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Plant extracts in clinical settings: A comprehensive review on health benefits and antimicrobial efficacy

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Abstract
This study is a comprehensive examination of many uses of plant extracts in therapeutic settings, emphasizing their antibacterial qualities and other advantages to health. It systematically explores the antioxidant activities of these extracts, which are effective in neutralizing free radicals and reducing oxidative stress. The paper also delves into the presence of phytochemicals like flavonoids and polyphenols, which contribute to human well-being. Anti-inflammatory properties are examined, revealing the extracts' potential in treating conditions such as arthritis and irritable bowel syndrome. Additionally, the review highlights the nephroprotective and hepatoprotective effects. The paper also investigates the role of plant extracts in treating female infertility, offering new, non-invasive therapeutic options. The review evaluates the extracts' ability to combat various pathogens in terms of antimicrobial efficacy, thereby reducing dependency on synthetic antibiotics. It also elucidates the mechanisms of action, including cell membrane disruption and enzyme inhibition. Clinical applications are assessed, covering wound healing, respiratory conditions, and gastrointestinal issues. The review acknowledges the challenges and future perspectives, emphasizing the need for standardized protocols and large-scale clinical trials. Overall, the paper is a comprehensive guide for understanding plant extracts' multifaceted applications and mechanisms in healthcare.

Keywords: Plant extracts, health benefits, antimicrobial activity

Introduction
The anti-inflammatory properties of plant extracts have gained attention for their potential use in managing conditions like rheumatoid arthritis and inflammatory bowel syndrome (Parameswaran and Patial, 2010) [1]. These extracts have also shown nephroprotective and hepatoprotective effects, making them a natural option for preserving renal and hepatic function (Naviglio *et al*., 2022) [2]. Recent advancements in reproductive medicine have also identified the potential role of plant extracts in improving female infertility (Elhussein *et al*., 2019) [3]. In addition to their health-promoting properties, plant extracts have demonstrated significant antimicrobial efficacy (Parameswaran and Patial, 2010) [1]. As antibiotic resistance becomes a growing concern, understanding the molecular mechanisms underlying the antimicrobial action of these extracts is crucial. These mechanisms often involve cell membrane disruption and enzymatic inhibition, providing a multifaceted strategy for eradicating pathogens (Parameswaran and Patial, 2010) [1].
The clinical versatility of plant extracts is further evidenced by their applicability in diverse medical conditions, including wound management, respiratory ailments, and gastrointestinal disorders. However, the field is not without its challenges. The absence of standardized protocols and the need for extensive clinical validation through large-scale trials remain critical hurdles. As the scientific community endeavors to overcome these challenges, plant extracts stand poised to redefine the landscape of contemporary medicine, offering a holistic, evidence-based approach to healthcare (Sá *et al*., 2023) [4].

Health benefits of plant extracts
In addition to their antimicrobial efficacy, plant extracts have been found to have various health benefits (Table 1). Since ancient times, numerous plant extracts have been used to treat various ailments with few side effects (Albogami and Hassan, 2021) [5]. Albogami and Hassan's clinical research has shown encouraging results regarding the effects of certain medicinal plant-based phenolic compounds on cancer, focusing on metabolism, oral bioavailability, and pharmacokinetics (Albogami and Hassan, 2021) [5]. In addition, plant-based therapies have shown promise in preventing and treating chronic kidney disease,

inflammation, and oxidative stress (Khan *et al*., 2022) [6].

Antioxidant Activity

One key aspect of evaluating plant extracts' health benefits is their antioxidant activity. Antioxidants are essential for limiting oxidative stress and lowering the risk of chronic disease (Zhang *et al*., 2015) [7]. Plant extracts rich in antioxidants can scavenge reactive oxygen species, inhibit membrane lipid peroxidation, and chelate metal ions. These activities contribute to preventing or slowing down degenerative diseases (Zhang *et al*., 2015) [7]. For example, the methanolic leaf extract of *Acalypha indica* has been found to possess hepatoprotective activity against CCl4-induced hepatotoxicity, indicating its potential as a source of natural antioxidants (Nambiar and Varghese, 2023) [8].

Phytochemicals and Bioactive Food Components

Phytochemicals and bioactive food components present in plant extracts have been shown to benefit human health. These medications can control risk factors and treat symptoms of common pediatric ailments, including memory impairment, respiratory illnesses, gastrointestinal disorders, metabolic imbalances, and oral cavity pathologies. (Ullah *et al*., 2021) [9]. Clinical investigations have shown that botanical extracts and bioactive dietary components boost children's health (Ullah *et al*., 2021) [9]. In addition, many foods and medicinal plants contain antioxidant phytochemicals, which have been demonstrated to have powerful antioxidant and free radical scavenging activities and anti-inflammatory effects (Zhang *et al*., 2015) [7].

Anti-Inflammatory Action

Many plant extracts and phytochemicals possess anti-inflammatory action, another critical aspect of their health benefits. Phytochemicals such as resveratrol, anthocyanins, and curcumin have been found to reduce inflammation through various mechanisms, including inhibition of prostaglandin production and nuclear factor-κB activity, enzyme inhibition, and increase of cytokine production (Zhang *et al*., 2015) [7]. The anti-inflammatory action is often coupled with their antioxidant and free radical scavenging abilities, further contributing to their overall bioactivities and health benefits (Zhang *et al*., 2015) [7].

Nephroprotective and Hepatoprotective Effects

Certain plant extracts have been found to have nephroprotective and hepatoprotective effects. For example, the methanolic extract of *Lantana camara* and Squash (*Cucurbita pepo*) has shown nephroprotective activity against cisplatin-induced nephrotoxicity in rats (Abdel-Hady *et al*., 2017) [10]. These plants contain chemical constituents that contribute to their health benefits, such as anti-diabetic, antifungal, antibacterial, and anti-inflammatory properties (Abdel-Hady *et al*., 2017) [10]. Similarly, the methanolic leaf extract of *Acalypha indica* has been found to have hepatoprotective activity against CCl4-induced hepatotoxicity (Nambiar and Varghese, 2023) [8]. These findings highlight the potential of plant extracts in protecting and improving the function of vital organs.

Female Infertility Treatment

Plant extracts have also been investigated for their potential in female infertility treatment. Ovatrine, a compound derived from plant extracts, has been used to increase the number of ovarian follicles and treat inflammation in the ovary or uterus (Hussein, 2020) [11]. Tea polyphenols, significant constituents of tea leaf extracts, have also shown potential health benefits, including an increase in the follicular number in the ovary (Hussein, 2020) [11]. These studies suggest that plant extracts may have a role in improving reproductive health. When evaluating the health benefits of plant extracts, it is essential to consider their safety and potential toxicological impacts. Proper biochemical, toxicological, and safety data are necessary to ensure the safe usage of plant extracts with conventional claims on health benefits (Gad *et al*., 2021) [12]. Unfortunately, many plant-derived products' chemical and toxicological profiles have not been thoroughly investigated (Gad *et al*., 2021) [12].

Antimicrobial efficacy of plant extracts

Antimicrobial resistance is a growing concern in medicine, leading to a renewed interest in deriving antimicrobial products from natural compounds, mainly plant extracts (Redfern *et al*., 2014a) [13]. Plant extracts have long been studied for their antimicrobial efficacy and have shown promising results (Table 2). The antibacterial activity of silver nanoparticles produced from *Phyllanthus amarus* and *Tinospora cordifolia* aqueous plant extracts was the subject of one investigation (Singh, 2014) [14]. The study that compared the antimicrobial activity of synthesized silver nanoparticles with their respective plant extracts revealed enhanced antimicrobial efficacy in the nanoparticles. Synthesizing silver nanoparticles using plant extracts appears to amplify their antimicrobial potency. A separate investigation assessed the antimicrobial activity of *Capparis spinosa* extracts (Mahboubi and Mahboubi, 2014) [15]. Extracts from the roots and fruits of *Capparis spinosa* showed notable antimicrobial activity against microorganisms, particularly fungi (Mahboubi and Mahboubi, 2014) [15]. Such findings underscore the role of *Capparis spinosa* extracts as effective antimicrobial agents.

Thymus vulgaris (Thyme) has also undergone extensive research for its antimicrobial properties (Redfern *et al*., 2014a) [13]. Tests on essential oils extracted from thyme indicate their effectiveness against various microorganisms. The Soxhlet method is a relatively straightforward extraction technique that can obtain antimicrobial compounds in thyme essential oil (Osorio-Tobón, 2020, Redfern *et al*., 2014b) [16, 7]. These findings point to thyme as a promising source of antimicrobial compounds. Moreover, research has extended to other plants for their antimicrobial properties. Extracts from native plants of temperate Australia, including Eucalyptus, Melaleuca, Prostanthera, and Westringia, have demonstrated antimicrobial activity against organisms such as *Pseudomonas aeruginosa* and *Staphylococcus aureus* (Wigmore *et al*., 2016) [18].

Such observations suggest that plants from different regions can possess antimicrobial properties. Furthermore, the antimicrobial activity of plant extracts has been compared to conventional antibiotics. In a study comparing the antibacterial activity of leaf extracts of *Azadirachta indica* and *Psidium guajava* against methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Staphylococcus aureus* (VRSA), the plant extracts showed lesser antimicrobial activity compared to the conventional antibiotics (C *et al*., 2017) [19]. The highlighted need for developing novel compounds with antimicrobial activity underscores the potential of plants as sources of new therapeutic agents.

Mechanisms of Action

The mechanism of action of antimicrobial activity of plant extracts is a topic of great interest in medicine and pharmacology (Figure 1). Traditional medicine has long relied on plant extracts to treat a wide range of conditions. However, the exact mechanisms by which these extracts exert their antimicrobial effects are not fully understood. The antibacterial activity of plants has been studied extensively, and their modes of action have been revealed. The synergistic effects between plant extracts and antimicrobial drugs in combating *Staphylococcus aureus* diseases have been explored, revealing that the mechanism of action of plant extracts is not yet fully understood (Betoni *et al*., 2006) [20]. Challenges exist in medicinal plant antimicrobial activity, including variations in antimicrobial susceptibility tests and difficulties in developing new antimicrobials from plant extracts. The importance of understanding the mechanisms of action, interactions with other substances, and pharmacokinetic and pharmacodynamic profiles of medicinal plant extracts has been emphasized (Vaou *et al*., 2021) [21]. Although the antimicrobial properties of plant extracts have been acknowledged for a long time, the specific mechanisms through which they act are still not well-defined. Some proposed mechanisms include membrane damage, alterations in intracellular pH, membrane potential, and ATP synthesis (Sanchez *et al*., 2010) [22]. For instance, extracts from edible and medicinal plants have been shown to compromise the membrane integrity of *Vibrio cholerae* cells, leading to changes in membrane potential, internal pH, and ATP synthesis (Sanchez *et al*., 2010) [22].

The composition of plant extracts can vary depending on factors such as the season of harvest, region of cultivation, plant parts used, and type of processing (Vaou *et al*., 2021) [32]. These variations can affect the levels and mechanisms of various compounds in the extracts, making it challenging to compare the antimicrobial activity of different plant extracts. The antimicrobial compounds from medicinal plants may inhibit the growth of bacteria, fungi, viruses, and protozoa by different mechanisms than those of currently used antimicrobials (Vaou *et al*., 2021) [21]. These compounds may have significant clinical value in treating resistant microbial strains. Different plant species have been investigated for their antimicrobial activities. Antimicrobial activity has been demonstrated with plants' organic extracts, including *Ambrosia maritima* and *Bituminaria bituminosa* (Ramli *et al*., 2022) [23]. The mechanisms of action of these extracts are not fully understood, but understanding their mechanisms of action is essential for optimizing their use as natural antimicrobial agents. *Mangifera indica* (Mango) plant extracts have also been studied for their antimicrobial activity (Alaiya and Odeniyi, 2023) [24].

The mechanisms of action of phytochemicals in these extracts have been described, and they are believed to contribute to the antimicrobial activity exhibited by the extracts. *Vinca rosea* (Periwinkle) whole plant extract has been shown to have antimicrobial activity. The action mechanism is thought to involve agitating fungal cell walls and the discharge of cellular components (Angelin Jebamalar *et al*., 2019) [25]. *Ocimum sanctum* (Tulsi) plant extract has been found to have antibacterial activity, and its ability to reduce silver ions to silver nanoparticles contributes to its antimicrobial properties (Rai *et al*., 2020) [26]. Ocimum plant extract has also been shown to inhibit the growth of bacterial strains (Rai *et al*., 2020) [26]. The mechanisms of action of plant extracts can vary based on the plant species and compounds contained in the extracts. Some plant extracts may disrupt membrane integrity, while others may affect intracellular pH, membrane potential, or ATP synthesis (Sanchez *et al*., 2010) [22]. Phytochemicals in plant extracts may also inhibit microbial enzyme synthesis (Alaiya and Odeniyi, 2023) [23].

Clinical Applications

Wound Healing

The complex tissue repair mechanism focuses on re-establishing the architecture and functionality of damaged areas. Factors like infections, pre-existing medical conditions, and drug interventions can hinder the effective healing of wounds (Ibrahim *et al*., 2018) [27]. Recently, there has been a growing interest in the potential of natural products, mainly plant extracts, as wound healing agents. Bioactive phytochemical elements such as alkaloids, essential oils, flavonoids, tannins, saponins, and phenolic compounds abound in these natural products, giving them therapeutic value (Ibrahim *et al*., 2018) [27]. Numerous research have examined plant extracts' wound-healing effects. Natural compounds with anti-inflammatory, antioxidant, antibacterial, and pro-collagen synthesis capabilities have garnered attention for their potential in wound healing (Ibrahim *et al*., 2018) [27]. Select natural products have been studied *in vitro*, *in vivo*, and clinical settings for their ability to enhance wound healing and the underlying processes that make this possible (Ibrahim *et al*., 2018) [27]. Biochemical mechanisms that enable plant extracts to accelerate wound healing have also been examined. These mechanisms include angiogenesis, stimulation of NF-B cells, promotion of proinflammatory cytokines, an increase in iNOS, and α-1 type-1 collagen production (Ullah *et al*., 2022) [28].

The therapeutic efficacy of plant extracts in wound healing is primarily attributed to their antioxidant, anti-inflammatory, and antibacterial properties (Abdullah *et al*., 2020) [29]. Specifically, *Orthosiphon aristatus* has been highlighted for its effectiveness in treating diabetic foot ulcers, owing to its antioxidant, anti-inflammatory, and antihyperglycemic attributes (Abdullah *et al*., 2020) [29]. These properties are instrumental across various stages of the wound-healing process (Abdullah *et al*., 2020) [29]. Additionally, certain bioactive compounds in medicinal plants have been found to exhibit growth factor-like activity, thereby stimulating the early expression of growth factors essential for wound repair (Oguntibeju, 2019) [30]. Ethnobotanical research conducted in Sistan and Baluchestan Province, Southeastern Iran, has identified a range of medicinal plants with wound-healing effects, including *Verbascum* spp., *Glycyrrhiza glabra*, *Salvia officinalis*, *Echium amoenum*, *Medicago sativa*, *Mentha pulegium*, *Aloe vera*, *Datura stramonium* L., *Alhagi* spp., *Pistacia atlantica*, *Hypericum perforatum*, and *Prosopis cineraria* (Oguntibeju, 2019) [30].

These plants contain antioxidants and other bioactive compounds contributing to their wound-healing properties (Dastyar and Lysiuk, 2023) [31]. The mechanisms by which plant extracts promote wound healing are diverse. Saponins, for example, can stimulate pro-collagen synthesis, whereas tannins and flavonoids possess antiseptic and antibacterial properties (Ibrahim *et al*., 2018) [27]. Plant extracts can also stimulate fibroblasts, promote angiogenesis, and modulate the different phases of the wound-healing process (Ibrahim *et al*., 2018, Oguntibeju, 2019) [27, 30]. Both *in vitro* and *in vivo* investigations have shown that certain plant extracts have

wound-healing capabilities. For example, *Aspilia africana* has been shown to have wound-healing effects, including wound contraction, high collagen deposition, and promotion of angiogenesis (Komakech *et al*., 2019) [32]. The phytochemicals present in *A. africana*, such as saponins, alkaloids, tannins, flavonoids, and phenols, contribute to its anti-inflammatory, antimicrobial, and antioxidant activities, which are essential for wound healing (Komakech *et al*., 2019) [32].

Respiratory Conditions

Respiratory conditions are a significant health concern worldwide, and using plant extracts in traditional medicine to treat respiratory conditions has gained attention. Traditional medicine, including plant mixtures and herbal remedies, has been practiced for centuries and continues to be an essential source of healthcare for many communities (Vandebroek *et al*., 2010) [33]. In particular, plant extracts have been used to treat respiratory conditions such as cough, bronchitis, tuberculosis, and other infections (Bocanegra-Garcia *et al*., 2009) [34]. Plant extracts for respiratory conditions have been studied in various regions, including the Dominican Republic, Venda, Mexico, Uganda, and Kenya. Botellas (Bottled herbal mixtures) in the Dominican Republic were commonly used to treat reproductive health and genitourinary conditions. In contrast, teas prepared from plant mixtures were used to treat respiratory conditions in New York City (Vandebroek *et al*., 2010) [33]. In Venda, South Africa, plants traditionally used for respiratory conditions were tested for antimicrobial activity, and four showed antimicrobial activity against specific pathogens (Pallant and Steenkamp, 2008) [35].

Similarly, in Mexico, extracts from plants used in traditional medicine for respiratory infections were evaluated for their effect on various microorganisms associated with respiratory diseases, and some extracts showed activity against the tested bacteria (Bocanegra-Garcia *et al*., 2009) [34]. In Uganda, a survey of herbal remedies used to treat pediatric diseases found that respiratory tract infections were among the predominant conditions treated with plant preparations (Tugume and Nyakoojo, 2019) [36]. The survey also revealed that decoctions involving boiling plant parts were the most common method of herbal medicine preparation. However, it is essential to note that boiling may cause degradation of bioactive ingredients, especially aromatic compounds, if it takes a long time (Tugume and Nyakoojo, 2019) [36]. Plant extracts for respiratory conditions are not limited to specific regions. Persian medicine references also recommend various medicinal herbs for respiratory diseases, and some have been found to have activity against respiratory viruses (Hajimonfarednejad *et al*., 2023) [37].

Additionally, studies have shown that certain plant extracts possess inhibitory activity against rapidly growing mycobacteria, which are associated with respiratory tract infections (Temitope *et al*., 2014) [38]. The bioactivity of plant extracts against respiratory pathogens has been attributed to various mechanisms. These include denaturing and degrading proteins, inhibiting enzymes, interfering with the electron flow in the respiratory chain, and interfering with adenosine diphosphate (ADP) phosphorylation (Salem *et al*., 2012) [29]. Furthermore, using a mixture of plants in herbal medicine preparation has increased the effectiveness of herbal remedies due to synergistic effects (Tugume and Nyakoojo, 2019) [36].

Gastrointestinal Issues

Gastrointestinal issues are common health problems that affect the digestive system, including the stomach, intestines, and other organs involved in digestion. Ulcers, gastritis, and irritable bowel syndrome are more severe disorders that can arise from poor gut health. Traditional medicine has long recognized the potential of plant extracts in treating gastrointestinal issues, and recent research has provided further evidence of their effectiveness. Phytochemicals, especially phenolics, found in fruits and vegetables have been suggested to be major bioactive compounds for health benefits (Sun *et al*., 2002) [12]. Fruits such as cranberry, apple, red grape, and strawberry have been found to have high antioxidant and antiproliferative activities, which can be beneficial for gastrointestinal health (Sun *et al*., 2002) [12]. These fruits feature significant concentrations of phenolic chemicals, which have been demonstrated to have anti-inflammatory and antioxidant properties (Sun *et al*., 2002) [12]. In addition to fruits, other plant extracts have also been studied for their potential in improving gastrointestinal health. For instance, it has been discovered that oregano extract possesses antibacterial and antioxidant characteristics that can help preserve food and enhance digestive health (Veenstra and Johnson, 2019) [41]. Oregano extract has been shown to have anti-inflammatory effects, which can be beneficial for gastrointestinal conditions such as gastritis and inflammatory bowel disease (Veenstra and Johnson, 2019) [41]. Traditional medicine also recognizes the potential of medicinal plants in treating gastrointestinal issues. In a study conducted in Ethiopia, several medicinal plants were identified for their use in treating gastrointestinal disorders (Bekele *et al*., 2018) [42]. Similarly, a Moroccan investigation revealed medicinal herbs used to treat acute digestive tract issues (Es-Safi *et al*., 2020) [43]. These plants are often used in traditional remedies and have been passed down through generations. *Celtis australis*, commonly known as Mediterranean hackberry, is another medicinal plant used in different countries as a natural remedy for stomach disorders (Benamar *et al*., 2022) [44]. It contains bioactive compounds with various pharmacological activities, including hepatoprotective, analgesic, anti-inflammatory, cytotoxic, antioxidant, and antimicrobial properties. The leaves and fruits of *C. australis* are commonly used in traditional remedies for stomach disorders. Medicinal plants have been used to treat digestive system disorders in various regions. In the village of Tanap, within the jurisdiction of Sanggau, the Dayak Muara community utilizes a variety of therapeutic flora. These include *Bryophyllum pinnatum* (commonly known as cocor bebek), *Euphorbia tirucalli* (known locally as patah tulang), and *Mimosa pudica* (referred to as putri malu) for addressing dental issues. Additionally, *Artocarpus anisophyllus* (locally termed entawak) is used for alleviating abdominal pain (Yusro *et al*., 2022) [45]. These plants are prepared and administered in different forms, such as decoctions and direct consumption.

Challenges and Future Perspectives

Despite plant extracts' promising antimicrobial efficacy, inherent challenges associated with their use as antimicrobial pharmaceuticals emphasized the need for accurate evidence of the effectiveness of medicinal plant compounds before their use (Vaou *et al*., 2021) [21]. Well-controlled toxicological and clinical studies are rare, and there is a lack of standardized tests for assessing the antimicrobial efficacy of plant extracts (Vaou *et al*., 2021) [21]. Additionally, variations in antimicrobial susceptibility tests can affect the obtained results, and more research is needed to understand the mechanisms of action and pharmacokinetic profiles of plant

extracts (Vaou *et al*., 2021) [21]. Plant extracts have demonstrated promising antimicrobial efficacy and health benefits in clinical settings. Some medicinal plants have been tested and found to have antimicrobial action against human pathogenic bacteria, suggesting their potential utility as natural antimicrobials (Manandhar *et al*., 2019) [46]. However, some challenges need to be addressed, such as the need for standardized tests and well-controlled clinical studies to provide accurate evidence of the effectiveness and safety of plant extracts (Vaou *et al*., 2021) [21]. Despite these challenges, plant extracts hold great potential as alternative antimicrobial agents and therapeutic interventions for various health conditions (B and O, 2019, Kairamkonda *et al*., 2017) [47, 48].

3. Tables, Figures and Equations

Table 1: Effect of plant extracts on human health

Plant Name	Plant Part	Extract Fraction	Health Effect	Reference
Acalypha indica	leaf	methanol extract	hepatoprotective activity against CCL4-induced hepatotoxicity	(Nambiar and Varghese, 2023) [8]
Cissus quadrangularis	stem	methanol extract	anti-arthritic	(Shamina *et al*., 2022) [49]
Helianthus annuus	shoots	aqueous extract	Antibacterial activity aginst *Staphylococcus aureus* and *Escherichia coli*	(Bassey *et al*., 2022) [50]
Anthocleista djalonesis	shoots	aqueous extract	Antibacterial activity aginst *Staphylococcus aureus* and *Escherichia coli*	(Bassey *et al*., 2022) [50]
Musa paradisiaca	-	ethanolic extract	Antibacterial	(Deepa and Sivakumar, 2020) [51]
Castanea sativa, *Prunus dulcis*, *Juglans regia*, *Olea europaea*, *Helichrysum stoechas*, *Quercus robur*, *Glycyrrhiza glabra*, *Vitis vinifera*, *Crataegus monogyna Jacq*, *Pinus pinaster*	fruits, leaves, flowers	-	antioxidant, tyrosinase inhibition, antimicrobial	(Ribeiro *et al*., 2015) [52]

Table 2: Antimicrobial activity of some plant extracts

Plant Name	Plant part	Extract fraction	Antimicrobial activity against	Reference
Artemisia vulgaris	leaf extract	methanol	*Escherichia coli*, *Salmonella typhi*, MDR *Salmonella typhi*, *Klebsiella pneumoniae*, *Citrobacter koseri*	(Manandhar *et al*., 2019) [46]
Cinnamomum tamala	leaf extract	methanol	*Escherichia coli*, *Salmonella typhi*, MDR *Salmonella typhi*, *Klebsiella pneumoniae*, *Citrobacter koseri*	(Manandhar *et al*., 2019) [46]
Ageratina adenophora	leaf extract	methanol	*Escherichia coli*, *Salmonella typhi*, MDR *Salmonella typhi*, *Klebsiella pneumoniae*, *Citrobacter koseri*	(Manandhar *et al*., 2019) [46]
Oxalis corniculata	leaf extract	methanol	*Escherichia coli*, *Salmonella typhi*, MDR *Salmonella typhi*, *Klebsiella pneumoniae*, *Citrobacter koseri*	(Manandhar *et al*., 2019) [46]
Phyllanthus amarus	leaf extract	methanol, ethanol, petroleum, ether, water	*Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Aspergillus Niger*, *Fusarium oxysporum*, *Rhizopus stolonifer*	(Sen and Batra, 2012) [53]
Trapa natans	whole plant	ethanol methanol aqueous, chloroform, hexane	*Staphylococcus aureus*, *Enterococcus faecalis*, *Lactobacillus salivarius*, *Bacillus subtilis*, *Streptococcus mutans*, *Klebsiella pneumoniae*, *E. coli*, *Pseudomonas aeruginosa*, *Proteus vulgaris and Proteus mirabilis*. *Aspergillus flavus*, *Aspergillus Niger*, *Penicillium notatum*, *Rhizopus stolonifer and Candida albicans*.	(Kiruba *et al*., 2023) [54]
Derris scandens	leaf and stem extracts	methanol	Gram-negative bacteria, Gram-positive bacteria, *Saccharomyces cerevisiae*	(Shahriar *et al*., 2023) [55]
Oliveria decumbens	not specified	essential oil, ethanol	*Staphylococcus aureus*, *Staphylococcus epidermidis*, *E. coli*, *Pseudomonas aeruginosa*, *Helicobacter pylori*, *Acinetobacter baumannii*, *Enterococcus faecalis*, *Enterobacter cloacae*, *Shigella dysenteriae*, *Klebsiella pneumoniae*, *Corynebacterium diphtheriae*, *Bacillus cereus*	(Amin *et al*., 2022) [56]
Wiedemannia orientalis	flower extract	aqueous, ethanol, methanol, acetone	*Escherichia coli*, *Proteus vulgaris*, *Pseudomonas aeruginosa*, *Listeria monocytogenes*, *Klebsiella pneumoniae*, *Bacillus subtilis*, *Bacillus megaterium*, *Staphylococcus aureus*, *Candida albicans*	(Keser *et al*., 2022) [57]

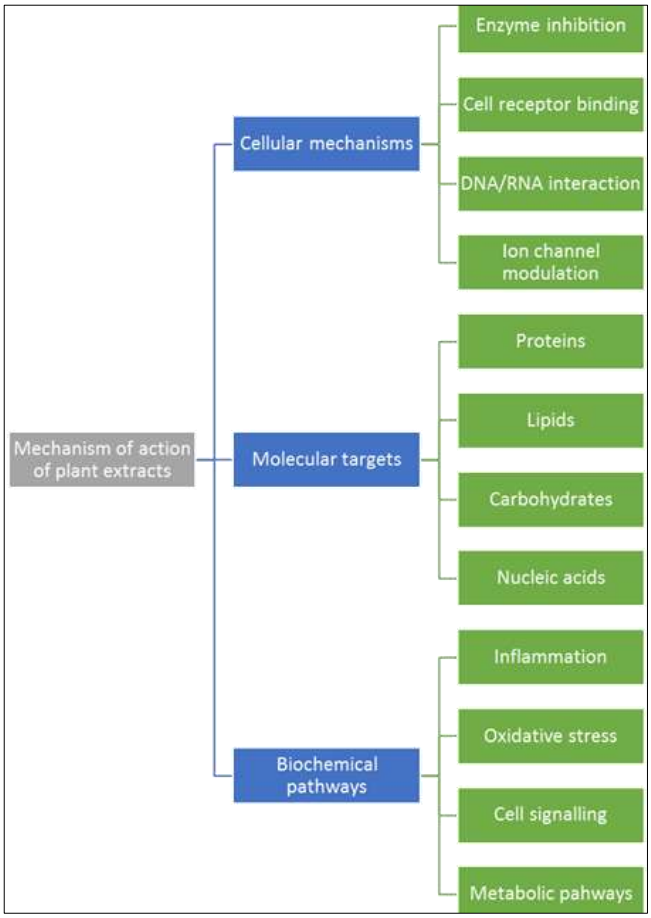

Fig 1: Comprehensive overview of the mechanisms of actions of plant extracts across cellular, molecular, and biochemical domains

4. Conclusions

Assessing health benefits derived from plant extracts is an intricate endeavor encompassing multiple dimensions. Key areas of investigation in existing literature include antioxidant properties, phytochemical composition, anti-inflammatory effects, and nephroprotective and hepatoprotective activities. Additionally, some studies have delved into the potential applications of plant extracts in treating female infertility. It is crucial, however, to acknowledge the methodological limitations and inadequate sample sizes that characterize many of these studies. Such constraints necessitate further research to provide conclusive evidence regarding the efficacy and safety of plant extracts. Despite these limitations, plant extracts remain a promising reservoir of natural compounds with potential health benefits. Their evaluation and application in developing new therapeutic agents, particularly those with antimicrobial properties, continue to be vibrant areas of scientific inquiry. Rigorous studies are imperative for establishing these plant-derived compounds' clinical efficacy and safety profiles.

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