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Review Article

Medicinal plants with antimicrobial activities (part 2): Plant based review

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Abstract: In our previous review we mentioned that many plants possessed antimicrobial activities including *Achillea santolina, Adiantum capillus-veneris, Agrimonia eupatoria, Agropyron repens, Ailanthus altissima, Alhagi maurorum, Allium cepa, Allium porrum, Allium sativum, Allium schoenoprasum, Alpinia galangal, Althaea officinalis, Althaea rosea, Ammannia baccifera, Ammi visnaga, Anagyris foetida, Anchusa strigosa, Anethum graveolens, Anthemis nobelis, Antirrhinum majus, Apium graveolens, Arachis hypogaea, Arctium lappa, Artemisia campestris, Arundo donax, Asclepias curassavica, Asparagus officinalis, Avena sativa, Bacopa monniera, Ballota nigra, Bauhinia variegata, Bellis perenni, Benincasa hispida, Betula alba, Bidens tripartite, Brassica rapa, Bryophyllum calycinum, Caesalpinia crista, Calamintha graveolens, Calendula officinalis, Calotropis procera, Canna indica, Capparis spinosa, Capsella bursa-pastoris, Capsicum annuum, Capsicum frutescens, Carthamus tinctorius, Carum carvi, Cassia occidentalis, Casuarina equisetifolia, Celosia cristata, Centaurea cyanus, Chenopodium album* and *Chrozophora tinctoria* . This review was designed as a second part of the medicinal plants with antimicrobial activities.
Keywords: medicinal plants, herbs, antibacterial, antimicrobial.

Introduction:

The excessive use of antibiotics has contributed to the emergence and spread of antibiotic- resistant bacteria in communities [1-22]. Medicinal plants were used as an antimicrobial agents to avoid the development of multi-drug resistant bacteria, they were acting by different mechanisms. Our previous reviews showed that medicinal plants exerted a wide range of antimicrobial activity [23-24]. These plants included: *Achillea santolina*[25], *Adiantum capillus-veneris* [26], *Agrimonia eupatoria* [27], *Agropyron repens* [28], *Ailanthus altissima* [29], *Alhagi maurorum* [30], *Allium species* [31], *Alpinia galangal* [32], *Althaea officinalis* and *Althaea rosea* [33], *Ammannia baccifera* [34], *Ammi visnaga* [35], *Anagyris foetida* [23], *Anchusa strigosa* [36], *Anethum graveolens* [37] , *Anthemis nobelis* [38], *Antirrhinum majus* [39], *Apium graveolens* [40], *Arachis hypogaea* [41], *Arctium lappa* [42], *Artemisia campestris* [43], *Arundo donax* [44], *Asclepias curassavica* [45], *Asparagus officinalis* [46], *Avena sativa* [47], *Bacopa monniera* [48], *Ballota nigra* [49], *Bauhinia variegate* [50], *Bellis perenni* [51], *Benincasa hispida* [52], *Betula alba* [53], *Bidens tripartite* [54], *Brassica rapa* [55], *Bryophyllum calycinum* [56], *Caesalpinia crista* [57], *Calamintha graveolens* [23], *Calendula officinalis* [58], *Calotropis procera* [59], *Canna indica* [60], *Capparis spinosa* [61], *Capsella bursa-pastoris* [62], *Capsicum species* [63], *Carthamus tinctorius* [64], *Carum carvi* [65], *Cassia occidentalis* [66], *Casuarina equisetifolia* [67], *Celosia cristata* [68], *Centaurea cyanus* [69], *Chenopodium album* [70] and *Chrozophora tinctoria* [71]. This review was designed as a second part of the medicinal plants possessed antimicrobial activities.

Plants with antimicrobial activities:

Chrysanthemum cinerariaefolium

Chrysanthemum cinerariaefolium extracts showed antibacterial activity against *Staphylococcus aureus*. Growth inhibition diameter of the ethanolic extract against *Staphylococcus aureus* SPMIC-29, *Staphylococcus aureus* SPMIC-130 and *Staphylococcus aureus* SPMIC-132 strains were 9 ±1.54, 11 ±2.94 and 6 ±0.84, and that of methanolic extract were 10 ±0.45, 9 ±1.95 and 11 ±1.76 mm respectively. The diameter of the growth inhibition of *Chrysanthemum cinerariaefolium* leaf extract against three different strains of *Pseudomonas aeruginosa* (*Pseudomonas aeruginosa* PA-37, *Pseudomonas aeruginosa* PA-38 and *Pseudomonas aeruginosa* PA-39) were 4-8 mm for methanolic extract and 9-11mm for ethanolic extract. The diameter of the growth inhibition of *Chrysanthemum cinerariaefolium* leaf extract against five various strains of the Candida species [*Candida tropicalis* (B- 1389/09), *Candida albicans* (CAGMC6), *Candida albicans* (B- 1622/09), *Candida parapsilosis* (B1597/09) and *Candida cruzei* (ATCC- 6258)] were 4-

7mm for methanolic extract (10µl) and 4-15mm for ethanolic extract (10µl) [72].
Pyrethrins, complex esters extracted from *Chrysanthemum cinerariaefolium*, exhibited only minimal *in vitro* activity against herpes simplex virus (HSV). However, in employing a guinea pig model of HSV genital infection, no *in vivo* activity was recorded [73].

Cicer arietinum

The antibacterial activities of the extracts obtained from *Cicer arietinum* L. varieties (seed extract, fruit skin extract and aerial part extract) were studied *in vitro*. Chickpea seed extracts (Cse) showed varying antibacterial activity against Gram negative strains (*E. coli*, *P. aeruginosa*, *K. pneumoniae*) in MIC range 16–64 µg/ ml, but were less active against gram-positive (*S. aureus*, *B. subtilis*, *E. faecalis*) strains with MIC of 64 µg/ ml. Statistically different MICs were observed between the extracts of the fruit skin (Cfs) and the aerial part (Cap) ($p<0.05$). The antibacterial activity of Chickpea fruit skin (Cfs) and Chickpea aerial parts (Cap) extracts were not statistically different ($p>0.05$) as they showed the same degree of inhibition against Gram-negative (*E. coli* and *K. pneumoniae*) bacteria and gram positive bacterium, (*E. faecalis* at the concentration of 32 µg/ml). Additionally, they were both less effective against *P. aeruginosa*, *S. aureus*, and *B. subtilis* at a concentration of 64 µg/ml. Of all the Chickpea extracts, Chickpea seed extract (Cse; $p < 0.05$). exhibited the strongest antifungal activity against *C. albicans* at a concentration of 8 µg/ml. Even at a concentration of 16 µg/ml, fruit skin (Cfs) and aerial part (Cap) extracts showed lower antifungal activity than the seed extract [74-75].

The hydroalcoholic extract and its acetone and methanol fractions of the root of *C. arietinum* were studied for their antibacterial activity by disc diffusion method against different gram positive (*Staphylococcus aureus* and *Bacillus subtilis*) and gram negative (*Escherchia coli*) bacteria. It was observed that the hydroalcoholic extract and its acetone and methanol fraction showed significant activity against all the tested microorganisms [*E. coli* (NCIM - 2831), *S. aureus*, (NCIM - 2079) *B. subtilis* (NCIM - 2439)] and the hydroalcoholic extract showed the highest activity (13 mm) against *S. aureus* [76].

Cicer arietinum L ferritin was successfully isolated with two subunits with molecular weights of 20.1- kDa and 29- kDa respectively. The antibacterial effect of ferritin extracted from Chick pea (*Cicer arietinum* L.*)* was evaluated against Gram negative microorganisms (*Escherichia coli*, *Pseudomonas aeruginosa*, *Kliebsiella pneumonia*, *Proteus vulgaris*), as well as Gram-positive microorganism (*Staphylococcus aureus*, *Staphylococcus epidermis*). Among all the test pathogens *E. coli* was found susceptible (with zone of inhibition 8 mm) to the purified ferritin extract [77].

Several proteins, including a glucanase, a chitinase, an antifungal cyclophyllin-like protein, and three antifungal peptides designated cicerin, arietin, and cicearin were isolated from the chickpea (*Cicer arietinum* L) [78].

Two antifungal peptides with novel N-terminal sequences were isolated from chickpea. Although the two chickpea peptides, cicerin and arietin, were similar in molecular weight (5-8 kDa), they differed somewhat in antifungal activity. Arietin was more potent against *M. arachidicola*, *B. cinerea*, and *F. oxysporum* while cicerin exhibited a higher cell-free translation-inhibiting activity than arietin [79].

An antifungal protein, was isolated from Cicer *arietinum* and purified by gel filtration and tesred using agar diffusion method against human pathogenic fungi of ATCC strains and against clinical isolates of *Candida krusei*, *Candida tropicalis* and *Candida parapsilosis*. MIC values were varied from 1.56 to 12.5 µg/ml. Protein isolated from Cicer *arietinum* also inhibited the growth of fungal strains which are resistant to fluconazole [80].

The crude water extract of *Cicer arietinum* showed most significant antifungal activity against *Drechslera tetramera* even at lower concentration of 5%. In dichloromethane fraction, the inhibitory effect was found to be proportional with the applied concentration [81].

The antiviral activities of the extracts from the seed, fruit skin and aerial parts of ten varieties of *Cicer arietinum* (Chickpea) were evaluated against Herpes *simplex* type 1 *(HSV*-1*)* and *Parainfluenza-3 (PI*-3*)* viruses. Madin-Darby Bovine Kidney and Vero cell lines were employed for antiviral assessment of the *Citer arientinum L.* extracts, in which acyclovir for *HSV*-1 and oseltamivir for *PI*-3 were tested as reference drugs. *Cicer arietinum* seed extracts (Aydin 92 variety) possesses significant antiviral activity against both DNA (max to min CPE inhibitory conc: 32-4 µg/ ml) and RNA (max to min CPE inhibitory conc: 32-16 µg/ ml) viruses compared to the fruit skin and aerial part extracts as well as the controls. Besides, the extracts of fruit skin (Menemen 92 variety) and aerial parts (Aydin 92 variety) showed remarkable activity against DNA viruses at 32 - 1 µg/ ml concentration [82].

Cichorium intybus

The antibacterial effect of *Cichorium intybus* extracts was examined against Gram Positive (*Bacillus subtilis*, *Staphylococcus aureus* and *Rhizobium leguminosarum*) and Gram negative (*Vibrio cholerae*, *Escherichia coli* and *Pseudomonas fluorescens*) bacterial species & two

fungal (*Aspergilus niger* and *Sachharomyces cerevisiae*) species. The ethyl acetate extract of chicory root showed antibacterial effects against Gram positive and Gram negative bacteria. Hexane extract of chicory on the other hand showed no such antibacterial effect [83-84].

The low molecular mass (LMM) extract of Cichorium intybus var. Silvestre (red chicory) has been shown to inhibit virulence-linked properties of oral pathogens including *Streptococcus mutans, Actinomyces naeslundii* and *Prevotella intermedia*. HPLC-DAD-ESI/MS(2) was used to investigate the compounds contained in this extract for their anti-virulence activity. The extract contained a number of components, including oxalic, succinic, shikimic and quinic acids, which interfere with the growth and virulence traits (i.e., biofilm formation, adherence to epithelial cells and hydroxyapatite) of oral pathogens involved in gingivitis and tooth decay. Succinic and quinic acid seem to be the most potent, mainly by interfering with the ability of oral pathogens to form biofilms (either through inhibition of their development or promotion of their disruption). The authors poastulated that one or more of these compounds may modulate plaque formation *in vivo*, which is a prerequisite for the development of both caries and gingivitis [85].

The antibacterial activity of the root extracts of chicory was examined against pathogenic bacteria, Gram positive (*Bacillus subtilis, Staphylococcus aureus* and *Micrococcus luteus*) and Gram negative (*Escherichia coli* and S*almonella typhi*) bacteria by *in vitro* agar well diffusion method. The hexane and ethyl acetate root extracts of chicory showed pronounced inhibition than chloroform, petroleum ether and water extracts. Root extracts showed more inhibitory action on *Bacillus subtilis, Staphylococcus aureus* and S*almonella typhi* than *Micrococcus luteus* and *Escherichia coli* [86].

The root and leaf extracts (methanol, distilled water, chloroform, petroleum ether and acetone) of *Cichorium intybus* were investigated for antibacterial activity against Gram negative pathogenic bacteria (*Escherichia coli* and *Pseudomonas aeruginosa*). The extracts showed a wide spectrum of inhibition against the test pathogens. Methanolic extract of root and leaf proved to have the strongest antibacterial activity. Antibacterial activity of the test extracts at different inhibitory concentration varied significantly at 0.05 level of significance. The maximum activity was recorded at 200mg/ml concentration, the activity decreased with the decreasing of the concentration of the extract [87].

Several extracts displayed antibacterial activities against *Escherichia coli, Staphylococcus aureus, Bacillus thuringiensis, Bacillus subtilis*, and *Salmonella typhi*, while *Penicillium* sp. and *Aspergillus* sp. resisted all the extracts [88].

Synergistic activity of Cichorium intybus extracts and commonly used antibiotics, amoxicillin and chloramphenicol, were evaluated. Interactions between plant extract and antibiotics were tested against *Staphylococcus aureus* ATCC 25923, *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853 and clinical isolates *Staphylococcus aureus, Bacillus subtilis, Enterobacter cloacae, Klebsiella pneumoniae, Escherichia coli* and *Proteus mirabilis*. The combinations of acetone and ethyl acetate extract from Cichorium intybus and antibiotics resulted in additive effects against the tested bacteria [89].

The antimicrobial effectiveness of methanolic extract and different fractions (*n*-butanol, ethyl acetate, chloroform and *n*-hexane) of Cichorium intybus seeds was studied *in vitro*. The antimicrobial activity was determined by the disc diffusion method and minimum inhibitory concentration (MIC) against four bacterial strains (*P. multocida, E. coli, B. subtilis* and *S. aureus*) and three fungal strains(*A. flavus, A. niger and R. solani*). The results indicated that seeds methanolic extract and its fractions showed moderate activity as antibacterial agent. While Antifungal activity of Cichorium intybus seeds extract/fractions was very low against A. *flavus* and *A. niger* and mild against *R. solani* [90].

The ethyl acetate extract of chicory root had antifungal effect against *Aspergillus niger* and *Sachharomyces cerevisiae* [83].

Guaianolides-rich root extracts of Cichorium intybus have shown antifungal properties against anthropophilic fungi *Trichophyton tonsurans*, *T. rubrum*, and *T. violaceum* [91].

The antiviral activity of protein extracts from transgenic plants of Cichorium intybus was investigated against vesicular stomatitis virus. It was shown that the extracts from the hairy roots of chicory possess antiviral activity [92].

Cistanche tubulosa

The extracts of the aerial parts of the plant showed mild antibacterial and antifungal effects against *Bacillus subtilis, Enterococcus faecalis, Pseudomonas aeruginosa, Salmonella entrica, subsp. entrica. S. typhi, Escherichia coli, methicillin resistant Staphylococcus aureus, Fusarium axyosporum, Aspergilus niger* and *Aspergilus* fumigates[93]. Phenylethanoid glycosides, Campneosid I and Campneosid II, isolated from *Cistanche tubulosa*, have high antibacterial and antifungal activity. Campneosid I showed significant antibacterial activity against several

pathogenic strains of *Streptococcus* and *Staphylococcus* [94].

Citrullus colocynthis

Inhibitory and bactericidal activities of crude extracts, fractions and compounds of *Citrullus colocynthis* plant aerial parts and ripe deseeded fruits were performed against the drug sensitive standard strain of *Mycobacterium tuberculosis* H37Rv (ATCC 27294), 16 drug resistant strains of *Mycobacterium tuberculosis* and two Mycobacterium other than tuberculosis (MOTT) strains, using radiometric BACTEC system. Methanolic extract of ripe deseeded fruit of *Citrullus colocynthis* has shown good activity (MIC ≤ 62.5 µg/ml), one of the bioactive fractions demonstrated the best activity (MIC 31.2 µg/ml) against *Mycobacterium tuberculosis* H37Rv. However 3 bioactive fractions also inhibited 16 clinical isolates of *Mycobacterium tuberculosis* consisting of seven non-multidrug resistants, eight multidrug resistants, one extensively drug resistant and two of Mycobacterium other than tuberculosis (MOTT) bacilli with MICs in the range of 50-125, 31.2-125 and 62.5-125 µg/ml, respectively. Ursolic acid and cucurbitacin E 2-0-β-d-glucopyranoside were identified as the main biomarkers active against Mycobacterium tuberculosis H37Rv (MICs 50 and 25 µg/ml respectively), as well as against the 18 clinical isolates [95-96].

The maximum antimicrobial activity was exhibited by acetone, ethanol, methanol and distilled water extract of the fruits against *Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhi*, *Shigella shigella* and *Candida albicans.* Whereas petroleum ether extract is less effective against test strains [97].

The ethanolic extract showed dose dependent inhibitory activity against *Staphylococcus aureus* more than water extract. 5 mg/ml fruits ethanolic extract possessed a similar inhibitory effect to novobiocin against standard *Staphylococcus aureus* strain [98].

MIC and MBC/MFC were determined for plant organs at different maturation stages. Aqueous and diluted acetone extracts (from the plant's roots, stems, leaves and three maturation stages of its fruit and seeds) were screened for activity against Gram-negative and Gram-positive bacteria (*Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Enterococcus faecalis*) and various *Candida* spp. (*Candida glabrata*, *Candida albicans*, *Candida parapsilosis* and *Candida kreusei*). All extracts showed activity against all strains. The highest MICs and MBCs/MFCs were obtained from the fruit aqueous extracts (MIC 0.10 mg/ml against *C. albicans* and *C. glabrata*, 0.20 mg/ml against *E. coli* and *P. aeruginosa*), the lowest antibacterial and anticandidal activity was recorded for the root extracts of *Citrullus colocynthis* Schrad [99].

The antimicrobial activity of alkaloid extracted from *Citrullus colocynthis* were examined against five local bacterial isolates (*Escherichia coli*, *Staphylococcus aureus*, *Streptococcus* sp., *Bacillus subtilis*, and *Klipsella* sp.) using agar disc diffusion method. The most active antimicrobial activity of extracted alkaloid were shown against *Streptococcus* Sp. Broth dilution methods were used to determine the minimum inhibitory concentration (MIC) for the extracted alkaloid. The study showed that MIC values of 600 µg/ ml, 3000 µg/ ml, were recorded against *Staph. aureus,* and *E.coli* isolates respectively [100].

The antifungal and antimycotoxigenic power of methanolic and aqueous extracts of *Citrullus colocynthis* seeds were studied *in vitro*. The antifungal and antimycotoxigenic activity of methanolic and aqueous extracts were screened against *Aspergillus ochraceus* and *Aspergillus flavus.* The results suggest that the extracts showed a very good antifungal activity against *A. ochraceus*, but not against *A. flavus.* The extracts have good antiochratoxigenic power in liquid medium [101].

Citrus species

The antibacterial potential of the leaf essential oil and petroleum ether, chloroform, ethyl acetate and methanol extracts of the leaves of *Citrus aurantifolia* were studied against human pathogenic bacteria (*Bacillus cereus, Enterobacter faecalis, Salmonella paratyphi, Staphylococcus aureus, Escherichia coli, Proteus vulgaris, Klebsiella pneumoniae, Pseudomonas aeruginosa* and *Serratia marcescens*) by agar well diffusion method. Leaf essential oil as well as ethyl acetate, chloroform and methanol extracts of *Citrus aurantifolia* leaves exhibited pronounced activity against Gram-positive and Gram-negative bacteria and their activity was quite comparable with the standard antibiotics such as tobramycin, gentamicin sulphate, ofloxacin and ciprofloxacin screened under similar conditions [102].

Studying of the antibacterial effect of varieties of citrus available in Malaysian *(Citrus aurantifolia*, *Citrus reticulata*, *Citrus microcarpa*, *Citrus limon* and *Citrus sinensis*) against *Streptococcus pyogenes, Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa* showed that the methanol extract of the five varieties of citrus exerted no inhibition at 5 and 10 mg/ml. The methanol extract of *Citrus microcarpa*, *Citrus reticulata* and *Citrus sinensis* at 20 mg/ml showed better inhibition compare to *Citrus aurantifolia* and *Citrus limon* against *Staphylococcus aureus* and *Escherichia coli* [103].

Citrus sinensis, *Citrus limon*, and *Citrus aurantifolia* fruit peel extracts were investigated against gastrointestinal pathogens. Citrus *aurantifolia and* Citrus *limon* showed high zone of inhibition against

Shigella Spp., and *E. coli* strains. Whereas Citrus *aurantifolia* was effective against *Salmonella* Spp [104].

The antimicrobial potency of *Citrus aurantifolia* was studied against many bacterial and fungal pathogenes, in the different forms [juice of the fruit, burnt rind of the fruit commonly known as (epa-ijebu) in the Yoruba dialect, and the oil obtained from steam distillation of the fruit]. Antimicrobial activity was carried out by the agar well diffusion. The clinical isolates used included Anaerobic facultative bacteria, namely: *Staphylococcus aureus* ATCC 25213, *Staphylococcus aureus, Salmonella paratyphi, Shigella flexnerii, Streptococcus faecalis, Citrobacter spp, Serratia spp, Klebsiella pneumoniae, Pseudomonas aeruginosa, Escherichia coli* ATCC 25922, and *Escherichia coli*; Fungi such as *Aspergilus niger* and *Candida albicans*; and Anaerobes which includes *Bacteroides* spp, *Porphyromonas* spp, and *Clostridium* spp. Crude extracts of all solvents used varied in zones of inhibition. The anaerobes and the Gram-positive bacteria were susceptible to all the extracts with minimum inhibitory concentration (MIC) ranging from 32mg/ml-128g/ml. The antifungal study showed that only the oil extract was potent against *A. niger*, while *Candida albicans* was susceptible to all the extracts with MIC ranging from 256mg/ml-512mg/ml. The Gram-negatives showed MIC ranging from 64mg/ml-512mg/ml. Minimum bactericidal concentration (MBC) ranged between 32mg/ml to 512mg/ml depending on isolates and extracting solvent. The oil and palm-wine extract showed greater activity than the other extracts [105].

The antimicrobial efficacy of leaf extract of Citrus aurantifolia Linn (CA) was evaluated against some microorganisms - bacteria and fungus (Staphylococcus aureus, Escherichia coli, Klebsiella pneumonia, Pseudomonas spp, Aspergillus niger, Aspergillus fumigates, Mucor Spp and Pencillium Spp). 100 µl of 10 mg CA were assessed against eight test microorganisms by agar well diffusion method. A different solvent was used to obtain CA leaf extract using maceration technique. Due to its high yield value, hydroalcoholic extract of CA was used for estimating the antimicrobial activity. The study demonstrates that the hydroalcoholic extract of CA leaf exhibit antibacterial activity on Klebsiella pneumonia, Pseudomonas sp, Staphylococcus aureus and antifungal activity among Aspergillus niger, Aspergillus fumigates and Mucor species [106].

Citric acid extracted from *Citrus aurantifolia* was tested as antimicrobial agent. The largest inhibition area of citric acid was obtained against *Escherichia coli*, 3.92 cm, and the smallest inhibition area is obtained against *Lactobacillus acidophilus*, 2.16 cm [107].

Citrus aurantifolia oils were tested against *Mycobacterium tuberculosis*. The saturated fatty acid palmitic acid exhibited higher activity against multidrug-resistant *M. tuberculosis* strains (MICs = 50 µg/ml) than the unsaturated fatty acids oleic acid and linoleic acid, which showed less activity (MICs = 100 µg/ml) [108].

The antibacterial activity of Lemon, lime and sudachi juices was studied against seven strains of *Vibrio* species. All juices were effective in inhibiting the growth of the *Vibrio* strains. Citric acid, the major organic acid in these juices, were found to be responsible for inhibiting the growth of *Vibrio parahaemolyticus*, whereas the sauce adjusted to higher pH values had no bacterial activity. Diluted sudachi juice or citric acid solution also had antibacterial activity independently. The results suggest that citrus fruit juices were effective in preventing infection with *Vibrio* species [109].

The effect of essential oils, natural and concentrated lemon juice and fresh and dehydrated lemon peel was studied against *V.* cholerae O1 biotype Eltor serotype Inaba tox+. Products were used at different dilutions, when *V.* cholerae present at concentrations of 10^2, 10^4, 10^6 and 10^8 colony forming units (CFU) /ml, and after different exposure times. Concentrated lemon juice and essential oils inhibited *V.* cholerae completely at all studied dilutions and exposure times. Fresh lemon peel and dehydrated lemon peel partially inhibited growth of *V.* cholerae. Freshly squeezed lemon juice, diluted to 10^{-2}, showed complete inhibition of *V.* cholerae at a concentration of 10^8 CFU/ ml after 5 min of exposure time; a dilution of 2 x 10^{-3} produced inhibition after 15 min and a dilution of 10^{-3} after 30 min [110].

The antibacterial activity of crude extracts (aqueous and ethanolic) of *Citrus limonum* fruits against four wound isolates *Staphylococcus* sp, *Pseudomonas* sp, *Escherichia coli* and *Klebsiella* sp. showed that they exerted antibacterial activity with diameter of inhibition zone of 20, 18, 20 and 15 mm for ethanolic extract, and 15, 20, 11, and 10 mm for aqueous extract respectively [111].

The potential inhibitory effect of *Citrus lemon* and *Citrus sinensis* on lipophilic, yeast like fungus *Malassezia furfur* which causes *Pityriasis versicolor*, chronic superficial fungal disease of the skin have been studied using two different methods (Disc diffusion and microdilution methods). In screening of lemon and orange oil by disc diffusion method, the diameters of inhibition zone were found to be 50 and 20 mm which were greater than inhibition zone of reference antibiotics, gentamycin 16.5mm and streptomycin 17 mm. Minimum inhibitory concentrations (MIC) of lemon and orange oil against *M. furfur* were found to be 0.8 and 2.2 µl/ml [112].

The antimicrobial activity of *Citrus lemon* was studied *in vitro*. The citrus peel oils show strong antimicrobial activity. The antimicrobial activity has been checked in terms of MIC by using different solvents against microorganisms like *Pseudomonas aeruginosa* NCIM 2036 for which MIC was 1:20 by methanol extract, for *Salmonella typhimurium* NCIM 5021 the observed MIC was 1:20 by acetone extract. While, for *Micrococcus aureus* NCIM 5021 the observed MIC was 1:20 by ethanol extract [113].

The antimicrobial activity of different types and parts of lemon was evaluated against different microbial isolates. The antimicrobial effects of aqueous extracts of peel and juice from fresh and dried citrus and sweet lemon were evaluated against 6 Gram-positive and 8 Gram-negative bacterial and one yeast isolates, including *Staphylococcus aureus, Staphylococcus epidermidis, Streptococcus pyogenes, Enterococcus faecalis, Streptococcus pneumoniae, Streptococcus agalactiae, Pseudomonas aeruginosa, Enterobacter aerogenes, Klebsiella pneumoniae, Escherichia coli, Salmonella typhi, Proteus spp., Moraxella catarrhalis, Acinetobacter spp. and Candida albicans.*The water extracts of all the materials showed various inhibitory effects. The juice of *Citrus limon* has antimicrobial activities more than other types of extracts. *Escherichia coli, Staphylococcus epidermidis, Streptococcus agalactiae and Candida albicans* showed the highest resistance to these extracts. Lemon species might have antimicrobial activity against different Gram-positive, Gram-negative and yeast pathogens and could be used for prevention of various diseases caused by these organisms [114].

The effects of *Citrus limonum* essential oils (EO) compared to 0.2% chlorhexidine (CHX) and 1%sodium hypochlorite (NaOCl) was studied in multispecies biofilms formed by *Candida albicans*, *Enterococcus faecalis* and *Escherichia coli*. The biofilms were grown in acrylic disks immersed in broth, inoculated with microbial suspension (106 cells/ml) and incubated at 37°C /48 h. After the biofilms were formed, they were exposed for 5 minutes to the solutions: Citrus *limonum* EO, 0.2% CHX, 1% NaOCl or sterile saline solution. The discs were placed in sterile 0.9% NaCl and sonicated to disperse the biofilms. Tenfold serial dilutions were performed and the aliquots were seeded onto selective agar and incubated at 37C / 48 h. Next, the number of colony-forming units per milliliter was counted and analyzed statistically (Tukey test, $p < 0.05$). Citrus *limonum* EO promoted a 100% reduction of *C. albicans* and *E. coli*, and 49.3%of *E. faecalis*. CHX was less effective against *C. albicans* and *E. coli*, yielding a reduction of 68.8% and 86.7%, respectively. However, the reduction of *E. faecalis* using CHX (81.7%) was greater than that obtained using *Citrus limonum* EO. *Citrus limonum* EO was effective in controlling multi-species biofilms; the microbial reductions achieved by EO were not only similar to those of NaOCl, but even higher than those achieved by CHX, in some cases [115].

The antibacterial activity of *Citrus limon* was studied against Acne vulgaris. *Citrus limon* juice was used at different concentrations of (20%, 40%, 60%, 80% and 100%) on *Propioni bacterium acne*. The *Citrus limon* juice was found to be effective at all concentrations used [116].

Essential oil from the fresh leaf of *Citrus medica* L. var. *sarcodactylis* possessed strong antimicrobial activity against *Staphylococcus aureus* and *Bacillus subtilis* (MIC 2,500 ppm). However, the antimicrobial efficiency of essential oil from this plant was much lower (about 40%) than that of tetracycline solution at the same concentration [117].

The antibacterial effect of the peels of *Citrus medica* was evaluated on *Staphylococcus aureus* MTCC96, *Escherichia coli* MTCC739, *Proteus vulgaris* MTCC426, *Bacillus subtilis* MTCC441, *Klebsiella pneumonia* MTCC109 and *Pseudomonas aeruginosa* MTCC424. The solvent used for the extraction of plants was water ethanol. The *in vitro* antibacterial activity was performed by agar cup method. The most susceptible Gram-positive bacteria were *Staphylococcus aureus* while the most susceptible Gram-negative bacteria was *Klebsiella pneumonia* and *Pseudomonas aeruginosa*. The antibacterial activity of active extract was compared with the standard antibiotic, streptomycin (100 ppm) [118].

Antimicrobial activity of fruit juice and ethanolic extracts of root, leaf, bark, peel and pulp of *Citrus medica* were examined against seven bacteria (Bacillus *subtilis, Staphylococcus aureus, Enterococcus faecalis, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa* and *Proteus vulgaris*), two fungi (*Aspergillus flavus* and *A. niger*) and a yeast *Candida albicans* of clinical origin. The antimicrobial effects were studied using an *in vitro* disc diffusion method; minimum inhibitory concentrations (MIC) and minimum bactericidal concentrations (MBC) were determined by standard agar dilution method. All extracts and fruit juice showed varied level of antibacterial activity against one or more test bacteria. Root, leaf and bark extracts inhibited *S. aureus, E. faecalis* and *P. vulgaris* with maximum inhibition by root extract comparable to standard antibiotic. Fruit peels have shown least activity among all extracts and slightly inhibited growth of *S. aureus, K. pneumoniae* and *P. vulgaris*. The yeast *C. albicans* was not inhibited by any extract. Among bacteria *S. aureus* and *P. vulgaris* were highly susceptible to all extracts while *B. subtilis* was highly resistant and inhibited by only fruit juice. Root extract had the lowest MIC 0.5mg/ml and MBC 1mg/ml against *S. aureus*. The maximum MIC of extracts was 50 mg/ml and MBC 75 mg/ml. The

minimum MIC of juice was < 1% and MBC 1% against P. vulgaris while maximum MIC was 3.5% and MBC 7%. Antifungal activity was shown by only root extract and fruit juice while C. albicans was resistant to all tested samples [119].

The antimicrobial activity against the selected bacteria and fungi was observed for the alcoholic extract of *Citrus medica* , it was found active against all the tested bacteria and fungi (*Enterobacter aerogenes, Staphylococcus aureus,Bacillus subtilis, Proteus vulgaris, Klebsiella pneumoniae, Shigella flexneri, Chryseobacterium gleum* and fungi *Candida albicans, Aspergillus niger* and *Aspergillus flavus*). The maximum antibacterial activity was shown against *Staphylococcus aureus* (6.3 mm) by methanolic extract, whereas the maximum antifungal activity was shown against *A. niger (*6.3 mm) and minimum activity was shown against *A. flavus* (3 mm) [120].

The antibacterial investigation of crude extracts (aqueous and ethanolic) of fruits of *Citrus medica var limetta* against four wound isolates *Staphylococcus* sp, *Pseudomonas* sp, *Escherichia coli* and *Klebsiella* sp., showed that they exert antibacterial activity with diameter of inhibition zone of 10, 12, 10 and 10 mm for ethanolic extract, and 8, 9, 8 and 9 mm for aqueous extract respectively [111].

The aqueous extract of the peels of *C. limetta* produced a good antimicrobial activity against 15 isolates, *Staphylococcus aureus, Staphylococcus epidermidis, Streptococcus pyogenes, Enterococcus faecalis, Streptococcus pneumoniae, Streptococcus agalactiae, Pseudomonas aeruginosa, Enterobacter aerogenes, Klebsiella pneumoniae, Escherichia coli, Salmonella typhi, Proteus spp., Moraxella catarrhalis, Acinetobacter spp. and Candida albicans*, with inhibition zones ranged (from 10 to 35mm) against Gram-positive or Gram-negative bacteria with no activity against *Candida* [114].

The results of antimicrobial activity of peel essential oil of *Citrus limetta* var. Mitha tested by disc diffusion method, against different against bacteria and fungi showed that it exhibited maximum zone of inhibition against *Bacillus cereus* ATCC 14579 (28 mm) and *Bacillus subtilis* ATCC 6633 (26 mm) followed by *Staphylococcus aureus* ATCC 25923 (21 mm), whereas the minimum zone of inhibition was shown by *Fusarium oxysporum* ATCC 48122 (11 mm) after 48 h of incubation at their respective temperature (37°C for bacteria and 25°C for fungi). The inhibition zones, measured after 48 and 96 h, showed that it was active against all the tested bacteria and fungi [121].

The anti typhoid activity of aqueous extract of fruit peel *Citrus sinensis* was studied *in vitro*. The aqueous extracts of fruit peel *Citrus sinensis* exhibited antityphoid activity against *Salmonella typhi, Salmonella paratyphi* A *and Salmonella paratyphi* B [122].

The antibacterial activity of aqueous and ethanol extracts of *Citrus sinensis* leaves was evaluated aginst *Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae,* and *Staphylococcus aureus.* The *in vitro* antibacterial activity was performed by agar disc diffusion method. The aqueous extract showed a zone of inhibition against *Escherichia coli* (7mm), while on the other organisms it showed little or no zones of inhibition ranging from 0-3mm in diameter. The ethanol extract also showed little zones of inhibition against the tested organisms ranging from 1-3mm in diameter [123].

The peels were air-dried and ground to powder, extracted with 95% ethanol. The extract was subjected to antibacterial study against six *Salmonella paratyphi* B, one *Salmonella typhi* and three *Aeromonas hydrophila*. Agar diffusion method was employed to test the antibacterial activity of the extract and the MIC and MBC of the extract were determined by broth dilution technique. The results showed that the isolates were sensitive to the extract, with MIC of 0.25-2.5mg/ml and MBC of 0.5-5.0mg/ml [124].

Peels of *Citrus lemon, Citrus sinensis* and *Citrus limetta* were dried and extracted by cold water, hot water, methanol, ethanol, ethyl acetate and acetone. Extracts were subjected to antibacterial and antifungal susceptibility assay against (*Pseudomonas aeruginosa*, *Salmonella typhimurium*, *Micrococcus aureus, Trichophyton mentagrophytes*, *Microsporum canis* and *Candida albicans*) by agar well diffusion method. All the extracts of *Citrus lemon* were found to be effective against the tested bacterial pathogens except hexane extracts. Methanol and acetone extract showed maximum zone of inhibition of 18 mm. Only methanol extract was effective against fungal pathogens showing a zone of inhibition of 18 mm. Hexane extract of *Citrus sinensis* was found to be most effective against bacterial pathogens giving a zone of 13 mm. Only the cold water extract of orange was effective against fungal pathogens. Acetone extract of *Citrus limetta* was most effective giving a zone of 20 mm against bacterial pathogens. Only cold water and ethyl acetate extracts of *Citrus limetta* were effective against fungal pathogens giving a zone of inhibition of 17mm and 15 mm respectively [125].

The antimicrobial activity of methanolic extract of *C. sinensis* fruit peel was tested against three bacterial and two fungal strains using turbidimetric or tube dilution method and paper disc diffusion method. *C. sinensis* fruit peel methanolic extract exhibited antibacterial activity against *Escherichia coli* with minimum inhibitory concentration of 0.78 µg/ ml and minimum bactericidal concentration of 6.25 µg/ml, and

appreciable antifungal activity with minimum inhibitory concentration of 12.5 µg/ml [126].

The dried peels of *Citrus sinensis* were defated and then were subjected to the methanolic extraction. The methanolic extract obtained was dissolved in various solvents such as water, methanol, ethanol, chloroform, diethyl ether and were subjected to evaluation of antitubercular activity against *Mycobacterium tuberculosis* by Microplate Alamar Blue Assay (MABA) method. The results concluded that the extract dissolved in water as solvent showed significant activity at 50µgm/ml [127].

The antimicrobial activity of petroleum ether extract of the peels of *Citrus sinensis* was studied against various Gram positive organisms (*Staphylococcus epidermidis, Micrococcus luteus, Bacillus subtilis*), Gram negative organisms (*Escherichia coli, Pseudomonas vulgaris, Salmonella typhi*), and fungal strains (*Aspergillus niger, and Candida albicans*). Antimicrobial activity was conducted by the agar well diffusion method. The extract showed various levels of antimicrobial activity on the tested microorganisms. It was more effective against *Staphylococcus epidermidis*, *Micrococcus luteus* and *Pseudomonas vulgaris* followed by *Salmonella typhi*, *Escherichia coli* and *Candida albicans*, while it showed no activity against *Bacillus subtilis* and *Aspergillus niger* [128].

The antmicrobial effects of aqueous extracts of peel, juice and leaves from fresh *Citrus sinensis* was evaluated against 3 Gram-positive and 6 Gram-negative bacterial, including *S. aureus, S. pyogenes, E. feacalis, P. aeruginosa, K. pneumoniae, E. coli, S. typhi, Proteus spp., M. catarrhalis.* Citrus juices showed the highest antibacterial activity against most of the studied bacterial isolates. Moderate activity produced by the citrus peels and the lowest effect was produced by the extract of the citrus leaves [129].

The antimicrobial activity of *Citrus sinensis* oil was studied by paper disc diffusion method against *Bacillus subtilis* and *Escherichia coli*. Zones of inhibition of *E. coli* and *B. subtilis* were 13 and 17mm respectively [130].

The antimicrobial potential and the minimum inhibitory concentration (MIC) of aqueous and ethanol (cold and hot) extracts of Citrus sinensis peel extracts was investigated against *Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis* and *Prevotella intermedia*, using agar well diffusion method. The results showed that *Prevotella intermedia* and *Porphyromonas gingivalis* were resistant to aqueous extracts while *Aggregatibacter actinomycetemcomitans* was inhibited at very high concentrations. Hot ethanolic extracts showed significantly higher zone of inhibition than cold ethanolic extract. Minimum inhibitory concentration of hot and cold ethanolic extracts of Citrus sinensis peel ranged between 12-15 mg/ml against all three periodontal pathogens [131].

Citrus aurantifolia juice destroyed human immunodeficiency virus (HIV). Ten percent of *Citrus aurantifolia* juice produced a 1000-fold reduction in HIV activity in a laboratory sample [132].

To evaluate the effect of extracts of peels of Citrus sinensis (Cs) on the replication of coronavirus (CoV) and on the expression of TRP genes during coronavirus infection, HeLa-CEACAM1a (HeLa-epithelial carcinoembryonic antigen-related cell adhesion molecule 1a) cells were inoculated with MHV-A59 (mouse hepatitis virus-A59) at moi of 30. 1/50 dilution of the extracts was found to be the safe active dose. ELISA kits were used to detect the human IL-8 levels. Total RNA was isolated from the infected cells and cDNA was synthesized. Fluidigm Dynamic Array nanofluidic chip 96.96 was used to analyze the mRNA expression of 21 TRP genes and two control genes. Data was analyzed using the BioMark digital array software. Determinations of relative gene expression values were carried out by using the 2(-ΔΔCt) method (normalized threshold cycle (Ct) value of sample minus normalized Ct value of control). TCID50/ml (tissue culture infectious dose that will produce cytopathic effect in 50% of the inoculated tissue culture cells) was found for treatments to determine the viral loads. TRPA1, TRPC4, TRPM6, TRPM7, TRPM8 and TRPV4 were the genes which expression levels changed significantly after Cs extract treatments. The virus load decreased when Cs extracts was added to the CoV infected cells. Extract treatment had an effect on IL-8 secretion, TRP gene expression and virus load after CoV infection [133].

Clerodendrum inerme

When *Clerodendrum inerme* tested against *S. typhi, K. pneumonia, S. aureus, Proteus sp*. and *B. subtilis*, Iso amyl alcohol extract showed antibacterial activity against all the bacterial species, propanol extracts also active against all species except *Proteus sp*., while ethanol, methanol and chloroform extracts exerted activity against *Proteus sp*. and S. *aureus* only [134].

The antibacterial studies of *Clerodendrum inerme* were carried out by disc diffusion technique against *Shigella sonnei, Klebsiella pneumoniae, Bacillus subtilis, Salmonella typhi, Pseudomonas aeruginosa, Pseudomonas solanacerum* and *Xanthomonas citri.* The maximum antibacterial activities were observed in ethanol extract (0.30 ± 0.10). Among the seven bacterial organisms, growth suppression was observed in *Pseudomonas solanacearum, Xanthomonas citri* and *Klebsiella pneumonia* only [135].

The antimicrobial activity of *Clerodendrum inerme* was investigated against *E. coli, Shigella flexneri, Shigella dysenteriae, Vibrio cholerae, Salmonella paratyphi, Proteus* spp., *Staphylococcus aureus* and *Staphylococcus epidermis* using disc diffusion assay. The chloroform bark extract of of *C. inerme* showed excellent performance against all tested bacteria except *Staphylococcus epidermis*[136].

The effectiveness of the crude extracts of *Clerodendrum inerme* (L.) Gaertn. was studied against some of the human pathogenic bacteria, Gram positive (*Staphylococcus aureus, Staphylococcus aureus ATCC 25953, Staphylococcus albus, Streptococcus haemolyticus* Group-A, *Streptococcus haemolyticus* Group-B, *Streptococcus faecalis* and *Bacillus subtilis*) and Gram negative (*Escherichia coli, Edwardsiella tarda, Klebsiella pneumoniae, Proteus mirabilis, Proteus vulgaris, Pseudomonas aeruginosa, Salmonella typhi, Shigella boydii, Shigella dysenteriae, Shigella flexneri* and *Plesiomonas shigelloides*). Five plant extracts (Petrol, Benzene, Methanol, Ethyl acetate and Aqueous) under six different concentrations (500 mcg, 1mg, 2mg, 5mg, 10mg and 15mg/ml) were tested by disk diffusion method. Methanol, Ethyl acetate and Aqueous extracts of the plant showed significant inhibition against fifteen of the eighteen tested bacteria [137].

The antimicrobial activities of different extracts (ethanol, benzene and aqueous) of *Clerodendrum inerme* plant parts were evaluated *in vitro* by disc diffusion method against Gram positive - *Bacillus subtilis* (ATCC 6633), *Staphylococcus aureus* (ATCC 25923), Gram negative- *Escherichia coli* (ATCC 25922), *Psedomaonas aeruginosa* (ATCC 27853) and fungal strains *Aspergillus niger* (ATCC 16404), *Aspergillus flavus* (ATCC 9807), *Candida albicans* (ATCC5027) and *Candida glabrata* (ATCC 66032). The methanol leaves extract exhibited highest zone of inhibition against *S. aureus* and *A. niger* (16.67 ±0.47 and 15.0±0.0 mm, respectively) with low MIC values (0.78 mg/ml for each). However, no activity was shown by aqueous extract against the tested pathogenic strains [138].

The ethyl acetate and hexane extracts of leaves and stems of *Clerodendrum inerme* were screened for antifungal activity. The tested fungi were included clinical isolates of dermatophytes such as *pidermophyton floccosum, Trichophyton mentagrophytes, Trichophyton rubrum* and *Trichophyton tonsurans*, and plant pathogens such as *Aspergillus niger, Aspergillus flavus, Curvularia lunata, Botrytis cinerea* and *Fusarium oxysporum*. Leaf hexane extract (1 mg/ml) of *C. inerme* inhibited the plant pathogenic fungi better than the human dermatophytes [139].

Clerodendrum inerme showed antiviral activity against Hepatitis B virus with ED_{50} value of 16 mg/ml [140-141].

Clitoria ternatea

Different extracts of *Clitoria ternatea* showed inhibitory effects against *Pseudomonas aeruginosa, Escherichia coli, Klebsiella pneumonia, Bacillus subtilis, Aeromonas formicans, Aeromonas hydrophila* and *Streptococcus agalactiae*. Ethyl acetate extracts of *Clitoria ternatea* showed maximum zone of inhibition against *A. formicans* (18 mm), *A. hydrophilia* (19 mm), *B. subtilis* (19 mm) and *P. aeruginosa* (21 mm) next to that ethanol extract of *Clitoria ternatea* showed maximum zone of inhibition against *A. formicans* (18 mm) and *E. coli* (14 mm) followed by the acetone extract which showed maximum zone of inhibition against *S. agalactiae* (19 mm) and *K. pneumonia* (17 mm) [142].

Aqueous extracts of both seed and callus were prepared for evaluating the antimicrobial activity against selected pathogenic fungi and bacteria using the agar well diffusion technique. Seeds and leaf delivered calli of *Clitoria ternatea* were extracted using standardized laboratory protocol. The seed extract of *Clitoria ternatea* showed maximum zone of inhibition (22 ± 0.5 mm) against *Escherichia coli* (NCIM 2645) at 0.75 mg concentration and minimum (14 ± 1.0 mm) with *Micrococcus flavus* (NCIM 2376). The callus extract showed maximum zone of inhibition (16 ± 2.0 mm) against *Salmonella typhi*, the minimum zone of inhibition was recorded against *Escherichia coli* (NCIM 2645) and *Staphylococcus aureus* (12 ± 1.0 mm and 12 ± 0.9 mm, respectively). The seed extract of *Clitoria ternatea* showed strong antifungal activity on all the tested fungi but the callus extract exhibited marginal antifungal activity [143].

The antimicrobial activities of the methanol extracts of the leaf, stems, flower, seed and roots of *Clitoria ternatea* were tested *in vitro* against 12 bacterial species, 2 yeast species, and 3 filamentous fungi by the agar diffusion and broth dilution methods. The leaf and root extracts were found to be most effective against all of the tested organisms ($p<0.05$). The MIC (minimum inhibitory concentration), MBC (minimum bactericidal concentration) and MFC (minimum fungicidal activity) values of *C. ternatea* extracts ranged from 0.3 mg/ml to 100.00 mg/ml [144].

The antibacterial properties of *Clitoria ternatea* was investigated by agar disc and well diffusion methods. The organic solvent (petroleum ether, ethyl acetate and methanol) extracts from the leaves of *Clitoria ternatea* were tested against *Bacillus cereus, Staphylococcus aureus, Klebsiella pneumonia, Proteus vulgaris* and *Salmonella typhi*. The results showed promising antibacterial activity against the

tested microbial pathogens. Among extracts, methanol extract was found to possess a more potent inhibitory activity when compared to the other extracts (petroleum ether and ethyl acetate) [145].

An antifungal protein with a molecular mass of 14.3 kDa was isolated from the seeds of *Clitoria ternatea*. The protein showed lytic activity against *Micrococcus luteus* and broad-spectrum, fungicidal activity, particularly against the most clinically relevant yeasts, such as *Cryptococcus neoformans, Cryptococcus albidus, Cryptococcus laurentii, Candida albicans* and *Candida parapsilosis*. It also exerted an inhibitory activity on mycelial growth in several mould species including *Curvularia* sp., *Alternaria* sp., *Cladosporium* sp., *Aspergillus flavus, Aspergillus fumigatus, Aspergillus niger, Rhizopus* sp., and *Sclerotium* sp [146].

Clitoria ternatea leaf extract showed a favorable antifungal activity against *A. niger*, the minimum inhibition concentration was 0.8 mg/ml and minimum fungicidal concentration was 1.6 mg/ml, respectively. The leaf extract exhibited considerable antifungal activity against filamentous fungi in a dose-dependent manner with 0.4 mg/ml IC_{50} value on hyphal growth of *A. niger*. The main changes observed under scanning electron microscopy after *Clitoria ternatea* extract treatment were loss of cytoplasm in fungal hyphae and the hyphal wall became markedly thinner, distorted, and resulted in cell wall disruption. In addition, conidiophore alterations were also observed when *A. niger* was treated with *Clitoria ternatea* leaf extract [147].

A single protein (finotin), was obtained from seeds of *Clitoria ternatea*. The protein finotin showed broad and potent inhibitory effect on the growth of various important fungal pathogens of plants (*Rhizoctonia solani, Fusarium solani, Colletotrichum lindemuthianum, Lasiodiplodia theobromae, Pyricularia grisea, Bipolaris oryzae* and *Colletotrichum gloeosporioides*). It also inhibited the common bean bacterial blight pathogen *Xanthomonas axonopodis pv. phaseoli*. Moreover, finotin has powerful inhibitory properties against the bean *bruchids Zabrotes subfasciatus* and *Acanthoscelides obtectus* [148-149].

Colchicum balansae

The antibacterial properties of *Colchicum balansae* Planchon (CB) were studied. The results showed that *Colchicum* ethanol extract had a weak inhibitory effect against tested bacteria (*Staphylococcus aureus* ATCC 25923, *Staphylococcus epidermidis* ATCC 12228, *Enterococcus faecalis* ATCC 29212, *Klebsiella pneumoniae* ATCC 13883, *Escherichia coli* ATCC 25922, *Enterobacter cloacae* ATCC 23355, *Serratia marcescens* ATCC 8100, *Proteus vulgaris* ATCC 13315, *Pseudomonas aeruginosa* ATCC 27853, *Salmonella typhimurium* ATCC 14028). *S. aureus* ATCC 25923 was more sensitive to ethanol extract (10 mm inhibition zone). When comparing the antimicrobial activity of the control antibiotics, the ethanol extract exhibited lower antimicrobial activity [150].

Convolvulus arvensis

The aqueous and acetonic extracts of *Convolvulus arvensis* were tested against *Staphylococcus aureus, Streptococcus pyogenes, Escherichia coli* and *Klebsiella pneumonia* using five concentrations (500, 250,125, 0.06 and 0.03 mg/ ml). The aqueous extract of *Convolvulus arvensis* showed no antibacterial activity against all the tested microorganisms in all concentrations. However, ethanolic extract of *Convolvulus arvensis* L. showed antibacterial activity against all the tested microorganisms (except *Klebsiella pneumonia*) when used in a concentration of 0.06 mg/ml and more [151-152].

Corchorus aestuans

Fusidic acid which was obtained earlier from a fungi (*Fusidium coccineum*), then isolated from the plant *Corchorus aestuans*, has a wide range of antibacterial effects. The antimicrobial activity of various solvent extracts of *Corchorus aestuans* was evaluated against the clinical isolates of Gram-positive and Gram-negative bacterial strains and fungus by the zone of inhibition. The Gram-positive bacteria used were included *Staphylococcus aureus, Bacillus cereus* and *Micrococcus luteus*, and the Gram-negative bacteria were *Escherichia coli, Pseudomonas aeruginosa* and *Klebsiella pneumoniae*, fungus like *Aspergillus niger, Candida albicans, Candida tropicalis, Candida kefyr* and *Cryptococcus neoformans*. It was appeared that ethanol, methanol, ethyl acetate, acetone, chloroform, petroleum ether, hexane and aqueous extracts showed activity against bacteria and fungus. The Ethyl acetate extract of *Corchorus aestuans* showed more activity against *Micrococcus luteus*, zone of diameter 13±0.15mm and *Escherichia coli*, zone of diameter 13.07±0.12mm. Hot water extract of *Corchorus aestuans* showed more activity against *Candida kefyr*, zone of diameter 12.20±0.20mm and *Cryptococcus neoformans*, zone of diameter 11.17±0.29mm, when compared to other solvent extracts. Ethyl acetate extract against bacteria and hot water extract against fungus showed a varying degree of inhibition to the growth of tested organism, than ethanol, methanol and acetone extracts [153].

The antibacterial potential of the methanol extracts of leaves and aerial parts of *Corchorus aestuans* was studied against four Gram positive and Gram negative bacteria [*Bacillus subtilis* MTCC (121), *Staphylococcus aureus* MTCC (96), *Pseudomonas aeuroginosa* MTCC (429) and *Escherichia coli* MTCC (443)], using cup-plate method. The methanol extracts of leaves and aerial parts of the plant significantly

inhibited the growth of bacteria as compared to standard antibacterial drug (streptomycin) [154].

The leaf, capsule and root extracts of *Corchorus aestuans* were tested for antibacterial against Gram positive (*Bacillus subtilis, Bacillus pumilis, Bacillus cereus, Staphylococcus aureus*), Gram negative bacteria (*Escherichia coli, Psuedomonas aeuriginosa, Psuedomonas vulgaris, Serratia marceseans*) and antifungal activity (against *Aspergillusniger, Rhizopusstolonifer, Saccharomyces cervisiae*), they showed potent antibacterial activity. The leaf and root extracts of *Corchorus aestuans* showed more antibacterial activity compared to *Corchorus aestuans* capsule extract. In antifungal test, the methanolic extracts showed moderate activity. The chloroform and methanolic *Corchorus aestuans* leaf, capsule and root extracts showed potent antibacterial and antifungal activity [155].

Corchorus capsularis

Disc diffusion method was used to determine the antibacterial and antifungal activity of the crude methanolic extract of *Corchorus capsularis* (leaves) and its fructions against Gram positive bacteria (*Bacillus subtilis, Staphylococcus aureus, Beta hemolytic streptococcus, Bacillus cereus and Streptococcus pyrpgen*), Gram negative bacteria (*Shigella boydii, Salmonella typhi E.coli, Klebsiella* and *Vibrio mimicus*), yeast and fungi (*Candida albicans, Saccharomyces cerevisiae* and *Bacillus megaterium*). *Corchorus capsularis* extracts possessed antimicrobial antifrungal and anti-yeast activity. N-hexane fraction of methanolic extract of leaves of *Corchorus capsularis* showed the highest acivities against gram positive, gram negative bacteria and fungi with a zone of inhibition 0.9-1.5mm, followed by hexane extract [156-157].

Cordia myxa

The antimicrobial activity of *Cordia myxa* leaf extracts was studied against three bacterial strains (*E. coli, Staphylococcus aureus* and *Pseudomonas aeruginosa*), and three fungal strains (*Aspergillus niger, Penicillium spp* and *Scytalidium spp*). Antimicrobial activity tests were performed by Agar well diffusion method. *Cordia myxa* showed highest inhibition in case of *Staphylococcus aureus* and then *E. coli*. However, it showed no antifungal activity [158-159]. Extracts of *Cordia myxa* were tested for their anti–HIV–1 activity using the syncytia formation assay. All the extracts showed a weak anti–HIV–1 activity[160].

Coriandrum sativum

The antibacterial effect of aqueous and ethanolic extracts of different coriander parts was studied against nine different pathogenic bacteria isolated from urine, blood, stool and cerebraspinal fluid of different patients (*Burkhella capacia, Escherichia coli, Enterobacter cloacae, Gamella morbillorum, α-Haemolytic streptococci, Klebsiella pneumonia, Proteus mirabilis, Streptococcus pneumonia*, and *Salmonella typhi*). Cold aqueous extract of coriander seeds had inhibitory effect against some tested bacteria. On the other hand, ethanolic extracts of seeds, leaves and stems showed wide range of antibacterial activity and the highest values for inhibition zone was recorded against *Klebsiella pneumoniae* and *Proteus mirabilis* [161].

Essential oils from commercial samples of coriander were assayed for their antibacterial and antifungal activities. Twenty-five genera of bacteria and one fungal species (*Aspergillus niger*) were used as test organisms. The essential oils showed a high degree of inhibition against all the tested microorganisms [162].

The antimicrobial activity of ethanol, methanol, acetone, chloroform, hexane and petroleum ether extracts of *Coriandrum sativum* was investigated against infectious pathogenic bacteria such as *E. coli, Pseudomonas aeruginosa, Staphylococcus aureus* and *Klebsiella Pneumonia*; and many fungi including *Aspergillus niger, Candida albicans, Candida kefyr* and *Candida tropicalis* using agar well diffusion method. The methanol extract of *Coriandrum sativum* showed more antibacterial activity against *Staphylococcus aureus* (zone of diameter 12.17±0.29mm) and *Klebsiella pneumonia* zone (12.17±0.15mm), while, it showed more antifungal activity against *Candida albicans* (zone of diameter 14.20±0.20mm) and *Aspergillus niger* (10.10±0.10mm). It appeared that methanol extract showed a varying degree of antibacterial and antifungal effects more than ethanol, acetone, chloroform, hexane and petroleum ether extracts [163].

The antibacterial potential of the leaf essential oil, petroleum ether, chloroform, ethyl acetate and methanol extracts of the leaves of *Coriandrum sativum* were studied against human pathogenic bacteria (*Bacillus cereus, Enterobacter faecalis, Salmonella paratyphi, Staphylococcus aureus, Escherichia coli, Proteus vulgaris, Klebsiella pneumoniae, Pseudomonas aeruginosa* and *Serratia marcescens*) by agar well diffusion method. Leaf essential oil as well as leaf ethyl acetate, chloroform and methanol extracts of *Coriandrum sativum* exhibited pronounced activity against Gram-positive and Gram-negative bacteria and their activity was quite comparable with the standard antibiotics such as tobramycin, gentamicin sulphate, ofloxacin and ciprofloxacin screened under similar conditions [164].

The antibacterial effect of *Coriandrum sativum* essential oil against Gram-positive and Gram-negative bacteria was evaluated using classical microbiological techniques concomitantly with the use of flow cytometry for the evaluation of cellular physiology. The results showed that coriander oil has an effective

antimicrobial activity against all tested bacteria. Propidium iodide incorporation and concomitant loss of all other cellular functions such as efflux activity, respiratory activity and membrane potential seem to suggest that the primary mechanism of action of coriander oil was membrane damage, resulted in cell death [165].

Aliphatic (2E)-alkenals and alkanals isolated from the fresh leaves of the Coriandrum sativum were found to possess bactericidal activity against Salmonella choleraesuis ssp. choleraesuis ATCC 35640. (2E)-Dodecenal (C12) was the most effective against this food-borne bacterium with the minimum bactericidal concentration (MBC) of 6.25 microg/ml (34 microM), followed by (2E)-undecenal (C11) with an MBC of 12.5 microg/ml (74 microM). The time-kill curve study showed that these alpha, beta-unsaturated aldehydes were bactericidal against *S. choleraesuis* at any growth stage and that their bactericidal action came in part from the ability to act as nonionic surfactants [166-167].

Twelve essential oils were tested *in vitro* for antimicrobial activities against several strains of *Campylobacter jejuni*, a pathogen causing food-borne diseases worldwide. Coriander oil exhibited the strong antimicrobial activity against all tested strains. In evaluating the antimicrobial potency of coriander oil against *C. jejuni* on beef and chicken meat at 4 degrees C and 32 degrees C, it reduced the bacterial cell load in a dose-dependent manner. The type of meat and temperature did not influence the antimicrobial activity of the oil [168].

Antimicrobial effect of essential oils from the seeds of *Coriandrum sativum* was studied against gram-positive bacteria, gram-negative bacteria and *Saccharomyces cerevisiae*. Essential oil appeared effective against *Listeria monocytogenes* [169].

The antibacterial potential of two commercial essential oils (EOs) from *Coriandrum sativum* was studied against vaginal clinical strains of bacteria and yeast. Antimicrobial activities were determined using macro-diffusion (disc, well) and micro-dilution method against twelve clinical strains of bacteria: *Escherichia coli, Proteus mirabilis, S. aureus* and *Enterococcus* sp., *S. aureus* ATCC 25923, ATCC 6538 *and Escherichia coli* 25922 and two clinical *Candida albicans* ATTC 10231 strains. An antimicrobial effect of EOs was strain specific. Bactericidal activity was higher for coriander EO (MICs 0.4 – 45.4 µl/ml) against almost all tested bacteria, except multiple resistant strains of *Eneterococcus* sp. and *Proteus* sp. It showed low fungicidal activity [170].

Antimicrobial activities of essential oils were evaluated against *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa* and *Candida albicans* by microdilution method. The essential oils of *Coriandrum sativum* fruits obtained by hydrodistillation (HD EO) showed greater activity against *Staphylococcus aureus* and *Candida albicans* than that obtained by microwave-assisted hydrodistillation (MAHD EO). Moreover, their activities against *E. coli and P. aeruginosa* were the same with minimum inhibitory concentration, MIC 0.781 and 6.25 µl/ml, for HD EO and MAHD EO respectively [171].

The antibacterial activity of essential coriander oil (ECO) on bacteria with dermatological relevance and skin tolerance of antimicrobial effective ECO concentrations were investigated. Essential coriander oil showed good antibacterial activity towards the majority of the bacterial strains tested, including *Streptococcus pyogenes* (Lancefield group A) and methicillin resistant *Staphylococcus aureus* (MRSA), with mean minimal inhibitory concentrations of 0.04% v/v and 0.25% v/v, respectively. The skin tolerance of a cream and a lotion containing 0.5% and 1.0% ECO was assessed in 40 healthy volunteers using the occlusive patch test. No skin irritation could be observed by sensitive photometric assessment in any of the volunteers. The authors suggested that, because of its activity against *Streptococcus pyogenes, Staphylococcus aureus* and MRSA, with excellent skin tolerance, ECO might be useful as an antiseptic for the prevention and treatment of skin infections with Gram-positive bacteria [172].

A series of experiments were conducted to evaluate the ability of cilantro oil (the essential oil of Coriandrum *sativium*) to control the growth of *Listeria monocytogenes* on vacuum-packed ham. The *in vitro* minimal inhibitory concentration for five strains of *L. monocytogenes* was found to vary from 0.074% to 0.018% depending on strain. Cilantro oil treatments were then tested on ham disks inoculated with a cocktail of the five *L. monocytogenes* strains. The concentrations studied were 0.1%, 0.5%, and 6% cilantro oil diluted in sterile canola oil or incorporated into a gelatin gel in which lecithin was used to enhance incorporation of the cilantro oil. Gelatin gel treatments were also conducted with 1.4% monolaurin with or without 6% cilantro oil to determine if an interaction between the antimicrobials could increase inhibition of *L. monocytogenes*. Treated ham was then vacuum-packed and stored at 10 degrees C for up to 4 weeks. The only cilantro oil treatment which inhibited growth of *L. monocytogenes* on the ham samples was 6% cilantro oil gel. Samples receiving this treatment had populations of *L. monocytogenes* 1.3 log CFU/ml lower than controls at week 1 of storage, there was no difference between treatments from week 2 onward. It appears that immobilization of the antimicrobial in a gel enhanced the effect of treatments [173].

The hydroalcoholic extract of the crude *Coriandrum sativum* was screened for antibacterial

activity against various bacterial species by disk diffusion method. Assay was performed using clinical isolates of *B. cereus, S. aureus, P. aeruginosa* and *E. coli*. Crude extract of *Coriandrum sativum* was effective only against *Bacillus cereus* [174].

The synergistic antibacterial effect between *Coriandrum sativum* essential oil and six different antibacterial drugs (cefoperazone, chloramphenicol, ciprofloxacin, gentamicin, tetracycline and piperacillin) was investigated. The antibacterial activity of coriander oil was assessed using microdilution susceptibility testing and synergistic interaction by checkerboard assays. The association of coriander essential oil with chloramphenicol, ciprofloxacin, gentamicin and tetracycline against *Acinetobacter baumannii* showed *in vitro* effectiveness, which was an indicator of a possible synergistic interaction against two reference strains of *A. baumannii* (LMG 1025 and LMG 1041, FIC index from 0.047 to 0.375). However, when tested the involvement between coriander essential oil and piperacillin or cefoperazone, the isobolograms and FIC index showed an additive interaction. The *in vitro* interaction could improve the antimicrobial effectiveness of ciprofloxacin, gentamicin and tetracycline and may contribute to resensitize *A. baumannii* to the action of chloramphenicol [175].

The antifungal activity of essential oil from *Coriandrum sativum* fruits was evaluated against *Microsporum canis* and *Candida* spp. by the agar-well diffusion method and the minimum inhibitory concentration (MIC) and the minimum fungicidal concentration (MFC) were established by the broth microdilution method. The essential oil induced growth inhibition zones of 28 ± 5.42 and 9.25 ± 0.5mm for *M. canis* and *Candida* spp. respectively. The MICs and MFCs for M. canis strains ranged from 78 to 620 and 150 to 1.250 µg/ml, and the MICs and MFCs for *Candida* spp strains ranged from 310 to 620 and 620 to 1.250 µg/ml, respectively [176].

The antifungal activity of coriander essential oil was studied on germ tube formation, and the potential synergism with amphotericin B were also studied. Coriander essential oil has a fungicidal activity against the *Candida* strains tested, with MLC values equal to the MIC value and ranging from 0.05 to 0.4% (v/v). Flow cytometric evaluation of BOX, PI and DRAQ5 staining indicated that the fungicidal effect was a result of cytoplasmic membrane damage and subsequent leakage of intracellular components such as DNA. Also, concentrations bellow the MIC value caused a marked reduction in the percentage of germ tube formation for *C. albicans* strains. A synergetic effect between coriander oil and amphotericin B was also recorded against *C. albicans* strains, while for *C. tropicalis* strain only an additive effect was observed [177].

The antifungal activity and mode of action of the essential oils (EO) from *Coriandrum sativum* leaves were evaluated against Candida spp. In addition, the molecular targets affected in whole-genome expression in human cells was also studied. The EO showed anticandidal effects. *Coriandrum sativum* EO may bind to membrane ergosterol, increasing ionic permeability and causing membrane damage leading to cell death, but it did not act on cell wall biosynthesis-related pathways. The EO also inhibited Candida biofilm adherence to a polystyrene substrate at low concentrations, and decreased the proteolytic activity of *Candida albicans* at the minimum inhibitory concentration. In addition, the EO and its selected active fraction had low cytotoxicity on human cells [178].

Coriandrum sativum essential oil possessed antifungal activity against *Candida* species isolates from the oral cavity of patients with periodontal disease. 2-hexen-1-ol, 3-hexen-1-ol and cyclodecane were determined as the active constituents in the oil [179].

The efficacy and tolerability of 6% coriander oil was tested in unguentum leniens in the treatment of interdigital tinea pedis. The study was performed on 40 participants. 6% coriander oil showed highly significant improvement of the clinical signs in unguentum leniens ($p < 0.0001$) during the entire observation period. The number of positive fungal cultures also decreased ($p = 0.0654$). The tolerability of the tested substances was good [180].

Coronilla varia

Coronilla varia aerial parts extracts were tested for their antibacterial activity against *Streptococcus pyogenes* (ATCC 19615), *Staphylococcus aureus* (ATCC 25923), *Staphylococcus epidermidis* (ATCC 12228), *Pseudomonas aeruginosa* (ATCC 27853), *Klebsiella pneumoniae* (ATCC 13883) and *Escherichia coli*. Two agar diffusion methods, well diffusion assay and disc diffusion assay were used to compare the susceptibility of the bacterial strains to the plant extracts. *Coronilla varia* extracts showed antibacterial activity against *Streptococcus pyogenes* (ATCC 19615), *Staphylococcus aureus* (ATCC 25923), *Pseudomonas aeruginosa* (ATCC 27853), *Klebsiella pneumoniae* (ATCC 13883) and *Escherichia coli* [181].

Antibacterial activity of plant extract was determined by disc diffusion method against three Gram negative bacteria (*Proteus mirabilis* PTCC (1076); *Enterobacter cloacae* PTCC (1003), and *Klebsiella pneumonia* PTCC (1290)) and two Gram posetive (*Staphylococcus aureus* PTCC (1112) and *Bacillus subtilis* PTCC (1023)). The extracts from *Coronilla varia* had interesting activity against *Proteus mirabilis* in the concentration of 700 µg/disc and did

not show any activity against *Staphylococus aureus, Bacillus subtillis, Klebsiella pneumonia* and *Entrobacter cloacae* [182-183].

Cotoneaster racemiflora

The antibacterial and anti-methcillin resistant *S. aureus* (MRSA) activities of water, methanol and ethyl acetate extracts of the plant were investigated by broth microdilution method. Water extract possessed remarkable antibacterial against gram positive microorganisms. The MIC values were determined as 0.625 mg/ml for *S. aureus* (MSSA), *S. aureus* (MRSA), and *S. lutea*. It has been seen that water extract revealed a significant effect against MRSA. While *E. faecalis* was the most sensitive bacterium. *B. cereus* and *S. pneumonia* were resistant Gram-positive bacteria against water extract. The MIC value of water extract was determined as 0.039 mg/ml against *E. faecalis*. Although *E. coli* was affected by water extract at a 0.625 mg/ml dose, *K. pneumoniae, S. enteritidis,* and *P. aeruginosa* were found to be resistant to this extract. Gram-negative microorganisms were more resistant than Gram-positive bacteria against water extract of cotoneaster. Methanol extract exhibited significant antibacterial activity against *E. faecalis* at a concentration of 0.312 mg/ml. The MIC values of methanol extracts were determined as 2.5 mg/ml against *E. coli, P. aeruginosa* MSSA, and MRSA. *B. cereus, K. pneumoniae, S. lutea,* and *S. enteritidis* were not affected by this extract at all tested doses. The MIC value was determined as 0.625 mg/ml for *S. pneumoniae*. While, *P. aeruginosa and S. pneumoniae* which resisted water extract, they were affected by methanol extract. However, MIC values of the water extract were lower than those of methanol extract. Except for MRSA strain, the ethyl acetate extract of cotoneaster exhibited antimicrobial activity at a concentration of 2.5 mg/ml against both standard and isolated bacteria. The MIC value was determined as 1.25 mg/ml for MRSA strain. The authors concluded that *E. faecalis* was the most sensitive bacteria and *B. cereus, K. pneumoniae,* and *S. enteritidis* were the most resistant bacteria to the tested cotoneaster extracts except to ethyl acetate extract. The extracts of cotoneaster displayed antimicrobial activity against both *S. aureus* ATCC 43300 and all of the14 tested MRSA *S. aureus* strains. Water extract of Cotoneaster exhibited significant anti MRSA activity at doses of 0.625 mg/ml against 10 MRSA strains. The methanol extracts of Cotoneaster showed anti MRSA activity at a dose of 2.5 mg/ml against 7 MRSA strain [184].

Cressa cretica

Antibacterial activity of various extracts of *Cressa cretica* and the crude alkaloid solution was tested against four micro organisms (*E. coli, Staphylococcus aureus, Proteus* Spp and *Pseudomonas* spp.). Antibacterial analysis revealed considerable antibacterial activity exerted by all the extracts except hexane extract and in the case of *Proteus* spp the extracts showed greater activity compared to the control. All extracts showed maximum activity against *E. coli* [185-186].

The antibacterial effect of the different fractions (hexane, ethylacetate and methanol) of the whole methanolic extract of *Cressa cretica* were studied against wide ranges of bacteria (both positive and negative strain) and five fungi *Candida albicans, Candida tropicalis, Aspergillus fumigatus, Aspergillus niger* and *Fusarium oxysporum* by agar disc diffusion method. Among the three fractions, the ethylacetate fraction of *Cressa cretica* showed the highest activity, but among the pathogens highest activity was revealed against *Escherichia coli, Klebsiella pneumoniae* (zone of inhibition diameter was found to be 26 and 31mm, respectively). The ethylacetate fraction was active against both gram positive and gram negative bacterias. *Cressa cretica* showed higher inhibitory activity against the *Aspergillus fumigates, Aspergillus niger* (zone of inhibition diameter was found to be 26 and 22mm, respectively) than the *Candida albicans* and *Candida tropicalis* and, the least activity was recorded against *Fusarium oxysporum* [187].

The antibacterial and antifungal activity of methanolic extract of *Cressa cretica* was studied by cup plate method against various organisms like *E. coli, S aureus, S. typhi, B. subtilis,* and *C. albicans.* 200-800µg/ml of the ethanolic extract showed dose dependent antimicrobial activity , the diameter of zone of growth inhibition (mm) was 25-30 against *E. coli*,15-25 against *S. aureus,* 20-30 against *S. typhi*, 20-25 against *B subtilis*, and 20-25 against *C. albican* [188].

Antifungal activity was exerted by ethanol extract of *Cressa cretica* against *Penicillium citrinum* (32.2 mm) and *Candida albicans* (25.7 mm) [189].

The antifungal activity of crude solvent extract of *Cressa cretica* against the dermatophytic fungi *Aspergillus niger, Aspergillus flavus, Paecilomyces varioti, Microsporum gypseum* and *Trichophyton rubrum* was investigated. The various crude solvent extracts were found to be effective against the test organisms, the chloroform and aqueous extracts appeared to be the most effective antifungal extracts, compared to the ethanol, methanol and ethyl acetate extracts [190].

Crotalaria juncea

The ethanol extract of flowers part (CJFEE) and seeds part (CJSEE) were evaluated for the antibacterial activity by the agar disc diffusion method against *C. freundi, E. coli, E. faecalis, K. pneumonia, P. aeruginosa, S. flexneri, S. aureus, S. dysenteriae and V. cholare*. Results revealed that CJSEE possess significant antibacterial activity against the *E. coli, K. pneumonia, P. aeruginosa, S. aureus* and *V. chlorae*.

However, the ethanol extract of seeds part had higher antibacterial than ethanol extract of flower parts of *Crotalaria juncea* [191].

The antibacterial activity of *Crotalaria juncea* seed oil (CJSPE) was evaluated by the disc diffusion method against *E. faecalis, S. aureus , E. coli, K. pneumonia, P. aeruginosa, S. flexneri, S. dysenteriae* and *V. cholare*. Results showed that CJSPE have good antibacterial activity against the *Staphylococcus aureus, Escherichia coli, Klebsiella pneumonia* and *Shigella flexneri*. However, the zone of inhibition showed by CJSPE was found less than that of ciprofloxacin (5 µg/disc) used as standard [192].

Antibacterial activity of crude extracts prepared in sodium phosphate buffer against *Xanthomonas* strain was studied. There has been found a highly strong activity of *Crotalaria juncea* extracted in sodium phosphate buffer against plant bacterial pathogen, *Xanthomonas oxanopodis* pv. *Punicae* [193].

Moderate antifungal activity has been reported in the methylene chloride and methanol extract of aerial parts of *Crotalaria juncea* of Indonesian origin [194].

Cyminum cuminum

Ethanol extracts of seed of *Cyminum cuminum* were tested for antimicrobial activity *in vitro* by the microdilution method. Ethanol extract of seed exhibited antimicrobial activity against biofilm *Escherichia coli*[195].

All essential oils, and cuminic aldehyde, were tested, using agar diffusion and serial dilution methods, against different Gram-positive and Gram-negative bacteria isolated from different sources of food (pork fillet, minced meat and sausages) and clinical isolates, as well as three different *Candida albicans* isolates. All cumin oils and cuminic aldehyde exhibited a considerable inhibitory effect against all the tested organisms, except *Pseudomonas* spp [196].

The volatile oil of *Cuminum cyminum* was active against *Staphylococcus epidermidis, S. aureus, S. haemolyticus, Propionibacterium acnes, Corynebacterium diphtheriae, Erysipelothrix rhusiopathiae, Bacillus cereus, Clostridium tetani, C. difficile, Escherichia coli, Salmonella typhi, Klebsiella pneumoniae, Vibrio cholerae, Aeromonas hpydrophila, Mycobacterium tuberculosis* and *Neisseria gonorrhoeae, Asperigillus niger, Saccharomyces cerevisae* and *Colletrotrichum gloeosporioides*. The antimicrobial activity induced by methanolic, hydroalcoholic and aqueous extracts was less that that produced by volatile oils [197].

The essential oil of Bulgarian *Cuminum cyminum* was active against *Aspergillus niger, Bacillus subtilis, Staphylococcus epidermidis, Saccharomyces cerevisiae* and *Candida albicans* [198].

The inhibitory effect of steam distilled essential oil of cumin fruits was tested against 3 Gram-negative bacteria (*Pseudomonas fluorescens, Escherichia coli*, and *Serratia marcescens*), 4 Gram-positive bacteria (*Staphylococcus aureus, Micrococcus* spp., *Sarcina* spp., and *Bacillus subtilis*), an acid fast bacterium (*Mycobacterium phlei*), and one yeast (*Saccharomyces cerevisiae*). The results showed that cumin oils possessed strong antimicrobial activity [199].

The essential oils from seeds of *Cuminum cyminum,* exerted antifungal activity against *Aspergillus flavus* [200].

The cumin essential oil showed activity against *E. coli, Pseudomonas aeruginosa* and *Salmonella sp.* and their inhibitory zones were 18, 10 and 23 mm, respectively [201].

The antimicrobial activity of the essential oil of cumin (*Cuminum cyminum*) seeds was studied against different strains of microorganisms. Antimicrobial testing showed high activity of the essential *Cuminum cyminum* oil against *Candida albicans*, *Aspergillus niger*, the Gram positive bacteria *Bacillus subtilis* and *Staphylococcus epidermidis* as well as the yeast (*Saccharomyces cerevisiae*) [202].

Cuminum cyminum essential oil exhibited strong antimicrobial activity against *E. coli, S. aureus* and *L. monocytogenes*. Complete death time on exposure to *Cuminum cyminum* oil was 20, 180 and 90 min for *E. coli, S. aureus* and *L. monocytogenes*, respectively [203].

Cuminum cyminum essential oils possessed antifungal activity against *Botrytis cinerea, Rhizopus stolonifer* and *Aspergillus niger*. The incorporation of 750 µl/1 from *Cuminum cyminum* oils to PDA medium was completely inhibited the growth of *B. cinerea, R. stolonifer* and *A. niger* [204].

The fungicidal activities of p-isopropyl benzaldehyde and p-isopropyl benzoic acid extracted from *Cuminum cyminum* were studied against *Alternaria solani, Verticillium dahliae, Rhizoctonia cerealis, Alternaria alternata, Gaeumannomyces graminis, Sclerotinia sclerotiorum, Phytophthora capsici, Thanatephorus cucumeris, Blumeria graminis* [*Erysiphe graminis*] and *Botrytis cinerea*. The bioassay results showed that both compounds had fungicidal activities *in vivo* and *in vitro*. P-isopropyl benzaldehyde and p-isopropyl benzoic acid had better inhibitory effects against *Sclerotinia sclerotiorum*, and their EC_{50} were 2.1 and 7.3 mg/l respectively. In a concentration of 1000 mg/l, the protective effects of p-isopropyl benzaldehyde and p-isopropyl benzoic acid treatments

were higher than 50% against *Blumeria graminis*. At the same concentration, the control effect of p-isopropyl benzoic acid treatment was 57.52% against *Sclerotinia sclerotiorum*, which was comparable to sumilex treatment [205].

The effectiveness of the essentials oils from cumin (*Cuminum cyminum*) was studied on the growth of some bacteria commonly used in the food industry, *Lactobacillus curvatus*, *Lactobacillus sakei*, *Staphylococcus carnosus* and *Staphylococcus xylosus* or related to food spoilage *Enterobacter gergoviae*, *Enterobacter amnigenus*. The agar disc diffusion method was used to determine the antibacterial activities of the oils. *Cuminum cyminum* essential oils showed an inhibitory effect against all the tested bacteria [206].

The antifungal activities of the essential oils obtained from *Hyssopus officinalis*, *Cuminum cyminum*, *Thymus vulgaris* and cones of *Cupressus arizonica* were evaluated against *Aspergillus flavus*. Different concentrations of the essential oils on conidial germination and germ tube elongation were determined *in vitro*. Essential oils were applied in 5 levels (0, 0.125, 0.25, 0.375 and 0.5%). The results showed that the essential oil of *Cuminum cyminum* was more effective in comparison with others [207].

The storage life of the strawberry fruits was increased by the use of Cumin (*Cuminum cyminum*) essential oils significantly, because they inhibited the fungi (*Botrytis cinerea*) [208].

Cuminum cyminum oil exhibited higher antibacterial and antifungal activities with a high effectiveness against *Vibrio spp*. strains with a diameter of inhibition zones ranging from 11 to 23 mm, and MIC and MBC values ranging from (0.078-0.31 mg/ml) to (0.31-1.25 mg/ml) respectively [209].

A great inhibition of *Cuminum cyminum* essential oil was recorded on *Pseudomonas syringae* pv. Syringae [210].

The ranges of minimum inhibitory concentration of *Cuminum cyminum* oils against several food-borne pathogens (*Staphylococcus aureus*, *Bacillus cereus*, *Escherichia coli* O157:H7, *Salmonella enteritidis* and *Listeria monocytogenes*) were 0.37-3.0 mg/ml. Moreover, the combination of *B. persicum* and *Cuminum cyminum* essential oils confirmed synergistic and additive activities against the pathogens [211].

The antifungal activity of the volatile parts (at doses from 5 to 20 microl) of the essential oil of fruits of *Cuminum cyminum* was tested on dermatophytes and phytopathogens, fungi, yeasts and some new *Aspergilli*. Antifungal testing showed that *Cuminum cyminum* was active on all fungi but in particular on the dermatophytes, where *Trichophyton rubrum* was the most inhibited fungus at the lowest dose of 5 µl. Phytopathogens were less sensitive to the treatment [212].

The chemical composition of essential oils from cumin (*Cuminum cyminum*), laurel (*Laurus nobilis*), oregano (*Oreganum onites*), rosemary (*Rosmarinus officinalis*), anise (*Pimpinella anisum*) and clove (*Syzygium aromaticum*) was determined and their antibacterial activities were tested aginst *Salmonella typhimurium* CCM 5445, *Staphylococcus aureus* (MRSA) RSKK 95047, *Staphylococcus aureus* ATCC 6538P, *Escherichia coli* ATCC 29998 and *Escherichia coli* O157:H7 RSKK 232 by two different methods (disc diffusion and agar dilution). The results showed that oregano essential oil showed the highest inhibition (0.0625-0.125 mg/ml) effect followed by cumin (0.0625-2.0 mg/ml) and clove (0.25-1.0 mg/ml) [213].

Antibacterial activity of seed extracts of cumin (*Cuminum cyminum*) was investigated against 10 Gram positive and Gram negative bacteria. Disc diffusion method was used to test the antibacterial activity. Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) were determined by using standard procedures. The highest inhibition zone of 16.67±0.47 mm was found at 250 mg/ml against *Escherichia coli.* On the other hand, the inhibition zones 15.00±0.82 mm for ethanol, 15.33±0.47 for methanol, and 15.67±0.82 for acetone were recorded against *Bacillus subtilis*, *Sarcina lutea* and *Klebsiella pneumonia*, respectively. MIC value (20 to 50 mg/ml) and MBC value (40 to 60 mg/ml) were recorded against the studied bacteria [214].

Antibacterial activity of *Cuminum cyminum* essential oil was observed against Gram-positive and Gram-negative bacterial species. The activity was particularly high against the genera *Clavibacter*, *Curtobacterium*, *Rhodococcus*, *Erwinia*, *Xanthomonas*, *Ralstonia*, and *Agrobacterium*, which were responsible for plant or cultivated mushroom diseases worldwide. In general, a lower activity was observed against bacteria belonging to the genus *Pseudomonas* [215].

Antimicrobial activities and biofilm-formation preventive properties of *Cuminum cyminum* essential oils and chlorhexidine were assessed against *Streptococcus mutans* and *Streptococcus pyogenes*. The minimal bactericidal concentrations (MBC) of the oils and chlorhexidine and microbial decimal reduction time (D value) were determined. *Cuminum cyminum* induced mild antibacterial and *in vivo* biofilm preventive effects (less than chlorhexidine). *In vivo* experiments conducted on male and female volunteers who brushed with essential oil blended toothpastes indicated that lower concentrations of the oils were

significantly higher ($p<0.001$) and effective during the course of the study as compared to chlorhexidine [216].

The effect of different concentrations of *Cuminum cyminum* essential oil (0, 15, 30 and 45 µl/100 ml) and nisin (0, 0.5 and 1.5 µg/ml) combination at different temperatures (10, 25 and 35°C) was studied on growth of *Salmonella typhimurium* and *Staphylococcus aureus* in the brain-heart infusion (BHI) broth model. The concentrations of 0 µl/100 ml for essential oil and 0 µg/ml for nisin imply the negative control. The growth of *S. typhimurium* was significantly decreased by the concentration of essential oil ≥ 30 µl/100 ml in combination with nisin ≥ 0.5 µg/ml at temperature = 10°C ($p<0.05$). Also, in combination of the essential oil ≥ 15 µl/100 ml and nisin ≥ 0.5 µg/ml at temperature ≤ 25°C, the growth of S. aureus was significantly reduced ($p<0.05$). The results indicated that the combination of essential oil and nisin inhibited the growth of *S. typhimurium* and *S. aureus* bacteria and there was the possibility of using them as substitutes for chemical food preservatives [217].

The antimicrobial activity of cumin oil against many pathogenic bacteria, showed that *E. coli*, *S. aureus*, and *S. faecalis* were sensitive to various oil dilutions [218].

The antmicrobial activity of *Cuminum cyminum* essential oil was evaluated against: *Micrococcus luteus* LA 2971, *Bacillus megaterium* NRS, *Bacillus brevis* FMC 3, *Enterococcus faecalis* ATCC 15753, *Pseudomonas pyocyaneus* DC 127, *Mycobacterium smegmatis* CCM 2067, *Escherichia coli* DM, *Aeromonas hydrophila* ATCC 7966, *Yersinia enterocolitica* AU 19, *Staphylococcus aureus* Cowan 1, *Streptococcus faecalis* DC 74 bacteria, and *Saccharomyces cerevisiae* WET 136, *Kluvyeromyces fragilis* DC 98 fungi). *Cuminum cyminum* essential oil (2 µl) exerted antibacterial effect against all the tested microorganisms with MIC ranged from 10- 60mm. While the inhibition zone was higher in the bacteria *E. faecalis*, it was lowest in *E. coli* and *P. pyocyaneus*. Among the fungi, the inhibition zone against *K. fragilis* was higher than *S. cerevisiae*. In combined application of *Cuminum cyminum* essential oil (2 µl) and gentamicin antibiotics discs, a synergistic effect in *P. pyocyaneus* and *A. hydrophila*, an antagonistic effect in other bacteria were noted [219].

The antimicrobial effects of garlic, bay, black pepper, origanum, orange, thyme, tea tree, mint, clove, and cumin essential oils were studied against *Listeria monocytogenes* AUFE 39237, *Escherichia coli* ATCC 25922, *Salmonella enteritidis* ATCC 13076, *Proteus mirabilis* AUFE 43566, *Bacillus cereus* AUFE 81154, *Saccharomyces uvarum* UUFE 16732, *Kloeckera apiculata* UUFE 10628, *Candida albicans* ATCC 10231, *Candida oleophila* UUPP 94365, and *Metschnikowia fructicola* UUPP 23067. Thyme, origanum, clove, and orange essential oils were the most inhibitory against bacteria and yeasts. Cumin, tea tree, and mint oils inhibited the yeasts actively [220].

The activity of cumin seed essential oil and alcoholic extract against *Klebsiella pneumoniae* ATCC 13883 and clinical *K. pneumoniae* isolates was studied by evaluating the effect of subminimum inhibitory concentrations (sub-MICs) on cell morphology, capsule expression and urease activity. Growth of *K. pneumoniae* strains exposed to sub-MICs of *Cuminum cyminum* extracts resulted in cell elongation and repression of capsule expression. Urease activity was decreased [221].

The effects of the essential oils (EOs) of *Cuminum cyminum* on growth and aflatoxins production by *A. parasiticus* was evaluated. Minimal inhibitory concentrations (MICs) and minimal fungicidal concentrations (MFCs) of the EOs were determined. Determination of aflatoxin (AFB1, AFB2, AFG1, and AFG2) production was performed by immunoaffinity column extraction using reverse phase-high performance liquid chromatography. *Cuminum cyminum* oil exhibited strong activity (MIC_{90}: 1.6; MFC: 3.5 mg/ml) against *A. parasiticus*. Aflatoxin production was inhibited at 0.25 mg/ml of *Cuminum cyminum* [222].

Chloroformic and isoamyl alcohol extracts of *Cuminum cyminum* were investigated for their *in vitro* antibacterial activity against six human bacterial pathogens. The antibacterial activity was evaluated and based on the zone of inhibition using agar disc diffusion method. The tested bacterial strains were included *Streptococcus pyogenes, Staphylococcus epidermidis, Klebsiella pneumonia, Staphylococcus aurues, Serratia marcesnces*, and *Pseudomonas aeruginosa*. Chloroform and isoamyl alcohol extracts of *Cuminum cyminum* had significant effect against *P. aeruginosa, S. marcesnces* and *S. pyogenes* [223].

The potential of *Cuminum cyminum* (cumin) seed essential oil (EO) (as a plant based shelf life enhancer) was studied against fungal and aflatoxin contamination and lipid peroxidation. The EO showed efficacy as a preservative in food systems (stored wheat and chickpeas). The minimum inhibitory concentration and minimum aflatoxin inhibitory concentration of EO were 0.6 and 0.5 µl/ml respectively. The EO showed toxicity against a broad spectrum of food borne fungi. The antifungal action of EO on ergosterol content in the plasma membrane of *A. flavus* was determined. As a fumigant in food systems, the EO provided sufficient protection of food samples against fungal association without affecting seed germination. In view of the antifungal and antiaflatoxigenic nature, free radical scavenging potential and efficacy in food system, cumin seed EO may be able to provide protection of food

commodities against quantitative and qualitative losses, thereby enhancing their shelf life [224].

The *in vitro* antifungal activities of essential oil from *Cuminum cyminum* were studied against *C. albicans* ATCC 14053, *C. dubliniensis* ATCC CD60, *C. glabrata* ATCC 90030, *C. krusei* ATCC 6258 and *C. parapsilosis* ATCC 22019. *Cuminum cyminum* oil had a broad-spectrum antifungal activity against different pathogenic Candida species. Inhibition zone values were ranged from 7 to 50mm against the tested organisms. The best minimal inhibitory concentration (MIC) of *Cuminum cyminum* oil was recorded against *C. albicans* and *C. dubliniensis* (289 mg/l) [225].

The antifungal activity of cumin oil was evaluated on mycelia growth of 90 fungal isolates (eighty-seven species and 3 species varieties belonging to 32 genera). The agar-well diffusion method was used to evaluate fungal growth inhibition at a concentration of 100%. Cumin oil was highly effective against all the isolates of tested fungi. It was completely inhibited mycelial growth of all fungi when added to solid medium [226].

The effect of *Cuminum cyminum* essential oil was studied in the growth and FUM1 gene expression of fumonisin-producing *Fusarium verticillioides* strains isolated from maize. FUM1 transcript levels were quantified using a reverse transcription-polymerase chain reaction (RT-PCR) protocol. Minimum inhibitory concentration (MIC) values of *Cuminum cyminum* oil against *F. verticillioides* strains varied from 0.195 to 0.781 µl/ml (mean MIC value: 0.461 µl/ml) indicating 54.5% of the fungal strains were inhibited at 0.390 µl/ml. PCR analysis of FUM1 gene expression revealed that DNA fragment of 183 bp was amplified in all the isolates of *F. verticillioides* before treatment with *Cuminum cyminum* essential oil. Based on RT-PCR analyses, reduction in the expression of fumonisin biosynthetic genes was significant only for FUM1 gene ($p<0.05$), while no effect was observed on ITS gene [227].

The essential oils of *Cuminum cyminum* showed antiviral activities against herpes simplex virus 1 (HSV-1) using cytopathicity (CPE) assay. At concentration of 1000 µg the antiviral activity reached 91.60 ± 1.93 [228].

Cupressus sempervirens

The antibacterial activity of the methanol, ethanol and ethyl acetate extracts of the aerial parts of *Cupressus sempervirens* were studied against *S. aureus* (ATCC6538), *B. subtilis* (ATCC6633), *P. aeruginosa* (ATCC6643), *E. coli* (ATCC15224), *K. pneumonia* (MTCC618) and *S. typhimurium (*ATCC13048). The extracts were used in 8 concentrations (1, 2, 3, 5, 7.5, 10 , 12.5 and 15 mg/ml). All *Cupressus sempervirens* extracts induced dose dependent bacterial growth inhibition against all the tested bacteria [229].

The antibacterial and antifungal activities of water and chloroform extracts of *Cupressus sempervirens* were carried out against six bacterial strains *Bacillus subtillis, Proteus vulgaris, Staphylococus aureus* (Gram-positive), *Escherichia coli, Pseudomonas aeruginosa, Salmonella typhi* (Gram-negative), and fungal species *Aspergillus niger and Candida albicans*. *Cupressus sempervirens* showed high activity against Gram positive bacteria (zone of inhibition 9-14 mm for water extract and 9-12 mm for chloroform extract), low activity against Gram negative bacteria (zone of inhibition 1-6 mm for water extract and 1-5 mm for chloroform extract). However, water extract showed no activity against fungi, but chloroform extract showed mild activity against *Candida albicans* (3mm) [230].

The antibacterial activity of methanolic, ethanolic and ethyl acetate extracts of leaf of *Cupressus sempervirens* was determined against six bacteria (*Staphylococcus aureus, Bacillus subtilis, Pseudomonas aeruginosa, Escherichia coli, Klebsiella pneumoniae* and *Salmonella typhimurium*) using agar well diffusion method. Among the plant extracts, a significant antimicrobial activity was obtained by methanolic extracts followed by the ethyl acetate and ethanol extracts. The methanolic extract exhibited maximum inhibitory activity against *K. pneumonia, B. subtilis* and *S. aureus*. The ethanolic extract showed higher activity against *P. aeruginosa*. Greater inhibitory activity against *S. typhimurium* and *E. coli* was possessed by ethyl acetate extract of *Cupressus sempervirens* [231].

Essential oil exerted moderate *in vitro* antimicrobial activity against all tested bacteria, including Gram positive (*Bacillus cereus , Enterococcus feacalis, Serratia marcescens, Staphlococcus aureus*), and Gram negative (*Aeromonas hydrophila, Escherichia coli, Klebsiella pneumonia, Proteus vulgaris, Pseudomonas aeruginosa, Salmonella indica*) with diameter zones of inhibition 4 to 12 mm, with MIC and MBC values ranging from 62.5 to 250 µg/ml. However, the methanol extract of *Cupressus sempervirens* was strongly inhibited the growth of all tested bacteria [232].

The antimicrobial activity of *Cupressus sempervirens* essential oil was studied against ten bacteria and fungi (*Pseudomonas aeruginosa, Escherichia coli, Staphylococcus aureus, Bacillus subtilis, Halomonas elongate, Salmonella typhimurium, Enterococcus hirae, Aspergillus niger, Candida albicans* and *Trichoderma reesei*). The results revealed that the oil of *Cupressus sempervirens* inhibited the growth of susceptible bacteria, filamentous fungi and yeasts. The MIC and MCC values indicated that *Cupressus sempervirens* essential oil was highly

effective. In addition, MIC/MCC ratio confirmed a bactericidal and fungicidal activity of the essential oil. However, the antimicrobial activity of the *Cupressus sempervirens* essential oils was more pronounced against Gram-positive than Gram-negative bacteria [233].

The zone of inhibition of 2 and 4 µl/disc of essential oil of *Cupressus sempervirens* against the tested microorganisms were (respectively): *Micrococcus luteus* 10 and 13; *Staphylococcus aureus* 7 and 8; *Mycobacterium simegmatis* 10 and 11; *Pseudomonas pyocyaneus* 9 and 11; *Yersinia enterolitica* 8 and 9; *Aeoromonas hydrophila* 7 and 10; *Enterococcus faecalis* 7 and 9; *Bacillus megaterium* 7 and 9; *Streptococcus faecalis* 7 and 9; *Bacillus brevis* 7 and 8; *Saccharomyces cerevisiae* 9 and 10; and *Klyveromyces fragilis* 15 and 17 mm [234].

The essential oil of *Cupressus sempervirens* was tested against three bacteria (*Escherichia coli, Micrococcus luteus,* and *Bifidobacterium lactis*) and seven fungi *(A. niger, A. flavous, A. fumigatus, F. solani, F. oxysporium, P. digitatum,* and *C. terus*). The zone of inhibition of essential oils after 96 hr incubation against *Escherichia coli* was 16.11 mm, *Micrococcus luteus* 11.90 mm and *Bifidobacterium lactis* 24.05 mm. Regarding antifungal effect of the essential oil, the zone of inhibition ranged from 5.7 mm against *F. solani* to 29 mm against *P. digitatum* after 96 hr of incubation [235].

Diterpenes, 6-deoxytaxodione (11-hydroxy-7, 9(11), 13-abietatrien-12-one), and taxodione isolated from *Cupressus sempervirens* cones (fruits) showed potent antibacterial activities (IC_{50} 0.80 and 0.85 µg/ml) against methicillin-resistant *Staphylococcus aureus* [236].

The *in vitro* antifungal activity of the essential oil samples of *Cupressus sempervirens* were evaluated against 8 cultivated crop fungi (*Fusarium culmorum*, *Fusarium oxysporum*, *Fusarium equisiti*, *Fusarium verticillioides*, *Fusarium nygamai*, *Botrytis cinerea*, *Microdochium nivale* var. nivale and *Alternaria* sp), and all samples of essential oil of *Cupressus sempervirens* have shown a significant antifungal activity against all tested fungi [237].

Essential oils isolated from *Cupressus sempervirens* var. *dupreziana* leaves were tested for antifungal activity against 10 agricultural fungal species (*Gibberella avenacea, Fusarium culmorum, Fusarium oxysporum, Fusarium subglutinans, Fusarium verticillioides, Fusarium nygamai, Rhizoctonia solani, Microdochium nivale, Alternaria alternate*n and *Fusarium culmorum*). Results of *in vitro* antifungal test assays showed that oils significantly inhibited the growth of 10 plant pathogenic fungi [238].

Ethanol extracts of *Cupressus sempervirens, C. semipervirens* var. *horizontalis* and *Cupressus sempervirens* var. *cereiformis* were used to test their influence on herpes viruses (HSV-1). HeLa cells monolayers were infected with herpes viruses (HSV-1). Antiviral activity of the plant extracts assessed using Hematoxylin & Eosin method and observed under a light microscope. All tests were compared with a positive control, acyclovir. Results showed that all three plants have antiviral activity against HSV-1 virus. The most active extract was the extract obtained from *C. semipervirens.* Among the different parts tested, the fruit's extract possessed the strongest anti- HSV activity [239].

A proanthocyanidin polymer fraction (MW 1500–2000 daltons) isolated from *Cupressus sempervirens* L. exhibited true antiviral activity *in vitro* against two retroviruses, HIV and HTLV III B. No toxicity was observed at concentrations of 50 µg/ml which exceeded the IC_{50} values (1.5 to 15 µg/ml for HIV and 5 to 25 µg/ml for HTLV) [240].

Cuscuta planiflora

The antibacterial study of the methanol extract of Cuscuta planiflora showed moderate antibacterial activities against *Bacillus megaterium, Pseudomonas aeruginosa, Escherichia coli* and *Salmonella typhi* with MIC values of 4.96±0.20, 3.03±0.16, 3.47±0.20 and 4.07±0.08 mg/ml, respectively [241].

Cydonia oblonga

The antimicrobial activity of *Cydonia oblonga* leaves extracts against different microorganism strains was also investigated. Quince peel extract was the most active for inhibiting bacteria growth with minimum inhibitory and bactericide concentrations in the range of 102-5 x 10^3 microg polyphenol/ml. It appeared that chlorogenic acid acts in synergism with other components of the extracts to exhibit their total antimicrobial activities [242].

The ethanolic extract of *Cydonia oblonga* seeds was dissolved in dimethylsulfoxide (DMSO) to obtain the final concentrations: 500, 250, and125 mg/ml and the agar well diffusion method was used to determine antibacterial activity of extract. Six millimeter diameter wells were punched in to the agar and filled with 0.1ml of each extract. Solvents were used as negative control. Tract exexhibited antibacterial activity against *s. aureus* at all concentrations and the sensitivity increases directly with increasing the concentration, *s. epidermids* was sensitive at 500 mg/ml and *k. pneumonia* was sensitive at 250mg/ml. *E. coli* and *Moraxella* were resistant to ethanolic extract [243].

The antibacterial effects of *Cydonia oblonga* fruit and seed (ethanolic, acetonic and aquatic extracts)

were studied on some dermatic bacteria such as Pseudomonas aeruginosa, Staphylococcus aureus and Staphylococcus epidermidis. Ethanolic extract of quince seed was the most effective extract. Quince seeds extracts showed more antibacterial effect compared with Quince fruit. The aquatic extracts didn't show antibacterial effect [244].

The antibacterial effects of extracts of the fruit and seed of *Cydonia oblonga* Miller was studied against *Klebsiella pneumoniae*, *Escherichia coli* and *Enterobacter aerogenes*. The results showed that the ethanolic extract of seeds was the most effective. *E. coli* was the most sensitive bacterium to the extracts, and aqueous extract only showed antimicrobial effect against *E. aerogenes* [245].

The antimicrobial activity of *Cydonia oblonga* was studied *Cydonia oblonga* was performed by the diffusion method in dishes with disks embedded at the concentrations of 100, 200 and 400 mg/ml fruit decoction and crude extract from *Cydonia oblonga* leaves, were tested against six bacteria. The crude extract from leaves showed antibacterial activity, it partially inhibited the growth of *Streptococcus agalactiae* [246].

The antimicrobial effect of extracts from quince fruits was investigated against foodborne pathogenic (Staphylococcus aureus) strains. The antimicrobial effect was investigated by rapid impedance method. The antimicrobial effect of extracts was confirmed by decreasing of the integrated area of the impedimetric growth curve [247].

The *in vitro* anti-Helicobacter pylori activity of 33 substances, juices and plant extracts and 35 of their combinations were tested using an agar diffusion method on Columbia blood agar. Quince (*Cydonia oblonga*) juice demonstrated the strongest anti-H. pylori activity followed by cranberry juice [248].

The antifungal effects of ethanolic and acetonic extracts of *Cydonia oblonga* leaves were studied against Aspergillus niger. The results showed that the *Cydonia oblonga* extracts inhibited the growth of A. niger and ethanolic extract was more effective than acetonic extracts [249].

Anti-influenza viral activities of quince fruits phenolic extract was studied. Quince phenolics showed anti-influenza viral activity on the hemagglutination inhibition test [250].

Cymbopogon schoenanthus

Aqueous extract, proanthocyanidin rich extract, and organic extracts of *Cymbopogon schoenanthus* shoots from three different locations in south Tunisia were screened for antimicrobial activity. The proanthocyanidin extracts showed a good antimicrobial activity against *Streptococcus sobrinus* at low concentration (MIC=4mg/ml) [251].

Ethanol and chloroform extract of the plant were active against *Escherichia coli* and *Staphylococcus aureus*. However, ethanol extract was more active against *Escherichia coli*, while chloroform extract was more active against *Staphylococcus aureus* [252].

However, the aerial parts extract of *Cymbopogon schoenanthus* showed activity against *Staphylococcus aureus, Bacillus subtilis, Escherichia coli* and *Pseudomonas aeruginosa* [253].

The antimicrobial activity of *Cymbopogon schoenanthus* was evaluated against three pathogenic bacteria (*Staphylococcus aureus* MARSA, *Escherichia coli* and *Salmonella typhi*) and five common fungal species (*A. flavus, A. niger, C. spicifer, F. dimerum, M. circinelloides*), four crop threatening pathogenic fungi, (*Alternaria alternata*, *Cochliobolous spicifer*, *Stachybotrys atra* var microspora, and *Ulocladium botrytis*), as well as dermatophytic fungi (*Candida albicans*, *Candida tropicalis*, *Candida krusei*, *Epidermophyton floccosum*, *Trichophyton rubrum*, *Trichophyton mentagrophytes*, *Trichophyton verrucosum* and *Microsporium canis*). The aqueous extract of *Cymbopogon schoenanthus* showed antimicrobial activity against the tested fungi and bacteria while *F. dimerum, U. botrytis, C. albicans, C. tropicalis, E. floccosum* and *M. canis* tolerated the aqueous extracts. The organic extracts (methanol, ethylacetate and n-butanol) were more effective than the aqueous extract, they showed higher antifungal activity against the tested fungi, but *A. flavus, F. dimerum, S. atra var. microspora, C. albicans, C. tropicalis, C. krusei, E. floccosum, M. canis, T. rubrum* and *T. verrucosum* tolerated these extracts. Organic extraction of *Cymbopogon schoenanthus* showed high antibacterial activity against all the tested pathogenic bacteria (*Staphylococcus aureus* MARSA, *Salmonella typhi* and *Escherichia coli*) [254].

Cynodon dactylon

The *in vitro* antibacterial evaluation of the leaves extract of *Cynodon dactylon* was carried out against *Escherichia coli, Staphylococcus aureus* and *Streptococcus pyogenes.* 10% concentration of extract was found to be most effective as antibacterial concentration [255].

The aqueous extract of *Cynodon dactylon* (50-400 mg/ml) was used to determine the antimicrobial activity against *Pseudomonas aeruginosa, Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae, Proteus mirabilis* and *Candida albicans*. The aqueous extract of *Cynodon dactylon* exerted concentration

dependent antimicrobial activity against all the tested microorganisms except *Candida albicans* [256].

The hydroalcoholic extract of *Cynodon dactylon* was investigated for its antibacterial activity against two Gram positive bacteria (*Staphylococcus aureus* and *Staphylococcus albus*) and two gram-negative bacteria (*Escherichia coli* and *Pseudomonas aeruginosa*) using agar well diffusion method (zone of inhibition) and micro-dilution method (minimum inhibitory concentration). Hydroalcoholic extract of *Cynodon dactylon* possessed an effective antibacterial activity, from results of minimum inhibitory concentration, it appeared that all tested bacterial strains were sensitive to *Cynodon dactylon* extract [257].

The antimicrobial activity of *Cynodon dactylon* crude extracts from seven different solvents (acetone, chloroform, diethyl ether, ethanol, ethyl acetate, methanol, and n-pentane) was investigated against some pathogens (*Bacillus cereus, Bacillus subtilis, Escherichia coli, Klebsiella spp., Pseudomonas aeruginosa, Staphylococcus aureus, Streptococcus pyogenes,* and *Streptococcus pneumonia)* using disc diffusion method. The antimicrobial study revealed broad spectrum antimicrobial activity for ethanol (7.0–10.0 ± 0.0–1.0 mm) and ethyl acetate (7.0–12.0 ± 0.0–1.0 mm) extracts against all of the bacterial pathogens. Both methanol and acetone extracts showed activity against *B. cereus* (8.0 ± 0.0 mm) and *B. subtilis* (7.0 ± 0.0 mm), while chloroform extract showed activity against *B. subtilis* (7.0 ± 0.0 mm) and *S. pyogenes* (8.3 ± 0.6 mm). activity was observed from n-pentane extraction. Great antimicrobial activity were observed for both ethyl acetate and ethanol extracts with size of inhibition ranging from 8.0 ± 0.0 mm to 15.7 ± 0.6 mm for ethyl acetate and 8.0 ± 0.0 mm to 13.0 ± 0.0 mm for ethanol extract. No significant antimicrobial activity was observed against *A. niger* [258].

Six different organic solvents were used to extract the bioactive compounds from the leaves of *Cynodon dactylon* to screen the antibacterial activity against bacterial pathogens (*Bacillus subtilis, Streptococcus pyogens, Klebsiella pneumoniae, Staphylococcus aureus, Escherichia coli, Proteus mirabillis* and *Pseudomonas aeruginosa*) by paper disc method. The butanolic extract of *Cynodon dactylon* was the most active against most of the tested organism, followed by ethyl acetate, methanol, petroleum ether and chloroform extract [259].

The antimicrobial activity of ethanol, methanol, acetone, chloroform, hexane and petroleum ether extract of *Cynodon dactylon* was tested against infectious disease causing bacterial pathogens (*E.Coli, Pseudomonas aeruginosa, Staphylococcus aureus* and *Klebsiella pneumonia*) and fungi (*Aspergillus niger, Candida albicans, Candida kefyr* and *Candida tropicalis*) using the agar well diffusion method. It was observed that ethanol, methanol, acetone, chloroform, hexane and petroleum ether showed activity against bacteria and fungi. The ethanol extract of *Cynodon dactylon* showed more activity against *Pseudomonas aeruginosa* (zone of diameter 13.83±0.29mm), *Staphylococcus aureus* (zone of diameter 12.0±0.10mm) and the ethanol extract of *Cynodon dactylon* showed more activity against *Aspergillus niger* (zone of diameter 12.23±0.21mm) and *Candida albicans* (zone of diameter 11.0±0.20mm), when compared to other solvent extracts [260].

The antimicrobial activity of *Cynodon dactylon* crude extract from three different extraction (hot and cold aqueous extraction and methanol extraction) was investigated against some of the Gram positive bacteria (*Staphylococcus epidermidis* and *Bacillus cereus*) and Gram negative bacteria (*Escherichia coli, Pseudomonas aeroginosa, Salmonella typhi* and *Shigella dysenteriae*) using disc diffusion method. Amoxicillin and Gentamicin were taken as positive control. The aqueous extract of *Cynodon dactylon* had antimicrobial activity against all the test organisms which indicated broad spectrum activity of the extract against both Gram positive and Gram negative bacteria, while, no clear zone formed with methanol extract [261].

The antibacterial activity of the leaf extracts of *Cynodon dactylon* was investigated against pathogenic bacteria (*Bacillus subtilis, Staphylococcus aureus, Escherichia coli Klebsiella pneumonia* and *Pseudomonas aeruginosa*), by *in vitro* agar well diffusion method. The results showed that chloroform *Cynodon dactylon* leaf extracts possessed antibacterial activity against all the tested bacteria. Chloroform extracts of *Cynodon dactylon* at a concentration of 75µl /ml exhibited relatively higher zone of inhibition compare to 25 and 50µl/ml. However, the *Bacillus subtilis, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa* and *Staphylococcus aureus* were resistant to aqueous leaf extracts of *Cynodon dactylon* [262].

Antiviral activity of a large scale produced plant extract of *Cynodon dactylon* on white spot syndrome virus (WSSV) was studied in black tiger shrimp *Penaeus monodon* by an *in vivo* testing. The plant extract of *Cynodon dactylon* was incorporated with artificial pellet feed at a concentration of 1% or 2%. *Cynodon dactylon* was highly effective in preventing WSSV infection with no mortality [263].

The *in vitro* virustatic and virucidal tests of the crude extract of *Cynodon dactylon* against infection with porcine reproductive and respiratory syndrome virus (PRRSV), were studied. Crude extract of *Cynodon dactylon* was prepared for cytotoxicity on tissue-culture cells that were used to measure virustatic and virucidal activities against PRRSV. Crude extract of *Cynodon*

dactylon at 0.78 mg/ml showed no cytotoxicity on the cell line, and at that concentration significantly inhibited replication of PRRSV as early as 24 hours post infection. *Cynodon dactylon* also inactivated PRRSV as determined by immunoperoxidase monolayer assay (IPMA) compared to the control experiments [264].

The luteolin and apigenin rich fraction was obtained from the ethanolic extract of *Cynodon dactylon*, and it was evaluated for cytotoxicity and anti-Chikungunya potential using Vero cells. The fraction exhibited potent viral inhibitory activity (about 98%) at the concentration of 50 µg/ml as observed by reduction in cytopathic effect, and the cytotoxic concentration of the fraction was found to be 250 µg/ml. RT-PCR analyses indicated that the reduction in viral mRNA synthesis in fraction treated infected cells was much higher than that of viral infected control cells [265].

Cyperus rotuntdus

The antimicrobial activity of oils of *Cyperus rotuntdus* was studied by disc agar diffusion method. The diameters of zones of inhibition were measured comparing with negative control, as well as ofloxacine, rifampicine and amphotricine B (5 µg/disc) as positive control for each micro-organism. *Cyperus rotundus* essential oil was significantly active against Gram-positive microorganisms (*Staphylococcus aureus* and *Streptococcus species*), moderately active against *Sarcina lutea*, *Bacillus subtilis* and the acid fast *Mycobacterium phlei* and fungi (*Candida* species). The oil is completely inactive against Gram- negative microorganisms [266].

Cyperus rotundus rhizomes petroleum ether, chloroform, ethanol and water extracts were evaluated against six important pathogenic microbes (*Staphylococcus epidermidis, Bacillus cereus, Pseudomonas aeruginosa, Escherichia coli, Aspergillus niger and Candida*). The antibacterial and antifungal activities were performed by both agar well diffusion and serial dilution methods. The ethanolic extract exhibited highest activity against the tested bacteria. However all extracts were ineffective against fungal strains. The inhibitory effect is very similar and comparable with that of standard drug [267].

The growth and acid production of *Streptococcus mutans* were reduced by the tuber extract of *Cyperus rotundus*. *S. mutans* is known as the causative bacteria in the formation of dental plaque and dental caries. Moreover, the same tuber extract inhibited the adherence of *S. mutans* to saliva coated hydroxyapatite beads. Glucosyl transferase enzyme, which synthesized water-insoluble glucan from sucrose, was also inhibited by the tuber extract. Accordingly *Cyperus rotundus* inhibited cariogenic properties of S. *mutans* [268].

The oil of *Cyperus rotundus* was tested against various bacterial and fungal strains (*Bacillus subtilis, Escherichia coli, Pseudomonas* aeruginosa and *Staphylococcus aureus, Candida parapsilosis, Aspergillus flavus, Aspergillus fumigatus* and *Fusarium oxysporum*) in different concentrations. At 100% concentration the oil showed good activity against *Escherichia coli, Staphylococcus aureus, Bacillus subtilis* and *Pseudomonas aeruginosa* and less activity against *Micrococcus luteus and Klebsiella sp.* At low concentration the oil was also effective against *S. aureus.* Oil also showed good antifungal activity against *Candida parapsilosis* and *Aspergillus fumigatus*. It also inhibited spore formation of *Fusarium oxysporum* and *Aspergillus flavus* [266].

The antibacterial properties of *Cyperus rotundus* root extracts (petroleum ether, acetone, methanol and water) was investigated against three Gram-positive and two Gram-negative bacteria causing respiratory tract infections. Results showed that methanol extract was the most active as comparison to other extract. The maximum inhibition was noted against *H. influenzae* (18.4±0.07 mm) followed by *S. pyogenes* (17.3±0.13mm), *P. aeruginosa* (16.2±0.07 mm) and *S. pneumoniae* (15.5±0.15 mm) and the minimum activity was recorded against *S. aureus* (15.3±0.05 mm) respectively [269].

Methanolic extract of the fresh aerial part of the *Cyperus rotundus* was fractionated by column chromatography method using petroleum ether, chloroform, ethyl acetate and methanol. The *in vitro* antibacterial activity was carried out against (*Bacillus subtilis, Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa*) for all fractions. The ethyl acetate fraction showed potent antibacterial activity compared to control and standard commercial antibiotic tetracycline [270].

The Antibacterial activity of Cyperus oil was studied against (*Staphylococcus aureus, Klebsiella pneumoniae, Proteus vulgaris, Streptococcus pyogenes, Eschirichia coli* and *Pseudomonas aeruginosa*). The MIC and MBC for each microbe were estimated. The oil of *Cyperus rotundus* exerted remarkable activity against Gram-positive bacteria, less antibacterial activity was recorded against Gram–negative bacteria and no activity against *Pseudomonas aeruginosa* and *Proteus vulgaris* [271].

Antimicrobial activity of *Cyperus routunds* ethanolic extract was carried out on human pathogenic bacteria such as *Morexilla catarhalis*, *Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus, Acinetobacter* and fungi *Candida albicans* and *Aspergillus niger*. Excellent, moderate low and no activity were found on these organism. Ethanolic extract caused 133.3% inhibition

of *K. pneumoniae* as compared to standard drug amoxicillin 20µg/ml. In case of *A. niger* and *S. aureus* 90 and 70 % inhibition was observed respectively, while the ethanolic extract showed low inhibition (46.66, 37.5 and 33.3% in *E coli*, *P. aeruginosa* and *M. catarhalis* respectively). No zone of inhibition was observed in *Acinetobacter* and *C. albican* [272].

Cyperus rotundus exerted virucidal effect against HSV [273]. Anti-HBV active constituents was isolated from the rhizomes of *Cyperus rotundus*. Five new patchoulane-type sesquiterpenoids, namely cyperene-3, 8-dione, 14-hydroxy cyperotundone, 14-acetoxy cyperotundone, 3β-hydroxycyperenoic acid and sugetriol-3, 9-diacetate, along with 32 known sesquiterpenoids were isolated from the active fractions of *Cyperus rotundus*. Nine eudesmane-type sesquiterpenoids significantly inhibited the HBV DNA replication with IC_{50} values of 42.7±5.9, 22.5±1.9, 13.2±1.2, 10.1±0.7, 14.1±1.1, 15.3±2.7, 13.8±0.9, 19.7±2.1 and 11.9±0.6 µM, of which, 4 compounds possessed high SI values of 250.4, 125.5, >259.6 and 127.5. Two patchoulane-type sesquiterpenoids effectively suppressed the secretion of HBsAg in a dose-dependent manner with IC_{50} values of 46.6±14.3 (SI=31.0) and 77.2±13.0 (SI=1.7) µM. Other 6 compounds possessed moderate activities against HBeAg secretion with IC_{50} values of 162.5±18.9 (SI=13.3), 399.2±90.0 (SI=10.6), 274.7±70.8 (SI=5.2), 313.9±87.5 (SI=7.2), 334.0±70.4 (SI=9.9) and 285.3±20.9 (SI=15.5) µM [274].

Conclusion:

This review was designed as a second part of a previously published review to cover the medicinal plants with antimicrobial activities.

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