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ANTIMICROBIAL PROPERTIES OF SOME SELECTED MEDICINAL PLANT

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ABSTRACT

Antimicrobial resistance represents a serious threat to human health across the globe. Plants produce a variety of bioactive secondary metabolites that could be used to fuel the future discovery pipeline. While many studies have focused on specific aspects of plants and plant natural products with antibacterial properties, a comprehensive review of the antimicrobial potential of plants has important role in prevention of several microbes such as bacterial fungus and further more information in future.

Keywords- Medicinal plant, antimicrobial properties, pharmacology, Chemical constituents

1. INTRODUCTION

Due to increasing concerns about the sustainability of human living, the control of the damaging effects of microorganisms is becoming very important. A wide range of microorganisms exist in a biological balance with the human body and its living environments, but an uncontrolled and rapid growth of microbes can lead to some dangerous problems. Antimicrobial agents are used as antibiotic drugs to control infections in the human body, but they can cause many side effects, especially increasing reactive oxygen species (ROS) in the human body. ROS are very dangerous to human health and well-being and play a role in producing cancer; further, they can increase potential health risks.

The herbal materials used as medicinal plants include several types of plants. Many of these herbal materials show medicinal activities such as antioxidant, anticancer, anti-inflammatory, antimicrobial, and antiviral activities. Furthermore, these herbs can play the main role in drug synthesis and development. These materials show a significant role in different biological applications such as cancer therapy, cardiovascular disease treatment, neural disease treatment and skin regeneration. Herbal medicines performed the primary medicinal functions in ancient cultures in Africa, Europe, the Americas, and especially in Asia. Herbal medicines are the primary medicine to treat infection in some developing countries. The extracts of herbal materials signify continuous attempts to investigate new compounds with potential antibacterial activity. Several studies have shown that different herbal medicines are sources of diverse molecules, many of which exhibit radical scavenger and antimicrobial properties which can defend the human body against pathogens and also cellular oxidation reactions.

Therefore, these materials are significant in synthesizing different types of herbal medicine for their antimicrobial, antiviral, and antioxidant potential. These diverse molecules can control and inhibit pathogens with low toxicity to cells and are therefore considered as materials for new antimicrobial medicine research. Based on those above control methods for the terrible effect of the rapid growth of bacteria and viruses, many studies have focused on researching antibacterial and antiviral medicines with lower side effects.

An agent which can kill microorganisms or stop their growth is known as an antimicrobial agent or antimicrobial medicine. Antimicrobial medicines are categorized based on the primary microorganisms they act against such as bacteria and viruses.

Antimicrobial agents are divided into two groups based on their different chemical substances. The first group is synthetic antimicrobial agents (chemical antimicrobial agents) including antibiotic drugs and metal and metal oxide nanoparticles including silver, silver oxide, and so on. The second group is herbal antimicrobial agents. Antibiotics and other chemical antimicrobial agents play a big role as antimicrobial agents, but they lead to various side effects. One of the main side effects is the generation of free oxygen radicals (ROS). ROS are very toxic and have been thought to play a main role in producing cancer.

The second group is related to herbal antimicrobial agents, such as clove, cinnamon, turmeric, ginger, thyme, pennyroyal, mint, fennel, chamomile, burdock, eucalyptus, primrose, lemon balm, mallows, and garlic.

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2. ANTIMICROBIAL PROPERTY

Clove

Cloves are the aromatic flower buds of a tree in the family Myrtaceae, Syzygium aromaticum. They are native to the Maluku Islands, or Moluccas, in Indonesia, and are commonly used as a spice, flavouring, or fragrance in consumer products, such as toothpaste, soaps, or cosmetics.

Active compound-

Eugenol: This is the primary active compound in cloves and is responsible for its characteristic aroma and flavor. Eugenol also possesses antimicrobial, anti-inflammatory, and antioxidant properties.

Acetyleugenol: This is another compound found in cloves, which is structurally related to eugenol.

Caryophyllene: A natural compound with anti-inflammatory and antioxidant properties. It is also a common terpene found in various plants.

Figure.1 - clove plant

Antimicrobial Activity:

The antimicrobial activities of clove have been proved against several bacteria and fungal strains. Sofia et al. tested the antimicrobial activity of different Indian spice plants as mint, cinnamon, mustard, ginger, garlic and clove. The only sampled that showed complete bactericidal effect against all the food-borne pathogens tested Escherichia coli (E. coli), Staphylococcus aureus and Bacillus cereus was the aqueous extract of clove at 3%. At the concentration of 1% clove extract also showed good inhibitory action.

In another work published by Dorman and Dean, the antibacterial activity of black pepper, geranium, nutmeg, oregano, thyme and clove was tested against 25 strains of Gram positive and Gram negative bacteria. The oils with the widest spectrum of activity were thyme, oregano and clove respectively.

The antibacterial activity of clove, oregano (Origanum vulgare), bay (Pimenta racemosa) and thyme (Thymus vulgaris) essential oil was tested against E. coli O157:H7 showing the different grades of inhibition of these essential oil. Likewise formulations containing eugenol and carvacrol encapsulated in a non-ionic surfactant were tested against four strains of two important foodborne pathogens, E. coli O157:H7 and Listeria monocitogenes, results reinforces the employment of eugenol to inhibit the growth of these microorganisms in surfaces in contact with food. Rana et al. determined the antifungic activity of clove oil in different strains and reported this scale of sensibility Mucor sp.>Microsporum gypseum>Fusarium monoliforme NCIM 1100>Trichophytum rubrum>Aspergillus sp.>Fusarium oxysporum MTCC 284[22]. The chromatographic analyses showed that eugenol was the main compound responsible for the antifungic activity due to lysis of the spores and micelles. A similar mechanism of action of membrane disruption and deformation of macromolecules produced by eugenol was reported by Devi et al. The activities of clove oil against different dermatophytes as Microsporum canis (KCTC 6591), Trichophyton mentagrophytes (KCTC 6077), Trichophyton rubrum (KCCM 60443), Epidermophyton floccosum (KCCM 11667) and Microsporum gypseum were tested and results indicate a maximum activity at concentration of 0.2 mg/mL with an effectiveness of up to 60%. Pure clove oil or mixes with rosemary (Rosmarinus officinalis spp.) oil were tested against Staphylococcus epidermidis, Staphylococcus aureus, Bacillus subtilis, E. coli, Proteus vulgaris, Pseudomonas aeruginosa and results showed minimum inhibitory concentrations between 0.062% and 0.500% (v/v) which is promising as antiinfenccious agents or as food preservative.

The anticandidal activity of eugenol and carvacrol was tested in a vaginal candidiasis model, microbial and histological techniques were employed to compare the samples with the controls. The results suggest that eugenol and carvacrol could be a promising antifungal agent for treatment and prophylaxis of vaginal candidiasis.

In addition to the wide spectrum of activity of eugenol against bacteria, a study showed that eugenol and cinnamaldehyde at 2 μg/mL inhibited the growth of 31 strains of Helicobacter pylori, after 9 h and 12 h of incubation, respectively, being more potent that amoxicillin and without developing resistance. The activity and stability of those compounds was checked at low pH values since Helicobacter pylori resides in the stomach. Solid lipid nanoparticles containing eugenol were prepared employing stearic acid, caprylic triglyceride and Poloxamer 188 in different concentrations by a modified hot homogenization ultrasonication method. The particles formed were characterized by the particle size, polydispersitivity index, morphology, zeta potential, crystalline state and encapsulation efficiency. The antifungal activity of solid lipid nanoparticles was tested in vivo by using a model of oral candidiasis (Candida albicans) in immunosupressed rats. The results showed the increase in the therapeutic effectiveness of eugenol and the modification of the release when administrated as solid lipid nanoparticles. Beta-cyclodextrin inclusion complexes containing eugenol and clove bud extracts were tested against two common foodborne pathogens, Salmonella enterica serovar Typhimurium LT2 and Listeria innocua. Clove products have a great potential as food additives since they are very effective and for being natural products are preferred for consumers. Moreover, the solubility and the delivery are improved with the encapsulation process.

Cinnamon

Cinnamon (Cinnamomum verum and Cinnamomum zeylanicum) is one of the plants that belong to the Lauraceae family. This traditional herbal medicine is from Australia and Asia. Based on the antioxidant, antimicrobial, and anticarcinogenic activities of this plant, it is widely used in medical industries. Previous investigations have found cinnamon to have antimicrobial characteristics. Cinnamon has been traditionally used for its antiseptic, antioxidant, and antimicrobial properties. Previous studies have investigated the antimicrobial activities of cinnamon against various bacteria, such as Bacillus and E. coli. Cinnamon oil has shown antibacterial effects against E. coli, Listeria monocytogenes, Bacillus, Enterococcus faecalis, Salmonella typhimurium, Pseudomonas aeruginosa, Yersinia enterocolitica and Staphylococcus aureus.

Figure.2 - Cinnamon

Active compound

Cinnamaldehyde:

Primary compound responsible for cinnamon’s flavor and aroma.
Exhibits antioxidant properties

Cinnamic Acid:

Found in the form of cinnamate after metabolism.
Potential benefits include anti-inflammatory and antioxidant properties.

Cinnamate:

Formed from cinnamic acid during digestion.
Plays a role in cinnamon’s overall health effects.

Antimicrobial Activity:

These spices namely garlic (Allium sativum), turmeric (Curcuma longa) and cinnamon (Cinnamomum zeylanicum) were tested against Bacillus subtilis DSM3256 and Escherichia coli ATCC25922. All the spices used in research study were effective against the test bacterial strains but the best activity was shown by garlic forming a maximum zone of 26mm against Bacillus subtilus DSM 3256 and 22mm against E.coli ATCC 25922. The aqueous extracts of garlic made wider zones as compared to ethanolic extracts. The ethanol extracts of turmeric and cinnamon showed better results as compared to the aqueous, cinnamon ethanolic extract showed maximum zone of 17mm against E.coli (ATCC 25922 and 16mm against Bacillus subtilus DSM 3256, while aqueous extracts of garlic have shown better results as compared to the ethanol extracts. Maximum zone of inhibition given by ethanolic extract of turmeric was 14mm against Bacillus subtilis DSM 3256 and 11mm against E.coli ATCC 25922 .The diameter of zone of inhibition obtained against the three spices at 100% concentration by disk diffusion method was also compared to those obtained against two standard antibiotics imipenem and nalidixic acid as shown in table #3garlic extract produced wider zone of inhibition of 26mm as compared to nalidixic acid for Bacillus subtilis DSM 3256 while E.coli ATCC 25922 was resistant against nalidixic acid but the growth of E.coli was inhibited by garlic, turmeric and cinnamon. Imipenem was effective against both E.coli and Bacillus subtilis forming zones of 35mm and 23mm, respectively.

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Turmeric

Turmeric (Curcuma longa) is one of the herbal medicines used traditionally. It belongs to the Zingiberaceae family. Due to the existence of curcumin (a polyphenolic compound), the extracts of turmeric have shown antimicrobial and antioxidant activity. Therefore, the phenolic compound of curcumin is responsible for its antioxidant activities. The phytochemical structures in turmeric include vitamin C, cineole, tumerone, borneol, zingiberene, d-sabinene, and d-phellandrene. Many types of chemical compounds are found in turmeric including sesquiterpene Ketones, monoterpenes, and sesquiterpene alcohols (e.g., zingeberene). Fresh turmeric contains zingiberene, while the most significant curcuminoid presented in turmeric is curcumin. Previous literature has reported that turmeric has an antimicrobial (antibacterial and antifungal) effect. Curcumin is known for its inhibitory action on microorganisms such as E. coli, S. aureus, Salmonella typhimurium, and Pseudomonas aeruginosa.

Figure.3 - Turmeric plant

Active Compound:

Curcumin: Turmeric owes its characteristic yellow color and many of its health benefits to curcumin. Curcumin has demonstrated various therapeutic properties, including anti-inflammatory, antioxidant, and antifungal effects.

Antimicrobial activity:

The present study was undertaken to study the antifungal effect of curcumin and other synthetic antifungal agents against Aspergillus species isolated from poultry feed. During this study poultry feeds collected from poultry farm of Odisha Veterinary College. Various concentrations of curcumin like 25mg/disc, 50mg/disc, 100mg/disc and 200mg/disc were prepared and were tested by disc diffusion method. In this method antifungal activity of various agents like ketoconazole, voriconazole, itraconazole, clotrimazole, Amphotericin B, miconazole, caspofungin, fluconazole were tested and its zone of inhibition was found to be approximately ≥ 18 mm, ≥ 15mm, ≥ 16mm, ≥ 18mm, ≥ 7 mm, ≥ 10mm, ≥ 18 mm and≥ 10mm respectively. It has been revealed that curcumin treated Aspergillus species showed lesser zone of inhibition than synthetic antifungals like ketoconazole, voriconazole, itraconazole, clotrimazole Amphotericin B, caspofungin but in comparison to fluconazole and miconazole curcumin shows larger zone of inhibition. The antifungal sensitivity pattern shows that curcumin (200 mg/disc) has got the highest potential of antifungal action against A. flavus and A. fumigatus in comparison to synthetic antifungals.

Ginger

Ginger (underground rhizome of Zingiber officinale roscoe and herbaceous perennial plants) is one of the essential herbal medicinal plants from the Zingiberaceae family. Ginger (the rhizome of Zingiber officinale) is native to Asia and has been used as a medicine for more than two thousand years around the world. Ginger contains polyphenol components, including phenolic acids, gingerols, paradols, and shogaols. These principal components are responsible for its biological properties such as antioxidant, antidiabetic, antimicrobial, renoprotective, antihypertensive, antiulcer, anti-inflammatory, cardiovascular, analgesic, and gastrointestinal activities. The antioxidant activity of ginger is related to the chemical compounds present in ginger such as zingiberene, zingerone, shogaols, and gingerols. Some studies have analyzed the antioxidant activities of ginger and its components in numerous in vivo and in vitro lab experiments. Some researchers have demonstrated the potential antioxidant properties of ginger extract.

Figure. 4- Ginger plant

Active Compounds:

Gingerol: Ginger contains bioactive compounds, with gingerol being the primary active constituent. Gingerol has demonstrated antimicrobial properties, including antifungal activity against various fungal strains.

Antimicrobial Activity

The antioxidant effect and the total phenols of ginger extract were studied. The total phenols of the alcohol extract were found to be 870.1 mg/g dry extract. 2,2-Diphenyl-1-picril hydrazyl radical (DPPH) scavenging reached 90.1% and exceeded that of butylated hydroxytoluene (BHT), the IC_{50} concentration for inhibition of DPPH was 0.64 µg/ml. The antioxidant activity in a linoleic acid/water emulsion system determined by means of thiobarbituric acid reactive substances (TBARS) was highest at 37 °C – 73.2%, and 71.6% when the formation of conjugated dienes was inhibited. At 80 °C the antioxidant activity at the highest concentration of a ginger extract was less efficient: 65.7% for conjugated dienes formation and 68.2% for TBARS. The ginger extract inhibited the hydroxyl radicals 79.6% at 37 °C and 74.8% at 80 °C, which showed a higher antioxidant activity than quercetin. The IC_{50} concentration for inhibiting OH at 37 °C was slower than that at 80 °C – 1.90 and 2.78 µg/ml, respectively. The ginger extract chelated Fe^{3+} in the solution.

Thyme

Thyme (Thymus vulgaris) is one of the active antimicrobial herbal medicine plants which belong to the Lamiaceae family. It is more active against different bacteria and can inhibit the growth of bacteria such as Lactobacillus plantarum, Brochothrix thermosphacta, and Brevibacterium linens. This potent antimicrobial ability is related to the presence of high concentrations of carvacrol, thymol, and phenols in the extracts and essential oils of thyme. Thyme extracts and essential oil have demonstrated a long list of medicinal properties, such as antibacterial, antioxidant, antitussive, spasmolytic, anticancer, and anti-inflammatory characteristics. The extract of this plant has been traditionally used as an antitumor medicine due to its antioxidant property. Numerous studies in the literature have demonstrated that the higher phenolic content of thyme is responsible for the high radical scavenging and antioxidant properties of this medicinal plant.

Figure.5 -Thyme Plant

The structural variability of extracts and oils of thyme has been the subject of numerous studies. Some studies on the antimicrobial activity of thyme plants have evaluated the composition of thyme extracts and oil influenced by growing conditions, the genotype, and ontogenic development The antimicrobial ability of thyme has been reported against Pseudomonas aeruginosa, S. aureus, Klebsiella pneumonia, E. coli, and Bacillus. The antiviral activity of thyme has been reported against herpes simplex virus type 1.

Active compound-

Thymol: Thymol is a major component of thyme essential oil and is known for its strong antifungal and antibacterial properties. It has been widely studied for its efficacy against various fungi, including those that can cause infections in humans.

Carvacrol: Another important compound in thyme oil, carvacrol, also exhibits antifungal and antibacterial activities. It contributes to the overall antimicrobial effects of thyme.

Terpinene: Thyme essential oil contains Terpinene, which has demonstrated antifungal properties in research studies.

Antimicrobial Activity: Soković et al. who had studied the antibacterial and antioxidant properties of Mediterranean aromatic plants concluded that Thymus vulgaris L. was between those plants, which were inhibitory to the growth of all the microorganisms. Thyme was one of the most active and exhibited greatest inhibition against Brevibacterium linens, Brochothrix thermosphacta, and Lactobacillus plantarum. This effectiveness can be attributed to the high contents of phenols, thymol and carvacrol in the oil, which are known to be powerful antibacterial agents. Some other researchers reported that Thymus vulgaris L. essential oil at low concentrations (2, 5 and 8%) in a solution of water, propyleneglycol and an emulsifying agent, present highly effective antioxidant when used for Nile Tilapia fillets, at refrigeration temperatures and by placing the fillet immersed in the solution. The reduction of oxidative processes in tilapia fillets by using the essential oil occurred between 5.0 and 96.5%. This demonstrates its high effectiveness, even at low concentration. Silva N et al. recently proved the antibacterial activity of thyme against ten foods borne and food spoilage bacterial strains, Bacillus cereus; Clostridium perfringens; Enterococcus faecalis; Enterococcus faecium; Escherichia coli; Listeria monocytogenes; Pseudomonas aeruginosa; Salmonella enterica; Staphylococcus aureus; and Staphylococcus epidermidis. Khalili ST et al. recently used encapsulated forms of thyme oil in the preservation of tomato fruits and found that the encapsulated oil at 700 mg/l concentration was capable of preserving the quality the tomato fruit during the one-month storage period. Ulbin- Figlewica et al. studied the antimicrobial activity of different concentrations (0, 1000, 2000 ppm) of thyme extracts against Bacillus subtilis and Pseudomonas fluorescens and suggest the usage of plant extracts in the development of edible films and coatings that used in order to protect foods. Antimicrobial activity of the extracts offers improved food safety.

Garlic

Garlic (Allium sativum) is an herbal medicine belonging to the Amaryllidaceous family. Garlic is native to Central Asia, especially Iran. Garlic has been demonstrated to possess biological activities including antioxidant, immunomodulatory activities, antidiabetic, anticancer, antibacterial, cardio protective and anti-inflammatory effects. The major components of garlic are phenolic, polysaccharides, and organosulfur contents. It also contains saponins, amino acid, flavonoids, vitamins A and C, B-complex vitamins, and minerals. These chemical components are the reason for the biological activity of garlic. Garlic has been known as a natural antioxidant and can inhibit the harmful effects of free radicals in cells. Antioxidant materials are naturally found in different plants and can neutralize free radicals through electron donation and by converting these harmful molecules to harmless products. Garlic is one of the traditional medicines with antimicrobial and antioxidant characteristics. Garlic was demonstrated to exhibit antibacterial activity against a varied range of different bacteria (Gram-positive and Gram-negative) such as Klebsiella, Enterococcus faecalis, Pseudomonas, Salmonella typhi, Proteus, Staphylococcus aureus, and Escherichia coli

Figure. 6- Garlic

Active Compound:

Allicin: When garlic is crushed or chopped, allicin is produced. Allicin is a sulphur-containing compound with potent antimicrobial properties, including antifungal activity.

Antimicrobial Activity: Varying concentrations of fresh garlic juice (FGJ) were tested for their antimicrobial activity against common pathogenic organisms isolated at SSG Hospital, Vadodara, using well diffusion method. Moreover, minimum inhibitory concentration (MIC) and minimum lethal concentration (MLC) of FGJ were tested using broth dilution method. Sensitivity pattern of the conventional antimicrobials against common pathogenic bacteria was tested using disc diffusion method. FGJ produced dose-dependent increase in the zone of inhibition at a concentration of 10% and higher. MIC of FGJ against the pathogens ranged from 4% to 16% v/v whereas MLC value ranged from 4% to 32% v/v with Escherichia coli and Staphylococcus aureus spp. showed highest sensitivity. FGJ has definite antimicrobial activity against common pathogenic organisms isolated at SSG Hospital, Vadodara. Further studies are needed to find out the efficacy, safety, and kinetic data of its active ingredients.

Eucalyptus

Eucalyptus (Eucalyptus) is a member of the Myrtaceae family. It is called the fever tree based on its strong antimicrobial ability. This herbal medicine is native to the Mediterranean, Australia, and Tasmania area and it has been used as traditional medication for the treatment of numerous diseases including diabetes, pulmonary tuberculosis, bacterial and fungal infections, and influenza. The medical applications of eucalyptus are based on the high antioxidant and antimicrobial abilities of its essential oil. High concentrations of several polyphenolic compounds including flavonoids, hydroxybenzoic acids, and hydrolysable tannins have been found in the extract of eucalyptus. These compounds are the reason for the high antimicrobial and antioxidant activity of eucalyptus. Recent studies have revealed the strong antibacterial ability of eucalyptus against S. aureus, Listeria monocytogenes, Bacillus, Klebsiella pneumoniae, Enterococcus faecalis, Pseudomonas aeruginosa, Salmonella Enteritidis, and Escherichia coli.

Figure.7 - Eucalyptus Plant

Active compound

Eucalyptol (1, 8-cineole): This is the primary active compound in eucalyptus oil, responsible for its characteristic aroma. Eucalyptol has been studied for its anti-inflammatory, analgesic, and antimicrobial properties.

Alpha-pinene: A natural compound also found in pine trees, alpha-pinene contributes to the aromatic profile of eucalyptus oil.

Beta-pinene: Another terpene found in eucalyptus oil, beta-pinene is known for its potential anti-inflammatory and bronchodilator effects.

Limonene: A citrus-scented terpene with potential antioxidant and anti-inflammatory properties.

Aromadendrene: A sesquiterpene that may contribute to the overall scent of eucalyptus oil.

Terpinen-4-ol: Known for its antimicrobial properties, terpinen-4-ol is found in varying amounts in different eucalyptus species.

Antimicrobial Activity:

Crude extract from fruit of Eucalyptus globulus (E. globulus) was screened for its in vitro antioxidant and antibacterial properties. Antioxidant activity was measured by two methods, namely the reducing power and lipid peroxidation inhibition.

Antibacterial activity was determined by using disc diffusion method against three bacteria (Staphylococcus aureus: ATCC 6538, Bacillus subtilis: ATCC 6633 and Klebsiella pneumoniae: E 47). The extract exhibited moderate inhibition of lipid peroxidation of linoleic acid emulsion ($51.34 \pm 0.72\%$) and high reducing power ($IC_{50} = 39.52$ μg/mL). It also exhibited strong antibacterial activity against B. subtilis and S. aureus with minimum inhibitory concentration (MIC) values of 30 μg/mL and 80 μg/mL, respectively. These results suggest that fruits of E. globulus have interesting antibacterial and antioxidant activities.

Fennel

Fennel (Foeniculum vulgare) is one of the herbal medicinal plants belonging to the Apiaceae family. Its native habitats include shores of Mediterranean Sea. There are some studies on the radical scavenging activity of fennel. These studies have revealed that the antioxidant ability of this plant is due to the presence of high phenolic content in its extracts. Fennel has been shown to have high antioxidant ability. The antioxidant ability of the extract of this plant is due to numerous antioxidant processes such as free radical scavenging, superoxide anion radical scavenging, total antioxidant, and hydrogen peroxide scavenging. The strong antioxidant characteristics of ethanol extracts and essential oil of this plant have been demonstrated by in vitro studies.

The hydro-ethanolic extracts of this plant have shown to possess free radical scavenging characteristics directly proportional to the content of phenolic compounds of fennel extract. The extracts and essential oil of this plant have been demonstrated to have significant antioxidant, antimicrobial, and anti-inflammatory properties The antimicrobial property of the essential oil (EO) and extract of fennel has been proven using the disk diffusion method . Fennel extracts and essential oils have demonstrated high inhibitory activity against Bacillus megaterium, Eschericha coli, Bacillus pumilus, S. aureus, Pseudomonas putida, Pseudomonas syringae, Salmonella typhi, Bacillus cereus, Micrococcus luteus, Klebsiella pneumonia and Bacillus subtili . The inhibitory ability of fennel also depends on its dosage. Consequently, fennel extract and oils could be a biosource of medicinal materials needed for the manufacturing of novel antimicrobial agents. Fennel has been shown to be inhibitory against influenza a virus.

Figure.8 - fennel Plant

Chemical Constituent

Anethole: The primary compound responsible for the characteristic sweet and liquorice-like flavour of fennel. It also has antimicrobial properties.

Fenchone: Another major component contributing to the flavour of fennel. It has been studied for potential therapeutic effects.

Antimicrobial Activity:

Faudale et al. (2008) measured the antioxidant activity of Wild, medicinal and edible fennels as free radical (DPPH), hydroxyl radical and superoxide anion scavenging activities. Wild fennel was found to exhibit a radical scavenging activity, as well as total phenolic and total flavonoids content, higher than those of both medicinal and edible fennels.The antimicrobial activity of fennel essential oil was assessed by using disk diffusion method (Gulfraz et al., 2008). Fennel essential oil showed more inhibitory activity against Bacillus cereus, Bacillus magaterium, Bacillus, pumilusBacillus, substilis, Eschericha coli Klebsiella pneumonia,

Micrococcus lutus, Pseudomonos pupida, Pseudomonos syringae, and Candida albicans than the effect of methanolic and ethanolic fennel seed extracts. The lowest MIC values of fennel essential oil were noticed for C. albicans and E. coli. It was observed that essential oil and seed extracts of fennel exhibit different degree of antimicrobial activities depending on the doses applied. Therefore, fennel essential oil could be a source of pharmaceutical materials required for the preparation of new therapeutic and antimicrobial agents.

Mentha

Mint (Mentha) is one of the aromatic perennial herbs belonging to the Lamiaceae family. It has been used for various applications, such as pharmaceuticals and cosmetics applications. The EO and aqueous extracts of mint potentially have antioxidant properties due to the existence of phenolic compounds. Mint essential oil has been shown to be an effective alternative short-term treatment of irritable bowel syndrome in humans, due to its anti-inflammatory abilities. The antioxidant activity of this plant exclusively relies on its chemical composition and can prevent oxidative stress at the cellular level or in a living organism. Other studies have reported the use of mint extract as an antioxidant and antimicrobial bioactive natural extract. Numerous studies have revealed the inhibitory ability of this plant depending on the type of bacteria and its strong antimicrobial ability against Gram-positive bacteria, especially S. aureus. Other studies have reported that the antimicrobial effect of this plant with different oil concentrations. Mint oil shows strong antimicrobial ability against different bacteria including S. aureus, S. epidermidis, E. coli, Bacillus cereus, Enterococcus faecalis, and Cronobacter sakazakii . This herbal medicine shows inhibitory activity against HSV-1 and HIV viruses.

Figure.9 - Mentha plant

Chemical Constituents-

Menthol: This is perhaps the most well-known compound in mint. It gives mint its characteristic cooling sensation and is often used in various products like toothpaste, chewing gum, and throat lozenges. Menthone: Another compound contributing to the minty flavor. It has a more pungent taste compared to menthol.

Antimicrobial Activity: The results of chemical analysis of Mentha longifolia essential oil are presented in Table 1. Th e main compounds in M. longifolia oil were transand cis-dihydrocarvone (23.64% and 15.68%) and piperitone (17.33%) followed by 1,8-cineole (8.18%) and neoisodihydrocarveol (7.87%). According to recent investigations, dominant compounds in essential oil from M. longifoila fl owers were Table. 2. Minimal inhibitory (MIC) and fungicidal concentrations (MFC) of M. longifolia essential oil and bifonazole (μl/ml) M. longifolia bifonazol Fungi MIC MFC MIC MFC Alternaria alternata 5 10 10 10 Aspergillus niger 2.5 10 10 10 Aspergillus ochraceus 10 10 10 15 Aspergillus fl avus 10 10 10 15 Aspergillus versicolor 2.5 10 10 10 Cladosporium cladosporioides 1 2.5 10 10 Cladosporium fulvum 2.5 2.5 5 10 Fusarium tricinctum 2.5 10 15 20 Fusarium sporotrichioides 2.5 10 15 20 Penicillium funiculosum 2.5 10 15 20 Penicilium ochrochloron 2.5 2.5 15 20 Trichoderma viride 10 10 15 20 Trichphyton mentagrafites 5 5 10 15 Candida albicans 2.5 5 10 15 60 vol. 34 (1) piperitone oxide, piperitenon oxide, β-caryophyllene, thymol, cis- and trans-dihydrocarvone and menthofuran (Mimica-Dukić 1992). Th ese authors found that essential oil from aerial parts of fl owering M. longifolia contains piperitone as the main compound followed by menthone, pulegone neo-menthol and isomenthone (Mimica-Dukić et al. 2003). Ghoulami et al. (2001) found high content of piperitone oxide and piperitenon oxide in sample M. longifolia oli from Maroko, while in Iranian samples ciscarveol (53-78%) was dominant (Zenali et al. 2005). Minimum inhibitory and fungicidal concentrations (MIC and MFC) of M. longifolia essential oil investigated in this study are presented in Table 2. Th e concentration of 10 μl/ml showed fungicidal activity against Aspergillus and Fusarium species, and Alternaria alternata, Penicillium funiculosum and T. viride. Concentration of 5 μl/ml was effi cient against Trichophyton menthagrophytes and yeast Candida albicans. Th e most sensitive micromycetes were Cladosporium fulvum, C. cladosporium cladosporioides and Penicillium ochrochloron where concentration of 2.5 μl/ml was lethal. Th e essential oil exhibited fungicidal characteristics with MIC and MFC of 1-10 μl/ml. Fungistatic and fungicidal activity of bifonazole was 5-20 μl/ml (Fig.4.). Previous results indicate that essential oil of M. longifolia showed higher antimicrobial and antifungal activity than tested commercial substances (Mimica-Dukić et al. 2003). Free radical scavenging capacities of the tested oil was measured by DPPH assay and results are shown in Figure 1. According to the results obtained, M. longifolia oil was found active with IC50 value of 0.659 ml/ml of solution. IC50 values of the synthetic antioxidants BHT was 0,328 mg/ ml and Trolox 0.0637 mg/ml were determined in parallel experiments. Th e results for antioxidant activity obtained in this work are in correlation with recent results of other authors (Mimica-Dukić et al. 2003; Gulluce et al. 2007; Mkaddem et al. 2009). Antioxidant and antifungal properties of the essential oils and various extracts from many plants are of great interest in both fundamental science and the food industry, since their possible use as natural additives emerged from a growing tendency to replace synthetic antioxidants by natural ones. The present study confirmed the antifungal activity of Serbian M. longifolia essential oil, as well.

3. CONCLUSION

This paper delving into Phytomedicine has unveiled a fascinating world of plant-derived antimicrobial properties. The diverse range of plants studied highlights their potential as natural sources for combating microbial threats. The findings not only contribute to our understanding of the intricate relationship between plants and pathogens but also underscore the promising avenues for harnessing botanical resources in the pursuit of novel antimicrobial solutions.

Explored phytomedicine's realm, unveiling plant-derived antimicrobial properties. Studied diverse plants, showcasing their potential as natural defenders against microbes. Project deepened understanding of the intricate plant-pathogen relationship. Findings contribute to the exploration of novel antimicrobial solutions. Highlighted the varied plant species with promising antimicrobial attributes. Signifies crucial step toward leveraging botanical resources for combating microbial threats.

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