems, EOLSS), 2012.

[71] E. Sezik, O. Üstün, K. Başer, M. Kürkçüoğlu, The chemical composition of the volatile oils of Pinus brutia, Pinus nigra, Pinus sylvestris growing in Turkey, in: International Symposium on Essential Oils, 1997, pp. 1–3.

[72] M. Krauze-Baranowska, M. Mardarowicz, M. Wiwart, L. Pobłocka, M. Dynowska, Antifungal activity of the essential oils from some species of the genus Pinus, Z. Naturforsch. C Biosci. 57 (5–6) (2002) 478–482.

[73] Z. Šarac, J.S. Matejić, Z.Z. Stojanović-Radić, J.B. Veselinović, A.M. Džamić, S. Bojović, P.D. Marin, Biological activity of *Pinus nigra* terpenes—evaluation of FtsZ inhibition by selected compounds as contribution to their antimicrobial activity, Comput. Biol. Med. 54 (2014) 72–78.

[74] A.C.R.d. Silva, P.M. Lopes, M.M.B.d. Azevedo, D.C.M. Costa, C.S. Alviano, D. S. Alviano, Biological activities of α-pinene and β-pinene enantiomers, Molecules 17 (6) (2012).

[75] A.M. Leite, E.d.O. Lima, E.L.d. Souza, M.d.F.F.M. Diniz, V.N. Trajano, I.A. d. Medeiros, Inhibitory effect of beta-pinene, alpha-pinene and eugenol on the growth of potential infectious endocarditis causing Gram-positive bacteria, Rev. Bras. Ciencias Farm. 43 (2007) 121–126.

[76] M.Z.M. Salem, A. Zeidler, M. Böhm, M.E. Mohamed, H.M. Ali, GC/MS analysis of oil extractives from wood and bark of *Pinus sylvestris, Abies alba, Picea abies*, and *Larix decidua*, BioResources 10 (4) (2015) 7725–7737.

[77] M. Rautio, A. Sipponen, J. Lohi, K. Lounatmaa, P. Koukila-Kähkölä, K. Laitinen, In vitro fungistatic effects of natural coniferous resin from Norway spruce (*Picea abies*), Eur. J. Clin. Microbiol. Infect. Dis. 31 (8) (2012) 1783–1789.

[78] M. Dığrak, A. İlçim, M. Hakkı Alma, Antimicrobial activities of several parts of *Pinus brutia, Juniperus oxycedrus, Abies cilicia, Cedrus libani* and *Pinus nigra*, Phytother Res. 13 (7) (1999) 584–587.

[79] M.Z.M. Salem, H.M. Ali, M.O. Basalah, Essential oils from wood, bark, and needles of *Pinus roxburghii* Sarg. from Alexandria, Egypt: antibacterial and antioxidant activities, BioResources 9 (4) (2014) 7454–7466.

[80] S. Bissa, A. Bohra, A. Bohra, Antibacterial potential of three naked-seeded (Gymnosperm) plants, Nat. Product. Radiance 7 (5) (2008) 420–425.

[81] A.K. Chaudhary, S. Ahmad, A. Mazumder, Study of antibacterial and antifungal activity of traditional *Cedrus deodara* and *Pinus roxburghii* Sarg, Cell Med. 2 (4) (2012), 37.1-37.4.

[82] P.G. Ray, S.K. Majumdar, Antimicrobial activity of some Indian plants, Econ. Bot. 30 (4) (1976) 317.

[83] A. Hassan, I. Amjid, Gas chromatography-mass spectrometric studies of stems essential oil of *Pinus roxburghaii* and their antibacterial and antifungal activities, J. Med. Plants Res. 3 (9) (2009) 670–673.

[84] Z. Iqbal, M. Zia-Ur-Rehman, S.J. Khan, A. Fatima, S. Mehmud, GC-MS studies of needles essential oils of *Pinus roxburghaii* and their antimicrobial activity, Pakistan J. Biochem. Mol. Biol. 44 (2011) 36–38.

[85] S.B. Glišić, S.Ž. Milojević, S.I. Dimitrijević, A.M. Orlović, D.U. Skala, Antimicrobial activity of the essential oil and different fractions of *Juniperus communis* L. and a comparison with some commercial antibiotics, J. Serb. Chem. Soc. 72 (4) (2007) 311–320.

[86] T.J. Claude, M. Christine, B. Songa, M.M. Jeanne, I.M. Goretti, C.J. Claude, Chemical composition, antibacterial and antifungal activity of the essential oil of Pinus patula growing in Rwanda, Am. J. Biomed. Life Sci. 2 (3) (2014) 55–59.

[87] E.-J. Hong, K.-J. Na, I.-G. Choi, K.-C. Choi, E.-B. Jeung, Antibacterial and antifungal effects of essential oils from coniferous trees, Biol. Pharm. Bull. 27 (6) (2004) 863–866.

[88] J.H. Lee, B.K. Lee, J.H. Kim, S.H. Lee, S.K. Hong, Comparison of chemical compositions and antimicrobial activities of essential oils from three conifer trees; *Pinus densiflora, Cryptomeria japonica*, and *Chamaecyparis obtusa*, J. Microbiol. Biotechnol. 19 (4) (2009) 391–396.

[89] M. Karapandzova, G. Stefkov, I. Cvetkovikj, E. Trajkovska-Dokik, A. Kaftandzieva, S. Kulevanova, Chemical composition and antimicrobial activity of the essential oils of Pinus peuce (pinaceae) growing wild in R. Macedonia, Nat. Prod. Commun. 9 (11) (2014), 1934578X1400901124.

[90] T.U. Rahman, G. Uddin, K.F. Khattak, W. Liaqat, M.I. Choudhary, Antibacterial, antifungal, insecticidal and phytotoxic activities of leaves of *Pinus wallichiana*, J. Chem. Pharmaceut. Res. 8 (1) (2016) 420–424.

[91] İ.E. Orhan, B. Özçelik, B. Şener, Evaluation of antibacterial, antifungal, antiviral, and antioxidant potentials of some edible oils and their fatty acid profiles, Turkish J. Biol. 35 (2) (2011) 251–258.

[92] A. Godghate, R. Sawant, Phytochemical analysis of leaves of *Tectona grandis* Linn, Int. J. Pharm. Biol. Sci. 5 (1) (2014) 355–359.

[93] G.A. Guerrero-Vásquez, K.Z. Andrade, J.M. González Molinillo, F.A. Macías Domínguez, Practical first total synthesis of the potent phytotoxic (±)-naphthotectone, isolated from Tectona grandis, Eur. J. Org Chem. 27 (2013) 6175–6180.

[94] K. Alabi, T. Oyeku, The chemical constituents extractable from teak tree (*Tectona grandis* Linn) obtained from Fountain University, Osogbo, Nigerian J. Basic Appl. Sci. 25 (1) (2017) 73–80.

[95] Y.K. Hamad, Y. Abobakr, M.Z. Salem, H.M. Ali, A.S. Al-Sarar, A.A. Al-Zabib, Activity of plant extracts/essential oils against three plant pathogenic fungi and mosquito larvae: GC/MS analysis of bioactive compounds, BioResources 14 (2) (2019) 4489–4511.

[96] D. Candra, S. Eka, W. Sinta, Acute toxicity of Indonesian natural food colorant *Tectona grandis* leaf extract in Wistar rats, J. Med. Sci. 19 (2019) 69–74.

[97] H.O. Elansary, M.Z.M. Salem, N.A. Ashmawy, M.M. Yacout, Chemical composition, antibacterial and antioxidant activities of leaves essential oils from Syzygium cumini L., Cupressus sempervirens L. and Lantana camara L. from Egypt, J. Agric. Sci. 4 (10) (2012) 144–152.

[98] A. Craveiro, C. Andrade, F. Matos, J. Alencar, M. Machado, Essential oil of *Eugenia jambolana*, J. Nat. Prod. 46 (4) (1983) 591–592.

[99] A.L. Tapondjou, C. Adler, D.A. Fontem, H. Bouda, C. Reichmuth, Bioactivities of cymol and essential oils of *Cupressus sempervirens* and *Eucalyptus saligna* against *Sitophilus zeamais* Motschulsky and *Tribolium confusum* du Val, J. Stored Prod. Res. 41 (1) (2005) 91–102.

[100] G. Uçar, M.B. Uçar, H. Fakir, Composition of volatile foliage isolates from *Cupressus sempervirens* varieties (var. Horizontal Mill. And pyramidalis Nyman) growing in Turkey, J. Essent. Oil Res. 19 (6) (2007) 562–565.

[101] A.-F.Z. Salem, M.Z.M. Salem, M. Gonzalez-Ronquillo, L. Camacho, M. Cipriano, Major chemical constituents of *Leucaena leucocephala* and *Salix babylonica* leaf extracts, J. Trop. Agric. 49 (2011) 95–98.

[102] O. Adekunle, A. Akinlua, Nematicidal effects of *Leucaena leucocephala* and *Gliricidia sepium* extracts on Meloidogyne incognita infecting okra, J. Agric. Sci. 52 (1) (2007) 53–63.

[103] K. Nokihara, A. Hirata, T. Sogon, T. Ohyama, Preparative scale isolation, purification and derivatization of mimosine, a non-proteinogenic amino acid, Amino Acids 43 (1) (2012) 475–482.

[104] C.-Y. Chen, Y.-D. Wang, Polyprenol from the whole plants of *Leucaena leucocephala*, J. Environ. Protect. 1 (1) (2010) 70–72.

[105] T.M. Ruuhola, M.-R.K. Julkunen-Tiitto, Salicylates of intact Salix myrsinifolia plantlets do not undergo rapid metabolic Turnover1, Plant Physiol. 122 (3) (2000) 895–906.

[106] F. Khatoon, M. Khabiruddin, W.H. Ansari, Phenolic glycosides from *Salix babylonica*, Phytochemistry 27 (9) (1988) 3010–3011.

[107] M.Z.M. Salem, Y.M. Gohar, L. Camacho, N.A. El-Shanhorey, A. Salem, Antioxidant and antibacterial activities of leaves and branches extracts of *Tecoma stans* (L.) Juss. ex Kunth against nine species of pathogenic bacteria, Afr. J. Microbiol. Res. 7 (5) (2013) 418–426.

[108] O. Binutu, B. Lajubutu, Antimicrobial potentials of some plant species of the Bignoniaceae family, Afr. J. Med. Med. Sci. 23 (3) (1994) 269–273.

[109] S. Raju, S. Kavimani, M. Uma, R. Sreeramulu, *Tecoma stans* (L.) Juss. Ex Kunth (bignoniaceae): ethnobotany, phytochemistry and pharmacology, J. Pharmaceut. Biomed. Sci. 8 (2011) 1–5.

[110] T. Sadananda, M. Jeevitha, K. Pooja, V.B. Raghavendra, Antimicrobial, Antioxidant activity and phytochemical screening of *Tecoma stans* (L.) Juss. Ex Kunth, J. Phytol. 3 (3) (2011) 68–76.

[111] A. Bianco, M. Massa, J.U. Oguakwa, P. Passacantilli, 5-deoxystansioside, an iridoid glucoside from *Tecoma stans*, Phytochemistry 20 (8) (1981) 1871–1872.

[112] M.Z.M. Salem, M.S. El-Shikh, H.M. Ali, Chemical characterization of the volatile oil isolated from leaves of *Schinus molle* L. and its antioxidant activity, J. Pure Appl. Microbiol. 7 (2013) 355–360.

[113] M.d.R. Martins, S. Arantes, F. Candeias, M.T. Tinoco, J. Cruz-Morais, Antioxidant, antimicrobial and toxicological properties of *Schinus molle* L. essential oils, J. Ethnopharmacol. 151 (1) (2014) 485–492.

[114] M. Maffei, F. Chialva, Essential oils from *Schinus molle* L. berries and leaves, Flavour Fragrance J. 5 (1) (1990) 49–52.

[115] C. Díaz, S. Quesada, O. Brenes, G. Aguilar, J.F. Cicció, Chemical composition of *Schinus molle* essential oil and its cytotoxic activity on tumour cell lines, Nat. Prod. Res. 22 (17) (2008) 1521–1534.

[116] E. Abdel-Sattar, A.A. Zaitoun, M.A. Farag, S.H.E. Gayed, F.M.H. Harraz, Chemical composition, insecticidal and insect repellent activity of *Schinus molle* L. leaf and fruit essential oils against *Trogoderma granarium* and *Tribolium castaneum*, Nat. Prod. Res. 24 (3) (2010) 226–235.

[117] A. Ennigrou, K. Hosni, H. Casabianca, E. Vulliet, S. Smiti, Leaf volatile oil constituants of *Schinus terebinthifolius* and *Schinus molle* from Tunisia, Foodbalt 1 (2011) 90–92.

[118] M.Z.M. Salem, H.M. Ali, N.A. El-Shanhorey, A. Abdel-Megeed, Evaluation of extracts and essential oil from *Callistemon viminalis* leaves: antibacterial and antioxidant activities, total phenolic and flavonoid contents, Asian Pac. J. Trop. Med. 6 (10) (2013) 785–791.

[119] P.S. Pramod, K.S. Trimbakrao, A. Vanita, Evaluation of unsaponified petroleum ether extract of *Lantana camara* L. Leaves for antioxidant activity and oxidative stability, Indian J. Pharmaceut. Educ. Res. 51 (4) (2017) 692–699, 2017.

[120] R. Seth, M. Mohan, P. Singh, S.Z. Haider, S. Gupta, I. Bajpai, D. Singh, R. Dobhal, Chemical composition and antibacterial properties of the essential oil and extracts of *Lantana camara* Linn. from Uttarakhand (India), Asian Pac. J. Trop. Biomed. 2 (3) (2012) S1407–S1411. Supplement.

[121] A. Ayub, S. Begum, S.N. Ali, S.T. Ali, B.S. Siddiqui, Triterpenoids from the aerial parts of *Lantana camara*, J. Asian Nat. Prod. Res. 21 (2) (2019) 141–149.

[122] S. Roy, A.K. Barua, The structure and stereochemistry of a triterpene acid from *lantana camara*, Phytochemistry 24 (7) (1985) 1607–1608.

[123] O.P. Sharma, R.K. Dawra, D. Ramesh, A triterpenoid acid, lantadene D from *Lantana camara* var. Aculeata, Phytochemistry 29 (12) (1990) 3961–3962.

[124] S.B. Mahato, N.P. Sahu, S.K. Roy, O.P. Sharma, Potential antitumor agents from Lantana camara : structures of flavonoid -, and phenylpropanoid glycosides, Tetrahedron 50 (31) (1994) 9439–9446.

[125] S. Begum, A. Ayub, B. ShaheenSiddiqui, S. Fayyaz, F. Kazi, Nematicidal triterpenoids from *Lantana camara*, Chem. Biodivers. 12 (9) (2015) 1435–1442.

[126] E.O. Sousa, C.M.B.A. Miranda, C.B. Nobre, A.A. Boligon, M.L. Athayde, J.G. M. Costa, Phytochemical analysis and antioxidant activities of *Lantana camara* and Lantana montevidensis extracts, Ind. Crop. Prod. 70 (2015) 7–15.

[127] G. Pramila, D. Jirekar, M. Farooqui, S. Naikwade, Biological activity of aqueous extract of some medicinal plants, Chem. Sin. 5 (4) (2014) 65–70.

[128] B. Mohamed Senouci, H. Hafida, B. Chahrazed, A. Djamel Eddine, Evaluation of antibacterial activity of some medicinal plants extracts commonly used in Algerian traditional medicine against some pathogenic bacteria, Phcog. J. 10 (3) (2018) 507–512.

[129] S. Mathew, T.E. Abraham, Studies on the antioxidant activities of cinnamon (*Cinnamomum verum*) bark extracts, through various in vitro models, Food Chem. 94 (4) (2006) 520–528.

[130] S.J. Koppikar, A.S. Choudhari, S.A. Suryavanshi, S. Kumari, S. Chattopadhyay, R. Kaul-Ghanekar, Aqueous Cinnamon Extract (ACE-c) from the bark of *Cinnamomum cassiacauses* apoptosis in human cervical cancer cell line (SiHa) through loss of mitochondrial membrane potential, BMC Canc. 10 (1) (2010) 210.

[131] F. Nazzaro, F. Fratianni, L. De Martino, R. Coppola, V. De Feo, Effect of essential oils on pathogenic bacteria, Pharmaceuticals 6 (12) (2013) 1451–1474.

[132] A.D.B. Melo, A.F. Amaral, G. Schaefer, F.B. Luciano, C. de Andrade, L.B. Costa, M. H. Rostagno, Antimicrobial effect against different bacterial strains and bacterial adaptation to essential oils used as feed additives, Can. J. Vet. Res. 79 (4) (2015) 285–289.

[133] M. Vangalapati, N.S. Satya, D.S. Prakash, S. Avanigadda, A review on pharmacological activities and clinical effects of cinnamon species, Res. J. Pharmaceut. Biol. Chem. Sci. 3 (1) (2012) 653–663.

[134] Y.-T. Tung, M.-T. Chua, S.-Y. Wang, S.-T. Chang, Anti-inflammation activities of essential oil and its constituents from indigenous cinnamon (*Cinnamomum osmophloeum*) twigs, Bioresour. Technol. 99 (9) (2008) 3908–3913.

[135] Y.-T. Tung, P.-L. Yen, C.-Y. Lin, S.-T. Chang, Anti-inflammatory activities of essential oils and their constituents from different provenances of indigenous cinnamon (*Cinnamomum osmophloeum*) leaves, Pharmaceut. Biol. 48 (10) (2010) 1130–1136.

[136] M.Z.M. Salem, M.S. El-Shikh, H.M. Ali, Antibacterial activity of extract from the stem bark of *Schinus terebinthifolius*, J. Pure Appl. Microbiol. 8 (5) (2014) 3865–3870.

[137] L.B. Lima, C.F.B. Vasconcelos, H.M.L. Maranhão, V.R. Leite, P.A. Ferreira, B. A. Andrade, E.L. Araújo, H.S. Xavier, S.S.L. Lafayette, A.G. Wanderley, Acute and subacute toxicity of *Schinus terebinthifolius* bark extract, J. Ethnopharmacol. 126 (3) (2009) 468–473.

[138] E.Y.A. Salih, P. Fyhrquist, A.M.A. Abdalla, A.Y. Abdelgadir, M. Kanninen, M. Sipi, O. Luukkanen, M.K.M. Fahmi, M.H. Elamin, H.A. Ali, LC-MS/MS tandem mass spectrometry for analysis of phenolic compounds and pentacyclic triterpenes in antifungal extracts of *Terminalia brownii* (fresen), Antibiotics 6 (4) (2017).

[139] M.Z.M. Salem, Evaluation of the antibacterial and antioxidant activities of stem bark extracts of Delonix regia and *Erythrina humeana* grown in Egypt, J. For. Prod. Ind. 2 (2) (2013) 48–52.

[140] S. Johann, N.P. Sá, L.A.R.S. Lima, P.S. Cisalpino, B.B. Cota, T.M.A. Alves, E. P. Siqueira, C.L. Zani, Antifungal activity of schinol and a new biphenyl compound isolated from *Schinus terebinthifolius* against the pathogenic fungus Paracoccidioides brasiliensis, Ann. Clin. Microbiol. Antimicrob. 9 (1) (2010) 30.

[141] J. Parekh, S. Chanda, In vitro antimicrobial activity and phytochemical analysis of some Indian medicinal plants, Turkish J. Biol. 31 (1) (2007) 53–58.

[142] F. Fatmawaty, H. Astuti, Antimalarial activity of *Delonix regia* on mice with *Plasmodium berghei*, J. Nat. Prod. 6 (2013) 61–66.

[143] U. Rawat, B. Srivastava, S. Semwal, O. Sati, Xanthones from *Pinus roxburghii*, J. Indian Chem. Soc. 83 (4) (2006) 391–392.

[144] N. El-Shaer, Lignan and Phenolic acids from oleoresin of Pinus roxburghii (Chir pine), Alexandria J. Pharmaceut. Sci. 16 (1) (2002) 31–34.

[145] H.O. Elansary, A. Szopa, P. Kubica, F.A. Al-Mana, E.A. Mahmoud, T.K.A. Zin El-Abedin, M.A. Mattar, H. Ekiert, Phenolic compounds of *Catalpa speciosa, Taxus cuspidata*, and *Magnolia acuminata* have antioxidant and anticancer activity, Molecules 24 (3) (2019) 412.

[146] H.O. Elansary, A. Szopa, P. Kubica, H. Ekiert, M.A. Mattar, M.A. Al-Yafrasi, D. O. El-Ansary, T.K. Zin El-Abedin, K. Yessoufou, Polyphenol profile and pharmaceutical potential of *Quercus* spp. bark extracts, Plants 8 (11) (2019).

[147] A. Abdelkhalek, M.Z.M. Salem, A.M. Kordy, A.Z.M. Salem, S.I. Behiry, Antiviral, antifungal, and insecticidal activities of *Eucalyptus* bark extract: HPLC analysis of polyphenolic compounds, Microb. Pathog. 147 (2020) 104383.

[148] J. Gautam, P. Kumar, P. Kushwaha, V. Khedgikar, D. Choudhary, D. Singh, R. Maurya, R. Trivedi, Neoflavonoid dalbergiphenol from heartwood of Dalbergia sissoo acts as bone savior in an estrogen withdrawal model for osteoporosis, Menopause 22 (11) (2015) 1246–1255.

[149] A. Abdel-Megeed, M.Z.M. Salem, H.M. Ali, Y.M. Gohar, *Brachychiton diversifolius* as a source of natural products: antibacterial and antioxidant evaluation of extracts of wood branches, J. Pure Appl. Microbiol. 7 (3) (2013) 1843–1850.

[150] M.Z.M. Salem, H.M. Ali, M.M. Mansour, Fatty acid methyl esters from air-dried wood, bark, and leaves of Brachychiton diversifolius R. Br: antibacterial, antifungal, and antioxidant activities, BioResources 9 (3) (2014) 3835–3845.

[151] T. Deguchi, Y. Hata, A. Tamai, M. Yamamoto, T. Fujita, Y. Yoshioka, M. Iwaki, K. Murata, Inhibitory activity of asana, heartwood of *Pterocarpus marsupium*, against xanthine oxidase, Nat. Prod. Commun. 14 (12) (2019), 1934578X19887891.

[152] T. Sarg, A.-M. Ateya, A. Abdel-Ghani, W. Badr, G. Shams, Phytochemical and pharmacological studies of Dalbergia sissoo growing in Egypt, Pharmaceut. Biol. 37 (1) (1999) 54–62.

[153] M.Z.M. Salem, M. El-Hefny, H.M. Ali, H.O. Elansary, R.A. Nasser, A.A.A. El-Settawy, N. El Shanhorey, N.A. Ashmawy, A.Z.M. Salem, Antibacterial activity of extracted bioactive molecules of *Schinus terebinthifolius* ripened fruits against some pathogenic bacteria, Microb. Pathog. 120 (2018) 119–127.

[154] R.A. Barnes, N.N. Gerber, The antifungal agent from osage orange wood, J. Am. Chem. Soc. 77 (12) (1955) 3259–3262.

[155] S.-C. Wang, J.H. Hart, Heartwood extractives of *Maclura pomifera* and their role in decay resistance, Wood Fiber Sci. 15 (4) (1983) 290–301.

[156] S.-J. Lee, A.R. Wood, C.G.A. Maier, R.A. Dixon, T.J. Mabry, Prenylated flavonoids from Maclura pomifera, Phytochemistry 49 (8) (1998) 2573–2577.

[157] M.Z.M. Salem, A. Abdel-Megeed, H.M. Ali, Stem wood and bark extracts of *Delonix regia* (Boj. Ex. Hook): chemical analysis and antibacterial, antifungal, and antioxidant properties, BioResources 9 (2) (2014) 2382–2395.

[158] B. Andersen, C. Frisvad Jens, I. Søndergaard, S. Rasmussen Ib, S. Larsen Lisbeth, Associations between fungal species and water-damaged building materials, Appl. Environ. Microbiol. 77 (12) (2011) 4180–4188.

[159] X. Xu, S. Lee, Y. Wu, Q. Wu, Borate-treated strand board from southern wood species: resistance against decay and mold fungi, BioResources 8 (1) (2013) 104–114.

[160] Y.M. Lee, H. Lee, Y. Jang, Y. Cho, G.-H. Kim, J.-J. Kim, Phylogenetic analysis of major molds inhabiting woods. Part 4. Genus Alternaria, Holzforschung 68 (2) (2014) 247–251.

[161] M.Z.M. Salem, EDX measurements and SEM examination of surface of some imported woods inoculated by three mold fungi, Measurement 86 (2016) 301–309.

[162] J.A. Elegbede, A. Lateef, Valorization of corn-cob by fungal isolates for production of xylanase in submerged and solid state fermentation media and potential biotechnological applications, Waste Biomass Valoriz. 9 (8) (2018) 1273–1287.

[163] J.A. Elegbede, A. Lateef, M.A. Azeez, T.B. Asafa, T.A. Yekeen, I.C. Oladipo, E. A. Adebayo, L.S. Beukes, E.B. Gueguim-Kana, Fungal xylanases-mediated synthesis of silver nanoparticles for catalytic and biomedical applications, IET Nanobiotechnol. 12 (6) (2018) 857–863.

[164] J.A. Elegbede, A. Lateef, M.A. Azeez, T.B. Asafa, T.A. Yekeen, I.C. Oladipo, A. S. Hakeem, L.S. Beukes, E.B. Gueguim-Kana, Silver-gold alloy nanoparticles biofabricated by fungal xylanases exhibited potent biomedical and catalytic activities, Biotechnol. Prog. 35 (5) (2019), e2829.

[165] J.A. Elegbede, A. Lateef, M.A. Azeez, T.B. Asafa, T.A. Yekeen, I.C. Oladipo, D. A. Aina, L.S. Beukes, E.B. Gueguim-Kana, Biofabrication of gold nanoparticles using xylanases through valorization of corncob by *Aspergillus niger* and *Trichoderma longibrachiatum*: antimicrobial, antioxidant, anticoagulant and thrombolytic activities, Waste Biomass Valoriz. 11 (3) (2020) 781–791.

[166] I.A. Adelere, A. Lateef, A novel approach to the green synthesis of metallic nanoparticles: the use of agro-wastes, enzymes, and pigments, Nanotechnol. Rev. 5 (6) (2016) 567–587.

[167] V.W. Yang, C.A. Clausen, Inhibitory Effect of Essential Oils on Decay Fungi and Mold Growth on Wood, Proceedings, One Hundred Third Annual Meeting of the American Wood Protection Association... St. Louis, Missouri, May 6-8, 2007, vol. 103, American Wood Protection Association, Birmingham, Ala, 2007, pp. 62–70, c2007.

[168] M. Broda, Natural compounds for wood protection against fungi-A review, Molecules 25 (15) (2020) 3538.

[169] S. Tripathi, K. Rawat, S. Dhyani, H. Pant, Potential of Lantana camara Linn. weed against wood destroying fungi, Indian For. 135 (3) (2009) 403.

[170] M. Masoumian, M. Zandi, Antimicrobial activity of some medicinal plant extracts against multidrug resistant bacteria, Zahedan J. Res. Med. Sci. 19 (11) (2017), e10080.

[171] A.A. Shad, S. Ahmad, R. Ullah, N.M. AbdEl-Salam, H. Fouad, N.U. Rehman, H. Hussain, W. Saeed, Phytochemical and biological activities of four wild medicinal plants, Sci. World J. 2014 (2014) 857363.

[172] W. Qi, J. Jellison, Characterization of a transplasma membrane redox system of the brown rot fungus Gloeophyllum trabeum, Int. Biodeterior. Biodegrad. 53 (1) (2004) 37–42.

[173] A.A. Al-Huqail, S.I. Behiry, M.Z.M. Salem, H.M. Ali, M.H. Siddiqui, A.Z.M. Salem, Antifungal, antibacterial, and antioxidant activities of *Acacia saligna* (labill.) H. L. Wendl. Flower extract: HPLC analysis of phenolic and flavonoid compounds, Molecules 24 (4) (2019) 700.

[174] M.M. Mansour, A. Abdel-Megeed, R.A. Nasser, M.Z.M. Salem, Comparative evaluation of some woody tree methanolic extracts and Paraloid B-72 against phytopathogenic mold fungi *Alternaria tenuissima* and *Fusarium culmorum*, BioResources 10 (2) (2015) 2570–2584.

[175] M.M.A. Mansour, M.Z.M. Salem, Evaluation of wood treated with some natural extracts and Paraloid B-72 against the fungus *Trichoderma harzianum*: wood elemental composition, in-vitro and application evidence, Int. Biodeterior. Biodegrad. 100 (2015) 62–69.

[176] K. Anand, R.M. Gengan, A. Phulukdaree, A. Chuturgoon, Agroforestry waste *Moringa oleifera* petals mediated green synthesis of gold nanoparticles and their anti-cancer and catalytic activity, J. Ind. Eng. Chem. 21 (2015) 1105–1111.

[177] M.M.S. Abbassy, M.Z.M. Salem, N.M. Rashad, S.M. Afify, A.Z.M. Salem, Nutritive and biocidal properties of agroforestry trees of *Moringa oleifera* Lam., *Cassia fistula* L., and *Ceratonia siliqua* L. as non-conventional edible vegetable oils, Agrofor. Syst. 94 (4) (2020) 1567–1579.

[178] L. Azeez, A.L. Adejumo, O.M. Simiat, A. Lateef, Influence of calcium nanoparticles (CaNPs) on nutritional qualities, radical scavenging attributes of *Moringa oleifera* and risk assessments on human health, J. Food Meas. Char. 14 (4) (2020) 2185–2195.

[179] B. Ajitha, Y. Ashok Kumar Reddy, S. Shameer, K.M. Rajesh, Y. Suneetha, P. Sreedhara Reddy, *Lantana camara* leaf extract mediated silver nanoparticles: antibacterial, green catalyst, J. Photochem. Photobiol. B Biol. 149 (2015) 84–92.

[180] O.A. Adeleye, A.O. Badru, O.E. Oyinloye, A.B. Fagbohun, L.G. Bakre, O. A. Bamiro, C.O. Babalola, A. Lateef, Green synthesized silver nanoparticles for cream formulation: its anti-inflammatory and healing activities, IOP Conf. Ser. Mater. Sci. Eng. 805 (2020), 012016.

[181] I.C. Oladipo, A. Lateef, M.A. Azeez, T.B. Asafa, T.A. Yekeen, S.B. Ogunsona, H. M. Irshad, S.H. Abbas, Characterization and biomedical application of phytosynthesized gold nanoparticles from *Datura stramonium* seed extract, IOP Conf. Ser. Mater. Sci. Eng. 805 (2020), 012021.

[182] I.C. Oladipo, A. Lateef, M.A. Azeez, T.B. Asafa, T.A. Yekeen, S.B. Ogunsona, H. M. Irshad, S.H. Abbas, Antidiabetic properties of phytosynthesized gold nanoparticles (AuNPs) from *Datura stramonium* seed, IOP Conf. Ser. Mater. Sci. Eng. 805 (2020), 012035.

[183] A.D. Aina, O. Owolo, M. Adeoye-Isijola, O.D. Olukanni, A. Lateef, T. Egbe, F. O. Aina, T.B. Asafa, S.H. Abbas, Ecofriendly production of silver nanoparticles from the seeds of *Carica papaya* and its larvicidal and antibacterial efficacy against some selected bacterial pathogens, IOP Conf. Ser. Mater. Sci. Eng. 805 (2020), 012038.

[184] A. Lateef, S.M. Oladejo, P.O. Akinola, D.A. Aina, L.S. Beukes, B.I. Folarin, E. B. Gueguim-Kana, Facile synthesis of silver nanoparticles using leaf extract of Hyptis suaveolens (L.) Poit for environmental and biomedical applications, IOP Conf. Ser. Mater. Sci. Eng. 805 (2020), 012042.

[185] P.O. Akinola, A. Lateef, T.B. Asafa, L.S. Beukes, A.S. Hakeem, H.M. Irshad, Multifunctional titanium dioxide nanoparticles biofabricated via phytosynthetic route using extracts of *Cola nitida*: antimicrobial, dye degradation, antioxidant and anticoagulant activities, Heliyon 6 (8) (2020), e04610.

[186] A. Lateef, M.A. Azeez, T.B. Asafa, T.A. Yekeen, A. Akinboro, I.C. Oladipo, F. E. Ajetomobi, E.B. Gueguim-Kana, L.S. Beukes, *Cola nitida*-mediated biogenic synthesis of silver nanoparticles using seed and seed shell extracts and evaluation of antibacterial activities, BioNanoScience 5 (4) (2015) 196–205.

[187] A. Lateef, M.A. Azeez, T.B. Asafa, T.A. Yekeen, A. Akinboro, I.C. Oladipo, L. Azeez, S.E. Ajibade, S.A. Ojo, E.B. Gueguim-Kana, L.S. Beukes, Biogenic synthesis of silver nanoparticles using a pod extract of *Cola nitida*: antibacterial and antioxidant activities and application as a paint additive, J. Taibah Univ. Sci. 10 (4) (2016) 551–562.

[188] L. Azeez, A. Lateef, S.A. Adebisi, Silver nanoparticles (AgNPs) biosynthesized using pod extract of Cola nitida enhances antioxidant activity and phytochemical composition of *Amaranthus caudatus* Linn, Appl. Nanosci. 7 (1) (2017) 59–66.

[189] A. Lateef, S.A. Ojo, B.I. Folarin, E.B. Gueguim-Kana, L.S. Beukes, Kolanut (*Cola nitida*) mediated synthesis of silver–gold alloy nanoparticles: antifungal, catalytic, larvicidal and thrombolytic applications, J. Cluster Sci. 27 (5) (2016) 1561–1577.

[190] M.A. Azeez, A. Lateef, T.B. Asafa, T.A. Yekeen, A. Akinboro, I.C. Oladipo, E. B. Gueguim-Kana, L.S. Beukes, Biomedical applications of cocoa bean extract-mediated silver nanoparticles as antimicrobial, larvicidal and anticoagulant agents, J. Cluster Sci. 28 (1) (2017) 149–164.

[191] A. Lateef, M.A. Akande, M.A. Azeez, S.A. Ojo, B.I. Folarin, E.B. Gueguim-Kana, L. S. Beukes, Phytosynthesis of silver nanoparticles (AgNPs) using miracle fruit plant (*Synsepalum dulcificum*) for antimicrobial, catalytic, anticoagulant, and thrombolytic applications, Nanotechnol. Rev. 5 (6) (2016) 507–520.

[192] S. Yallappa, J. Manjanna, S.K. Peethambar, A.N. Rajeshwara, N.D. Satyanarayan, Green synthesis of silver nanoparticles using *Acacia farnesiana* (sweet Acacia) seed extract under microwave irradiation and their biological assessment, J. Cluster Sci. 24 (4) (2013) 1081–1092.

[193] U.B. Jagtap, V.A. Bapat, Green synthesis of silver nanoparticles using Artocarpus heterophyllus Lam. seed extract and its antibacterial activity, Ind. Crop. Prod. 46 (2013) 132–137.

[194] S. Shobana, S. Veena, S. Sameer, K. Swarnalakshmi, L. Vishal, Green synthesis of silver nanoparticles using artocarpus hirsutus seed extract and its antibacterial activity, Curr. Pharmaceut. Biotechnol. 21 (10) (2020) 980–989.

[195] K.S.B. Naidu, N. Murugan, J.K. Adam, Sershen. Biogenic synthesis of silver nanoparticles from Avicennia marina seed extract and its antibacterial potential, BioNanoScience 9 (2) (2019) 266–273.

[196] S. Ahmed, Saifullah, M. Ahmad, B.L. Swami, S. Ikram, Green synthesis of silver nanoparticles using Azadirachta indica aqueous leaf extract, J. Radiat. Res. Appl. Sci. 9 (1) (2016) 1–7.

[197] M. Behravan, A. Hossein Panahi, A. Naghizadeh, M. Ziaee, R. Mahdavi, A. Mirzapour, Facile green synthesis of silver nanoparticles using Berberis vulgaris leaf and root aqueous extract and its antibacterial activity, Int. J. Biol. Macromol. 124 (2019) 148–154.

[198] S. Yudha S, D. Notriawan, E. Angasa, T. Eka Suharto, J. Hendri, Y. Nishina, Green synthesis of silver nanoparticles using aqueous rinds extract of *Brucea javanica* (L.) Merr at ambient temperature, Mater. Lett. 97 (2013) 181–183.

[199] D. Suresh, P.C. Nethravathi, Udayabhanu, H. Rajanaika, H. Nagabhushana, S. C. Sharma, Green synthesis of multifunctional zinc oxide (ZnO) nanoparticles using Cassia fistula plant extract and their photodegradative, antioxidant and antibacterial activities, Mater. Sci. Semicond. Process. 31 (2015) 446–454.

[200] V. Ganesh Kumar, S. Dinesh Gokavarapu, A. Rajeswari, T. Stalin Dhas, V. Karthick, Z. Kapadia, T. Shrestha, I.A. Barathy, A. Roy, S. Sinha, Facile green synthesis of gold nanoparticles using leaf extract of antidiabetic potent *Cassia auriculata*, Colloids Surf. B Biointerfaces 87 (1) (2011) 159–163.

[201] K. Jeeva, M. Thiyagarajan, V. Elangovan, N. Geetha, P. Venkatachalam, *Caesalpinia coriaria* leaf extracts mediated biosynthesis of metallic silver nanoparticles and their antibacterial activity against clinically isolated pathogens, Ind. Crop. Prod. 52 (2014) 714–720.

[202] P. Moteriya, S. Chanda, Green synthesis of silver nanoparticles from Caesalpinia pulcherrima leaf extract and evaluation of their antimicrobial, cytotoxic and genotoxic potential (3-in-1 system), J. Inorg. Organomet. Polym. Mater. 30 (10) (2020) 3920–3932.

[203] P. Kumar, P. Singh, K. Kumari, S. Mozumdar, R. Chandra, A green approach for the synthesis of gold nanotriangles using aqueous leaf extract of *Callistemon viminalis*, Mater. Lett. 65 (4) (2011) 595–597.

[204] Akrema Rahisuddin, Extracellular synthesis of silver dimer nanoparticles using *Callistemon viminalis* (bottlebrush) extract and evaluation of their antibacterial activity, Spectrosc. Lett. 49 (4) (2016) 268–275.

[205] B.T. Sone, E. Manikandan, A. Gurib-Fakim, M. Maaza, Sm2O3 nanoparticles green synthesis via *Callistemon viminalis*' extract, J. Alloys Compd. 650 (2015) 357–362.

[206] B.T. Sone, E. Manikandan, A. Gurib-Fakim, M. Maaza, Single-phase α-Cr2O3 nanoparticles' green synthesis using *Callistemon viminalis*' red flower extract, Green Chem. Lett. Rev. 9 (2) (2016) 85–90.

[207] A.M. Awwad, N.M. Salem, A.O. Abdeen, Green synthesis of silver nanoparticles using carob leaf extract and its antibacterial activity, Int. J. Integrated Care 4 (1) (2013) 29.

[208] Q. Sun, X. Cai, J. Li, M. Zheng, Z. Chen, C.-P. Yu, Green synthesis of silver nanoparticles using tea leaf extract and evaluation of their stability and antibacterial activity, Colloid. Surface. Physicochem. Eng. Aspect. 444 (2014) 226–231.

[209] S.M. Roopan, Rohit, G. Madhumitha, A.A. Rahuman, C. Kamaraj, A. Bharathi, T. V. Surendra, Low-cost and eco-friendly phyto-synthesis of silver nanoparticles using *Cocos nucifera* coir extract and its larvicidal activity, Ind. Crop. Prod. 43 (2013) 631–635.

[210] M. Govarthanan, Y.-S. Seo, K.-J. Lee, I.-B. Jung, H.-J. Ju, J.S. Kim, M. Cho, S. Kamala-Kannan, B.-T. Oh, Low-cost and eco-friendly synthesis of silver nanoparticles using coconut (*Cocos nucifera*) oil cake extract and its antibacterial activity, Artif. Cells Nanomedi. Biotechnol. 44 (8) (2016) 1878–1882.

[211] Y.-y. Mo, Y.-k. Tang, S.-y. Wang, J.-m. Lin, H.-b. Zhang, D.-y. Luo, Green synthesis of silver nanoparticles using eucalyptus leaf extract, Mater. Lett. 144 (2015) 165–167.

[212] M. Balamurugan, S. Saravanan, Green synthesis of silver nanoparticles by using *Eucalyptus globulus* leaf extract, J. Inst. Eng.: Series A 98 (4) (2017) 461–467.

[213] T. Wang, X. Jin, Z. Chen, M. Megharaj, R. Naidu, Green synthesis of Fe nanoparticles using eucalyptus leaf extracts for treatment of eutrophic wastewater, Sci. Total Environ. 466–467 (2014) 210–213.

[214] G.M. Sulaiman, W.H. Mohammed, T.R. Marzoog, A.A.A. Al-Amiery, A.A. H. Kadhum, A.B. Mohamad, Green synthesis, antimicrobial and cytotoxic effects of silver nanoparticles using Eucalyptus chapmaniana leaves extract, Asian Pac. J. Trop. Biomed. 3 (1) (2013) 58–63.

[215] R. Bhuvaneswari, R.J. Xavier, M. Arumugam, Facile synthesis of multifunctional silver nanoparticles using mangrove plant *Excoecaria agallocha* L. for its antibacterial, antioxidant and cytotoxic effects, J. Parasit. Dis. 41 (1) (2017) 180–187.

[216] A. Saxena, R.M. Tripathi, F. Zafar, P. Singh, Green synthesis of silver nanoparticles using aqueous solution of Ficus benghalensis leaf extract and characterization of their antibacterial activity, Mater. Lett. 67 (1) (2012) 91–94.

[217] M. Parveen, F. Ahmad, A.M. Malla, S. Azaz, Microwave-assisted green synthesis of silver nanoparticles from Fraxinus excelsior leaf extract and its antioxidant assay, Appl. Nanosci. 6 (2) (2016) 267–276.

[218] H. Bar, D.K. Bhui, G.P. Sahoo, P. Sarkar, S. Pyne, A. Misra, Green synthesis of silver nanoparticles using seed extract of *Jatropha curcas*, Colloid. Surface. Physicochem. Eng. Aspect. 348 (1) (2009) 212–216.

[219] H. Bar, D.K. Bhui, G.P. Sahoo, P. Sarkar, S.P. De, A. Misra, Green synthesis of silver nanoparticles using latex of *Jatropha curcas*, Colloid. Surface. Physicochem. Eng. Aspect. 339 (1) (2009) 134–139.

[220] S. Nayak, S.P. Sajankila, C.V. Rao, A.R. Hegde, S. Mutalik, Biogenic synthesis of silver nanoparticles using *Jatropha curcas* seed cake extract and characterization: evaluation of its antibacterial activity, Energy Sources, Part A Recovery, Util. Environ. Eff. (2019) 1–9.

[221] H.M.M. Ibrahim, Green synthesis and characterization of silver nanoparticles using banana peel extract and their antimicrobial activity against representative microorganisms, J. Radiat. Res. Appl. Sci. 8 (3) (2015) 265–275.

[222] P. Jamdagni, P. Khatri, J.S. Rana, Green synthesis of zinc oxide nanoparticles using flower extract of Nyctanthes arbor-tristis and their antifungal activity, J. King Saud Univ. Sci. 30 (2) (2018) 168–175.

[223] M.M.H. Khalil, E.H. Ismail, K.Z. El-Baghdady, D. Mohamed, Green synthesis of silver nanoparticles using olive leaf extract and its antibacterial activity, Arab. J. Chem. 7 (6) (2014) 1131–1139.

[224] B. Sadeghi, Green synthesis of silver nanoparticles using seed aqueous extract of *Olea europaea*, Int. J. Nano Dimens. (IJND) 5 (Issue 6) (2014) 575–581.

[225] E.A. Adebayo, J.B. Ibikunle, A.M. Oke, A. Lateef, M.A. Azeez, A.O. Oluwatoyin, A. V. AyanfeOluwa, O.T. Blessing, O.O. Comfort, O.O. Adekunle, Antimicrobial and antioxidant activity of silver, gold and silver-gold alloy nanoparticles phytosynthesized using extract of *Opuntia ficus-indica*, Rev. Adv. Mater. Sci. 58 (1) (2019) 313–326.

[226] C. Sundaravadivelan, M. Nalini, Biolarvicidal effect of phyto-synthesized silver nanoparticles using *Pedilanthus tithymaloides* (L.) Poit stem extract against the dengue vector *Aedes aegypti* L.(Diptera; Culicidae), Asian Pac. J. Trop. Biomed 17 (2012) 1–8.

[227] M.A. Ansari, M.A. Alzohairy, One-Pot facile green synthesis of silver nanoparticles using seed extract of *Phoenix dactylifera* and their bactericidal potential against MRSA, Evid. Based Complement Alternat. Med. 2018 (2018), 1860280, https://doi.org/10.1155/2018/1860280, 9 pages.

[228] B. Sadeghi, A. Rostami, S.S. Momeni, Facile green synthesis of silver nanoparticles using seed aqueous extract of *Pistacia atlantica* and its antibacterial activity, Spectrochim. Acta Mol. Biomol. Spectrosc. 134 (2015) 326–332.

[229] R. Gannimani, A. Perumal, S. Krishna, M. Sershen, A. Mishra, P. Govender, Synthesis and antibacterial activity of silver and gold nanoparticles produced using aqueous seed extract of *Protorhus longifolia* as a reducing agent, Digest J. Nanomater. Biostruct. 9 (2014) 1669–1679.

[230] R. Kumar, G. Ghoshal, A. Jain, M. Goyal, Rapid green synthesis of silver nanoparticles (AgNPs) using (*Prunus persica*) plants extract: exploring its antimicrobial and catalytic activities, J. Nanomed. Nanotechnol. 8 (4) (2017) 1–8.

[231] P. Sathiya, D. Geetha, P. Ramesh, Green synthesis of silver nanoparticles using *Psidium guajava* leaf extract and their characterization, Indian Streams Res. J. 4 (8) (2014) 1–10.

[232] A. Saravanakumar, M.M. Peng, M. Ganesh, J. Jayaprakash, M. Mohankumar, H. T. Jang, Low-cost and eco-friendly green synthesis of silver nanoparticles using *Prunus japonica* (Rosaceae) leaf extract and their antibacterial, antioxidant properties, Artif. Cells Nanomedi. Biotechnol. 45 (6) (2017) 1165–1171.

[233] G. Yaku, V. Venkateswerlu, T. Rao, Green synthesis of silver nanoparticles by sonicated method using *Pulicha indeca* stem extract: characterization and study of antibacterial activity, anticancer activity and cell viability test, Orient. J. Chem. 35 (2019) 1767–1773.

[234] K. Gopinath, S. Gowri, A. Arumugam, Phytosynthesis of silver nanoparticles using *Pterocarpus santalinus* leaf extract and their antibacterial properties, J. Nanostruct. Chem. 3 (1) (2013) 68.

[235] A. Rautela, J. Rani, M. Debnath, Green synthesis of silver nanoparticles from *Tectona grandis* seeds extract: characterization and mechanism of antimicrobial action on different microorganisms, J. Anal. Sci. Technol. 10 (1) (2019) 5.

[236] S. Ahmed, S. Ikram, Silver nanoparticles: one pot green synthesis using *Terminalia arjuna* extract for biological application, J. Nanomed. Nanotechnol. 6 (4) (2015) 309.

[237] A. Lateef, M.A. Azeez, T.B. Asafa, T.A. Yekeen, A. Akinboro, I.C. Oladipo, L. Azeez, S.A. Ojo, E.B. Gueguim-Kana, L.S. Beukes, Cocoa pod husk extract-mediated biosynthesis of silver nanoparticles: its antimicrobial, antioxidant and larvicidal activities, J. Nanostruct. Chem. 6 (2) (2016) 159–169.

[238] N. Salhi, A. Bouyahya, O. El-Goumari, M. El Jemly, I. Bourais, A. Zellou, Y. Cherrah, M.E.A. Faouzi, Investigation of in vitro and in vivo antioxidant and antidiabetic activities of *Pinus halepensis* extracts, J. Herbmed. Pharmacol. 10 (1) (2021) 123–131.

[239] M.P. Kähkönen, A.I. Hopia, H.J. Vuorela, J.-P. Rauha, K. Pihlaja, T.S. Kujala, M. Heinonen, Antioxidant activity of plant extracts containing phenolic compounds, J. Agric. Food Chem. 47 (10) (1999) 3954–3962.

[240] Ý. Gülçin, R. Elias, A. Gepdiremen, L. Boyer, E. Köksal, A comparative study on the antioxidant activity of fringe tree (*Chionanthus virginicus* L.) extracts, Afr. J. Biotechnol. 6 (4) (2007) 410–418.

[241] H. Miraliakbari, F. Shahidi, Antioxidant activity of minor components of tree nut oils, Food Chem. 111 (2) (2008) 421–427.

[242] P. Sithisarn, R. Supabphol, W. Gritsanapan, Antioxidant activity of Siamese neem tree (VP1209), J. Ethnopharmacol. 99 (1) (2005) 109–112.

[243] S.M. Willför, M.O. Ahotupa, J.E. Hemming, M.H.T. Reunanen, P.C. Eklund, R. E. Sjöholm, C.S.E. Eckerman, S.P. Pohjamo, B.R. Holmbom, Antioxidant activity of Knotwood extractives and phenolic compounds of selected tree species, J. Agric. Food Chem. 51 (26) (2003) 7600–7606.

[244] B. Sultana, F. Anwar, R. Przybylski, Antioxidant activity of phenolic components present in barks of *Azadirachta indica, Terminalia arjuna, Acacia nilotica*, and *Eugenia jambolana* Lam. trees, Food Chem. 104 (3) (2007) 1106–1114.

[245] M.B. Sadiq, W. Hanpithakpong, J. Tarning, A.K. Anal, Screening of phytochemicals and in vitro evaluation of antibacterial and antioxidant activities

of leaves, pods and bark extracts of *Acacia nilotica* (L.) Del, Ind. Crop. Prod. 77 (2015) 873–882.

[246] G. Vázquez, E. Fontenla, J. Santos, M.S. Freire, J. González-Álvarez, G. Antorrena, Antioxidant activity and phenolic content of chestnut (*Castanea sativa*) shell and eucalyptus (*Eucalyptus globulus*) bark extracts, Ind. Crop. Prod. 28 (3) (2008) 279–285.

[247] S.A.O. Santos, J.J. Villaverde, C.S.R. Freire, M.R.M. Domingues, C.P. Neto, A.J. D. Silvestre, Phenolic composition and antioxidant activity of *Eucalyptus grandis, E. urograndis* (*E. grandis*×*E. urophylla*) and E. maidenii bark extracts, Ind. Crop. Prod. 39 (2012) 120–127.

[248] A.H. El-Ghorab, H.M. Fadel, K.F. El-Massry, The Egyptian *Eucalyptus camaldulensis var. brevirostris*: chemical compositions of the fruit volatile oil and antioxidant activity, Flavour Fragrance J. 17 (4) (2002) 306–312.

[249] R. Manian, N. Anusuya, P. Siddhuraju, S. Manian, The antioxidant activity and free radical scavenging potential of two different solvent extracts of *Camellia sinensis* (L.) O. Kuntz, *Ficus bengalensis* L. and *Ficus racemosa* L, Food Chem. 107 (3) (2008) 1000–1007.

[250] L. Tzekiat, L.K. Chiang, Total phenolics, total tannins and antioxidant activity of *Cassia fistula* L. extracts of bark, stem, leaf and root under different age classes, Asian J. Pharmaceut. Res. Health Care 5 (2) (2013) 52–57.

[251] M.M. Mackeen, A.M. Ali, N.H. Lajis, K. Kawazu, Z. Hassan, M. Amran, M. Habsah, L.Y. Mooi, S.M. Mohamed, Antimicrobial, antioxidant, antitumour-promoting and cytotoxic activities of different plant part extracts of *Garcinia atroviridis* Griff. ex T. Anders, J. Ethnopharmacol. 72 (3) (2000) 395–402.

[252] K.C. Lamounier, L.C.S. Cunha, S.A.L. de Morais, F.J.T. de Aquino, R. Chang, E. A. do Nascimento, M.G.M. de Souza, C.H.G. Martins, W.R. Cunha, Chemical analysis and study of phenolics, antioxidant activity, and antibacterial effect of the wood and bark of *Maclura tinctoria* (L.) D. Don ex Steud, Evid. Based Complement. Alternat. Medicine 2012 (2012) 451039.

[253] Z.M. Zin, A. Abdul-Hamid, A. Osman, Antioxidative activity of extracts from Mengkudu (*Morinda citrifolia* L.) root, fruit and leaf, Food Chem. 78 (2) (2002) 227–231.

[254] P. Siddhuraju, K. Becker, Antioxidant properties of various solvent extracts of total phenolic constituents from three different agroclimatic origins of drumstick tree (*Moringa oleifera* lam.) leaves, J. Agric. Food Chem. 51 (8) (2003) 2144–2155.

[255] M. Jerez, A. Selga, J. Sineiro, J.L. Torres, M.J. Núñez, A comparison between bark extracts from *Pinus pinaster* and *Pinus radiata*: antioxidant activity and procyanidin composition, Food Chem. 100 (2) (2007) 439–444.

[256] C. Vieito, É. Fernandes, M.V. Velho, P. Pires, The effect of different solvents on extraction yield, total phenolic content and antioxidant activity of extracts from pine bark (*Pinus pinaster subsp. atlantica*), Chem. Eng. Trans. 64 (2018) 127–132.

[257] H.O. Elansary, A. Szopa, P. Kubica, H. Ekiert, M.A. Mattar, M.A. Al-Yafrasi, D. O. El-Ansary, T.K. Zin El-Abedin, K. Yessoufou, Polyphenol profile and pharmaceutical potential of *Quercus* spp. Bark Extracts, Plants 8 (11) (2019) 486.