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A REVIEW ON EXPLORING THE ANTIMICROBIAL POWER OF HERBAL PLANTS

Chahna Patel[1]*, Dr. Neha Tiwari[1], Dr. Pragensh Patani[1]

[1]*Khyati College of Pharmacy, Palodia, Ahmedabad, Email: chahnapatel8@gmail.com

Abstract
Traditional medicine has utilized herbal plants for centuries. In our environment, a large number of micro-organisms grow at rapid speed, which may cause harm to other living organisms and may also lead to the dangerous diseases, anti-microbial agents are used to solve this problem. The agents that kill and stop the growth of harmful microbes are known as anti-microbial agents. There are two types of antimicrobial agents include synthetic agents and herbal plants. Synthetic drugs are used as antimicrobial agents but they have various side effects like reactive oxygen species and antibiotic resistance. Herbal plants have fewer side effects than synthetic drugs. Plants have active chemical constituents that provide pharmacological action. This review provides a comparative analysis of ten herbal plants that possess anti-microbial activity. Herbal anti-microbial agent include Aloe vera (*Aloe barbadensis miller)*, Basil (*Ocimum basilicum*), Clove (*Syzygium aromaticum*), Cinnamon (*Cinnamomum verum and Cinnamomum zeylanicum*), Chamomile (*Matricaria chamomilla*), Dill (*Anethum graveolens*), Mint (*Mentha*), Garlic (*Allium sativum*), Ginger (*Zingiber officinale roscoe*) and Lemon balm (*Melissa officinalis*) all of these have been summarized.

Keywords: herbal plants, antimicrobial agents, synthetic drugs, side effect, comparative analysis

Introduction

Over 5000 years ago, there are various ancient civilizations, including Greece, India, Egypt, Rome, and China, utilized plants or by-products of plants to cure diseases and boost the body system, demonstrating their therapeutic effects. [1,2] The WHO (World Health Organization) mentioned that traditional medicine plants, used by 80% of the developing world, include around 1340 plants and 30000 antimicrobial compounds obtained from plants that provide antimicrobial activity. [3,4,5] The plants contain chemically active constituents involving alkaloids, tannins, flavonoids, and phenolic compounds that provide desired physiological action and also give medicinal value. [6,7] Micro-organisms present in the surroundings are rapidly growing and can disrupt the balance between humans and other living organisms and also lead to dangerous diseases. Anti-microbial agents act as a remedy for this problem. [8] The agent that kills and stops the growth of microorganisms is known as an antimicrobial agent. [9,10,11] Antimicrobial agents are divided into two groups such as the paramount group is synthetic antimicrobial agents, and the subordinate group is herbal antimicrobial agents, a type of synthetic antibiotic drugs are used as antimicrobial agents and control infections that affect the human body, although antibiotics have various adverse effects as they increase reactive oxygen species (ROS) in the human body, they are very harmful because they produce cancer and also increase health problem, while herbal plants acts to stop the formation of reactive oxygen species and also plays the role of free radical hunter. Biomaterials replaced antibiotics. [11,12] In 2019, the center for Disease Control and Prevention (CDC, the US) reported that approximately 35,000 people die annually in the United State from antibiotic resistance infections, and the WHO (World Health

Organization) announced that antimicrobial resistance is a major global health problem. [13,14,15] In the future, developed countries will use herbal medicine because of the extreme side effects of synthetic and semi-synthetic drugs leading to increased interest in natural antimicrobial properties of herbal plants. [16,17,18]

Herbal Plants Possessing Antimicrobial Activity

Aloe vera

Aloe vera, scientifically known as *Aloe barbadensis miller*, resides in the *Asphodelaceae* family and is mostly found in the Canary Islands, North Africa, the Middle East of Asia, and the Southern Mediterranean, it contains anthraquinons, vitamins, minerals, sugars, amino acids, enzymes, fatty acids, protein, hormones and others, and provides anti-microbial activity, antidiabetic, anti-inflammatory activity, anticancer, wound healing effect, antioxidant, and antihyperlipidemic. [19,20] Aloe vera has antimicrobial properties that are effective against both Gram-positive and Gram-negative bacteria, including staphylococcus aureus, Bacillus Subtilis, Staphylococcus epidermidis, Escherichia coli, Enterococcus Cialis Pseudomonas aeruginosa, Proteus mirabilis, Staphylococcus pyogenes, Bacilluscereus, Shigell sonnei, Bacillus elaterium, Entrobactera aerogenes, Salmonella typhi, and Agrobacterium tumefaciens. [21,22] Aloe vera acts as an antimicrobial agent by binding to microbial surfaces disrupting cell walls through physical and ionic interactions, and inhibit microorganism growth by leading to cell wall disruption, impaired cellular functions, electrochemical mechanisms, and leakage of metabolites, which ultimately prevents reproduction. [23,24]

Basil

Basil's botanical name is *Ocimum basilicum*, belongs to the *Lamiaceae* family and is found in Southeast Asia, India, Pakistan, Nepal, Western Asia, and Africa. [25] Basil contains essential oil, estragole, linalool, eugenol, methyl chavicol, methyl eugenol, 1,8-cineole, eucalyptol and bergamotene and provides wound-healing, antibacterial, antifungal, antioxidant, and anti-inflammatory activity and it act against both Gram-positive and Gram-negative bacteria, including Staphylococcus aureus, Salmonella enterica, Proteus stuartii, Coagulase-positive Staphylococci, and Group D streptococci. [26] Basil acts as an antimicrobial agent by the degradation of the cell wall and cytoplasmic membrane, cytoplasm coagulation, the inhibition of toxic bacterial metabolites, and the inhibition of the bacterial efflux system. [27]

Clove

Clove's scientific name is *Syzygium aromaticum*, part of the *Myrtaceae* family and grown in Africa and Asia. Clove includes β-caryophyllene, eugenol, α-humulene, eugenol acetate, and 2-heptanone, offer anti-allergic antimicrobial, anti-inflammatory, antioxidant, antimutagenic, and anticancer properties, it has antimicrobial activity against both Gram-positive and Gram-negative bacteria such as Escherichia coli, Klebsiella pneumonia, Listeria monocytogenes, Salmonella typhimurium and Staphylococcus aureus. [11,28,29] Clove acts as antimicrobial agents by protein content, alteration cell membrane permeability, effect on the structure of DNA and respiratory metabolism. [30]

Cinnamon

Cinnamon's scientific name is *Cinnamomum verum and Cinnamomum zeylanicum*, part of the *Lauraceae* family and located in Sri Lanka, Vietnam, China, and other countries. Cinnamon contains cinnamaldehyde, sesquiterpenes, eugenol, polysaccharides, flavonoids, and other components, and give various activity like antioxidant, anticarcinogenic and antimicrobial activities, it show anti-microbial activity against both Gram-positive bacteria and Gram-negative bacteria includes Pseudomonas aeruginosa, Escherichia coli, Salmonella typhimurium, Listeria monocytogenes, Bacillus, Enterococcus faecalis, Staphylococcus aureus, and Yersinia enterocolitica. [11,28,31] Cinnamon acts as an antimicrobial agent by alterations in the cell membrane, Inhibition of ATPase, cell division, motility, biofilm formation, and Inhibition of membrane porins. This multifaceted mechanism of action helps in effectively targeting and inhibiting microbial growth. [32]

Chamomile

Chamomile botanical name is *Matricaria chamomilla*, belongs to the *Asteraceae* family and found in Central and Western Asia, Southern and Eastern Europe, Northern Africa, and Western North America, it has chemical constituent are apigenin, flavonoids, terpenoids, matricin, and phenolic compounds, it provides anti-hypoglycemic, anticancer, antibacteria, antihypertensive, anti-stress, antifungal, antiviral, analgesic, anti-inflammatory, hepatoprotective property and antioxidative activity. [11,33] Chamomile act against both Gram-positive bacteria and Gram-negative bacteria such as Staphylococcus aureus, Escherichia coli, Bacillus and Salmonella thyphimurium. [34] Chamomile mechanism of action is disruption of cell wall of microbes and inhibition of microbial enzyme activity. [35]

Dill

Dill's scientific name is *Anethum graveolens*, part of the *Aspergillus* and native to the United States, Asia, and Europe. [36] Dill contains phenolic compound, carvacrol, euganol, thymol, cinnamaldehyde, menthol and other compound, it give various activity such as antimicrobial, ant-inflammatory and antioxidant, it show antimicrobial activity against Pseudomonas aeruginosa, Clostridium botulinum, Yersinia enterocolitica and Staphylococcus aureus. Dill kills bacteria by various mechanism involve reduction of protein synthesis, inhibition of intercellular ATP and cell wall destroy. [28,37]

Mint

Mentha is the botanical name of the mint, belongs to the *Lamiaceae* family and mint has flavonoids, phenolic compounds, and essential oils such as carvone (spearmint) and menthol peppermint) and provide anti-inflammatory, antioxidant, and antimicrobial. The antimicrobial activity of mints against Enterococcus faecalis, Staphylococcus aureus, Escherichia coli, Staphylococcus epidermidis, Cronobacter sakazakii, and Bacillus cereus. [11] Mint found in Africa, Asia, Europe, Australia, and America. Mechanism of mint, including inhibition of crucial enzymes, interference with cell signalling pathways, and disruption of microbial membranes. [38]

Garlic

Garlic botanical name is *Allium sativum*, part of the *Amaryllidaceae* family and found in Iran and Central Asia, it has ammonia acid, saponins, vitamins, minerals, phenolic, flavonoids, polysaccharides, and organosulfur, they give anticancer, antidiabetic, antimicrobial, antioxidant, cardioprotective and anti-inflammatory effect. Garlic gives effect on both Gram-positive and Gram-negative, such as Escherichia coli, Klebsiella, Enterococcus faecalis, Salmonella typhi, Pseudomonas, Proteus, and Staphylococcus aureus. [11,28,39] Garlic gives a mechanism of action by cell membrane integrity and cell permeability. [40]

Ginger

Ginger's specific name is *Zingiber officinale roscoe*, it resides in the *Zingiberaceae* family and is grown in Asia, Europe, the Middle East, and India. [41,42] Ginger has gingerol, paradols, shogols, and phenolic acids; they show various activities such as antiulcer, antidiabetic, antioxidant, antimicrobial, antihypertensive, gastrointestinal, anti-inflammatory, cardiovascular, and analgesic, it shows highly antimicrobial activity against Escherichia coli, Salmonella typhi, Pseudomonas aeruginosa, Vibro cholera, and Staphylococcus aureus. [11] The mechanism of ginger is to destroy mitochondria and cell membranes, and due to that cell structures are disturbed leading to cell death. [43]

Lemon balm

Melissa officinalis, the botanical name of lemon balm, is part of the *Laminaceae* family and is found in Asia, Europe, and North America, it consists of polyphenols, β-carotene, vitamin C, flavonoids and vitamin E and show various activities such as antioxidant, antimicrobial, anticancer, anti-

cardiovascular, antiviral, antispasmodic and anti-inflammatory activity. It shows antimicrobial activity against both Gram-positive and Gram-negative bacteria, including Escherichia coli, Pseudomonas aeruginosa, Bacillus cereus, Sarcina lutea, Staphylococcus aureus, Salmonella typhi, Klebsiella Proteus, and beta-hemolytic Streptococcus. [11,28,44] Mechanism of lemon balm includes interaction with membrane protein, structural destabilization of the phospholipid and altering pH gradients across the membrane. [45]

Minimum Inhibitory Concentration (MIC)

To determine the Minimum Inhibitory Concentration (MIC), a microbial culture is first prepared to a standard turbidity and the antimicrobial agent is then diluted into a series of concentrations. These dilutions are inoculated with the standardized microbial culture, incubated and the MIC is identified as the lowest concentration where no visible microbial growth is observed, indicating effective inhibition. This method helps to determine the smallest amount of the agent needed to inhibit microbial growth. [46]

TABLE 1 MINIMUM INHIBITORY CONCENTRACTION VALUE OF HERBAL PLANTS

Herbal Plants	Minimum Inhibitory Concentration	Target of bacteria	Result	Ref.
Aloe vera	1-10 mg ml^{-1}	Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa, Klebsiella pneumoniae	Low inhibitory activity	[46]
Basil	0.5-4 mg ml^{-1}	Methicillin-Resistant Staphylococcus aureus, Escherichia coli, Staphylococcus aureus	Moderate inhibitory activty	[47,48]
Clove	0.05-0.5 mg ml^{-1}	Escherichia coli, Listeria monocytogenes, Bacillus cereus, Staphylococcus aureus, Salmonella typhimurium, Bacillus cereus.	High inhibitory activity against all bacteria	[49,50]
Cinna-mon	0.1-2 mg ml^{-1}	Escherichia coli, Listeria monocytogenes, Bacillus cereus, Staphylococcus aureus, Salmonella typhimurium, Bacillus cereus.	High inhibitory activity against all tested bacteria	[50]
Chamo-mile	1-8 mg ml^{-1}	Staphylococcus aureus, Escherichia coli, Enterococcus faecalis	Low inhibitory activity	[51]
Dill	1-4 mg ml^{-1}	Staphylococcus aureus, Escherichia coli	Low inhibitory activity	[52]
Mint	0.5-1.5 mg ml^{-1}	Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa	Moderate inhibitory activity	[53]
Garlic	0.25-2 mg ml^{-1}	Escherichia coli, Listeria monocytogenes, Bacillus cereus, Staphylococcus aureus, Salmonella typhimurium.	High Inhibitory activity	[50]

Ginger	1-4 mg ml^{-1}	Escherichia coli, Staphylococcus aureus	Moderate inhibitory activity	[41,11, 54]
Lemon balm	1-6 mg ml^{-1}	Listeria strain, Escherichia coli	Low inhibitory effect	[11]

In Table 1, it is described that Clove, cinnamon, and garlic provide strong antimicrobial activity with low minimum inhibitory concentration value. [50,51] Herbal plants such as ginger, mint, basil, and dill provide moderate antimicrobial properties based on minimum inhibitory concentration value [41,47,52,53] compared to clove, cinnamon and garlic. Lastly chamomile, lemon balm and aloe vera have lower antimicrobial activity with a high minimum inhibitory concentration value [11,46] compared to other herbal plants.

Conclusion

In conclusion, this review represents the importance of herbal plants as antimicrobial agents because synthetic antimicrobial agents have major side effects. In the future, synthetic drugs will be replaced by herbal plants. Herbal plants have great potency and less side-effect. They show different mechanisms of action against various bacteria. This review, compares the antimicrobial efficacy of 10 herbal plants based on their minimum inhibitory concentration. Herbal plants include Clove, cinnamon, and garlic provide strong antimicrobial activity compare to other plants. Ginger, mint, basil, and dill provide moderate antimicrobial properties compared to clove, cinnamon and garlic as shown in Table 1. Lastly chamomile, lemon balm and aloe vera have lower antimicrobial activity compared to other herbal plants. Future research should focus on optimizing the extraction and formulation process of these herbs to increase their antimicrobial efficiency and exploring the synergy between various herbal plants could give effective combination for enhance activity.

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