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Review Article

Antibacterial Activity of *Psoralea cordifolia* Linn.: A Systematic Review

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ABSTRACT

Background: *Psoralea cordifolia* Linn. is also known as *Bakuchi* in Sanskrit and is found all over India. It has long been known for its therapeutic benefits and use in a variety of ailments. This plant belongs to the Fabaceae family, which serves a crucial role in maintaining a disease-free society. The antibacterial function of *P. cordifolia* L. is widely known. **Objectives:** The goal of this systematic review was to collect and evaluate data from *in vitro* studies on the antibacterial activity of *P. cordifolia* Linn. **Materials and Methods:** As a result, a systematic review was conducted using published literature gathered from Pubmed and Google Scholar till 2023. In total, 200 articles were found using a computer-based search engine. PubMed, Google Scholar and other databases were examined to investigate the anti-inflammatory properties of *P. cordifolia* L. Following the screening, 20 articles that met the requirements were chosen. *P. cordifolia* Linn. plant leaves, fruits, roots, seeds and their extract were employed to detect the various activities. **Results:** The design and outcomes of the twenty selected research varied greatly. **Conclusion:** The study finds that the varied extract of different parts and formulations and the chemical compounds of *P. cordifolia* L. that operate against the bacterial population that confirmed its antibacterial effectiveness. All the studies show Bakuchiol and Bavachin have more antibacterial activity as compared to others.

Keywords: *Psoralea cordifolia* Linn., Ethanol, methanol Extract, Bakuchiol, Antibacterial activity.

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INTRODUCTION

Psoralea corylifolia Linn. is an annual herb with alternate unifoliolate leaves. The fruit is ovoid, glabrous, black, pitted and mucronate and the inflorescence is a peduncled raceme. It is a member of the Fabaceae family and develops throughout India, particularly in the plains of Central and Eastern India. The plant has been used to cure a range of maladies, including leucoderma, heart and vascular problems, nephritis, osteoporosis and cancer.[1] Plant extracts have anti, bacterial, anti, cancer, antioxidant, anti-inflammatory, anti, fungal and immune-modulating properties.[2] Because of its efficiency against a wide range of bacteria, extract from the leaves, seeds and fruit of *P. cordifolia* L. may provide a natural alternative to antibiotics.[3] This plant's principal identified components are coumarins, flavonoids and meroterpenes. The main active chemicals in the seeds have mostly been identified. It can be used to treat Type II Diabetes mellitus when there is insulin resistance.[4] The fruit constitutes psoralenoside, isopsoralenoside, corylinin, isopsoralen, psoralen, neobavaisochin, methylcorylifol A, isoprenylcorylifol A, isoprenylneobavaisoavone, isobavachromene, psoralidin, neobavaiso avone, corylifol A, bakuchiol, coumestan, sophoracoumestan A, dihydroxybakuchiol, bisbakuchiol C, geranyliso avone and corylifols. This activity could be caused by phytochemicals. The antibacterial activity of psoralidin, bakuchicin, psoralin, prenyl avonoid and angelicin is significant. Isopsoralen, psoralen, isobavachalcone, bavachin, corylifol A, neobavaisoavone and bakuchiol make up the chemical content of the plant's leaves.[5] Bacteria are ubiquitous, mainly free-living creatures with only one biological cell. They have both gram-negative and positive characteristics. Gram-positive bacteria are bacteria that pass the Gram stains test, which is commonly used to classify bacteria into two basic groups based on cell wall type. The crystal violet stain used in the Gram-staining method of bacterial differentiation is absent in Gram-negative bacteria. *Klebsiella, Acinetobacter, Pseudomonas aeruginosa* and *E. coli* infections are examples of Gram-negative infections. All staphylococci, streptococci and a few listeria species are Gram-positive bacteria.[6]

The study's goal is to establish the greatest potential of *P. cordifolia* L. by examining its various sections, extraction methods and phytochemicals that yield the best outcomes. The goal of this brief review is to analyse and summarise the antibacterial activity of phytochemical components of *P. cordifolia* L. from diverse

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chemical groups. Based on information obtained from published and peer-reviewed research articles, the classes of phenolic acids, tannins and flavonoids exhibit antibacterial activity against diverse bacteria strains. The global problem of drug usage, along with the pharmaceutical industry's lack of novel antibiotic therapies, has resulted in the rise of drug-resistant bacteria, putting standard antibiotic results in jeopardy. Given the severity of this ailment, it is critical to research plant extracts as preventive and therapeutic approach.[7] Ensured knowledge may supply future schemes for responsive assistance for medical technologists' practises in determining the effect of distinct components of the *P. cordifolia* L. on various gram-negative and gram-positive bacteria. Furthermore, the findings of this study will assist researchers in gaining more relevant and thorough knowledge that will be valuable in their future practice.

MATERIALS AND METHODS

Literature Search

The study papers and journal papers utilised in the mini-review were gathered from online resources such as Google Scholar, PubMed, etc., using search phrases such as "*Bakuchi*," "*Psoralea cordifolia* L.", "Antibacterial," and "Extract." These databases serve as a basis for the quick reviewing method's evaluation of research articles and journals.

Eligibility Criteria

The following are the experimental research criteria for this work: (1) Presented in English, (2) Released within 2001 and today, (3) Obtained from reputable sources such as PubMed, Goggle scholar and (4) Addresses the antibacterial activity of phyto-chemicals discovered in *Psoralea cordifolia* L. roots, leaves, tender stem, seeds and fruits. The following are the exclusion criteria: (1) Review papers, (2) Non-English publications and studies, (3) published before 2001, (4) From untrustworthy sources and *P. cordifolia* L. activity against bacteria.

The flowchart in Figure 1 depicts the process of selecting articles.

Selection Strategy

The research' eligibility was assessed and determined by each author independently based on the previously stated criteria for acceptance and elimination. The title and abstract were evaluated first, accompanied by the believability. The papers' full texts were then studied for further evaluation.

Data Extraction

The researchers extracted eligible articles based on research characteristics such as the first writer's last name, year of the publication's release part of *P. cordifolia* L. used, category of compounds and specific substances extracted, targeted bacteria, the Minimal Inhibitory Concentration (MIC), Minimum bactericidal concentration, Zone of Inhibition (ZOI) of the extract and study results.

RESULTS

During the initial search, 200 literature papers and journals were found using PubMed (50) and Google Scholar (150). The data extracted from the collected literature papers and journals resulted data that did not satisfy the criteria were eliminated. The rejected publications have been eliminated. Using compilation, inclusion and exclusion criteria. Due to the exclusion of three investigations, a total of 200 papers and journals were kept. The 50 kinds of literature were screened based on title, abstract, relevancy, availability of full-text articles, language of research and year of publication. The screening technique returned 150 assessed

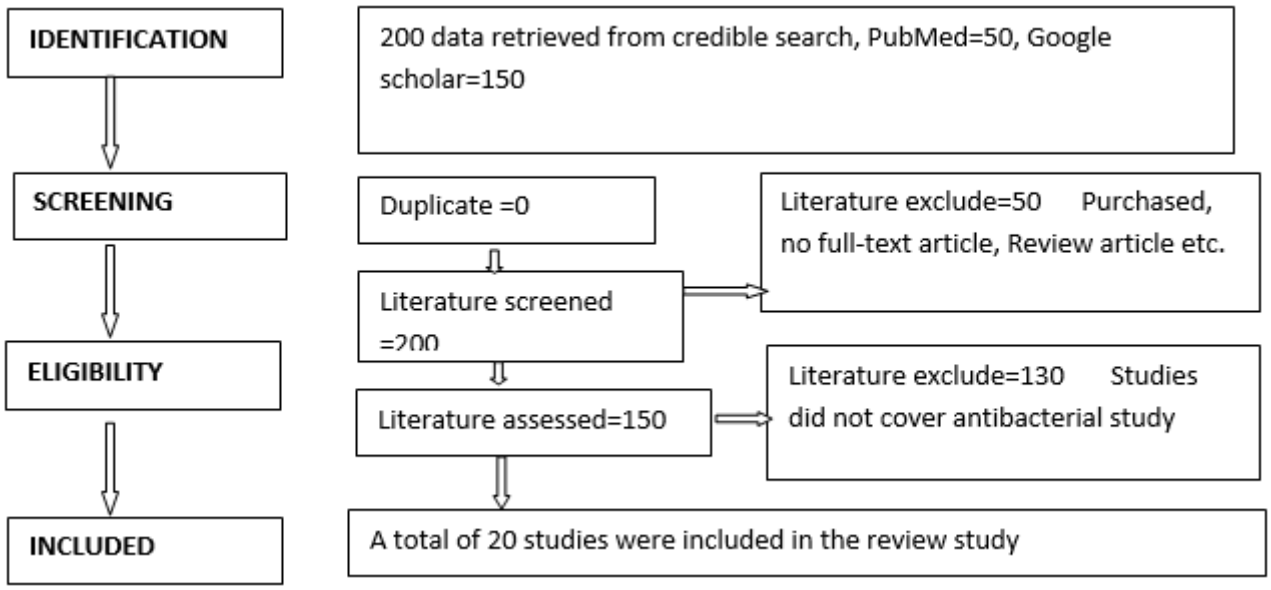

Figure 1: Schematic Diagram for study Selection.

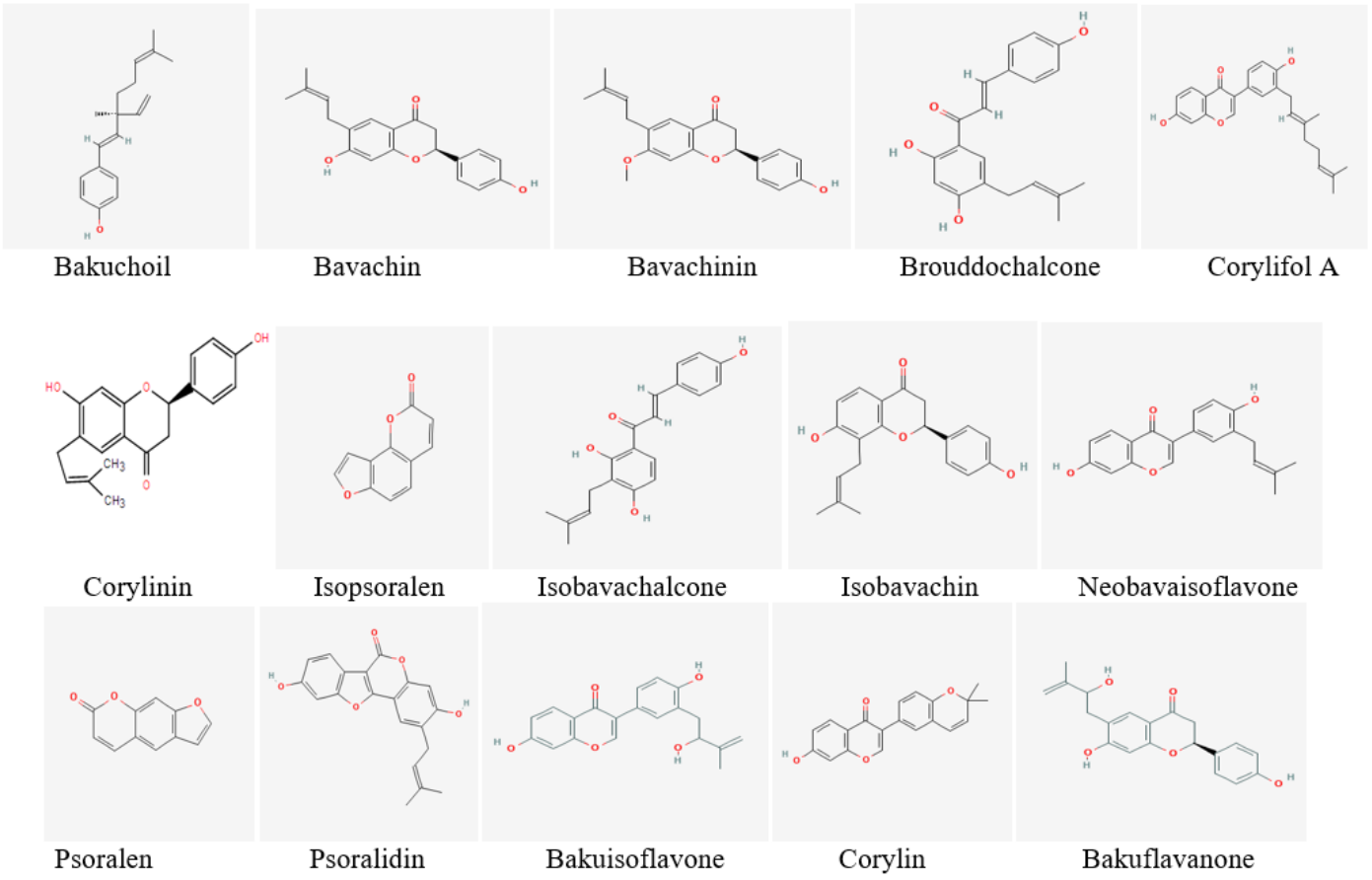

Figure 2: Different Chemical compounds of Psoralea cordifolia Linn. that have antibacterial activity.[National Centre for Biotechnology Information. PubChem Compounds Summary. https://pubchem.ncbi.nlm.nih.gov/compound/name of compound].

articles, which were then excluded based on their relevance to the antibacterial capabilities of *P. cordifolia* L., yielding a total of 130 discarded publications. Following the screening, 20 studies were obtained. The publications and studies that were retained were included in the review. Table 1 shows the data retrieved for each publication.

Phytochemical compounds present in *P. cordifolia* Linn. plant

The phytochemical substances found in *P. cordifolia* L. differ depending on the part of the plant they are found in. Alkaloids, sugars, flavonoids, glycosides, phenolics, tannins, steroids and saponins are the most prevalent phytochemical elements. Psoralen, coumarins, isopsorale, neobavaislfoavone and bovachin compounds were found in extracts of the roots of *P. cordifolia* L. in methanol, water and ethanol. Seed ethanol extract contains Bavachin, corylin, corylifol, isobavachalcone, 4-0-methylbrousso, Isobavachin, Corylifolinin, Bakuchiol, Psoralen, Isopsoralen, Psolaridine, Cadinene, Isopsoralen and Psoraledin.[4-6]

Overall, the chemical compounds present in *P. cordifolia* L. are Coumarins psoralidin, psoralen, bakuchiol, bavachinin, baldachin, corylin, corylifol, corylifolin, flavanones, isoflavones, chalcones, meroterpenes, coumarins, isobavachalcone, bakuchiol, Corylifol C, neobavaisoflavone and corylifol B.[7] The chemical compounds structure shown in Figure 2 and collected from different articles shown Figure 3.

Minimum Inhibitory and Bactericidal Doses of *P. cordifolia* L. Extract against Bacteria Pathogen Strains

P. cordifolia L. antibacterial activity yielded MIC (Minimum Inhibitory Concentrations) values of 9-32 µg/mL, MBC (Minimum Bactericidal Concentrations) values of 25-313 µg/mL and ZOI (Zone of Inhibition) values of 10-42 mm. These findings are from different studies of different parts of *P. cordifolia* L. and the methanol extract showed more effectiveness against gram-negative and gram-positive.[8] Furthermore, it can inhibit biofilm growth by disturbing microbial viability, lowering the expression of genes related to biofilm development and destroying enzymes and polysaccharides that aid in biofilm formation. Bavachin has the strongest antibacterial activity, with a MIC of 31 µg/mL.[9]

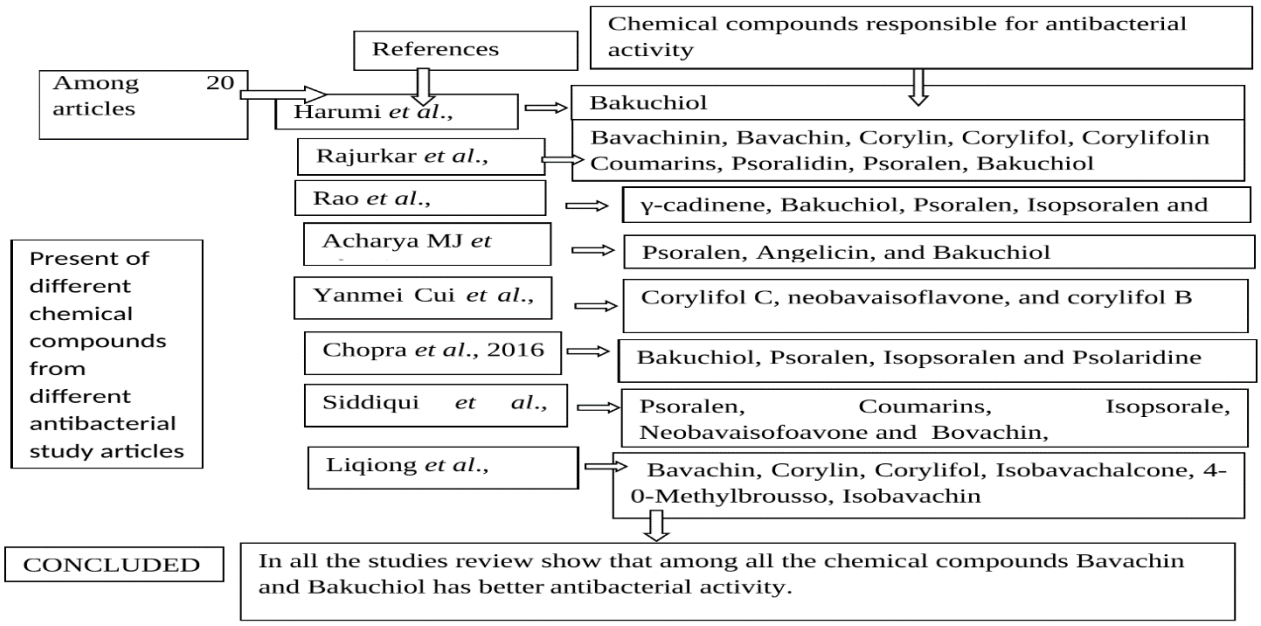

Figure 3: Diagrammatic presentation of chemical compounds present in *P. cordifolia* L.[2,8,9,13,19,21,23,27]

DISCUSSION

After screening, 20 articles that met the requirements were chosen. The antibacterial activity of *P. cordifolia* L. was demonstrated in many articles and plant leaves, fruits, roots and seeds were employed to detect the various activities. It contains a variety of phenolic chemicals that are responsible for its antibacterial action against various bacteria. Experimental research discovered the many kinds of substances found in the plant including flavonoids, polyphenols, tannins, phenolic acids and so on. Various antibacterial mechanisms have been proposed for the chemicals present in each section.[10]

Flavonoids, polyphenols, phenolic acid and tannins are among the substances found in *P. cordifolia* L. and they are thought to be the cause of microbe inhibition. By disrupting the cell membrane, flavonoids and phenolic acids cause cell lysis, which lowers DNA synthesis. Tannins particularly ellagitannins, trap metal ions essential for bacterial development. The inhibitory mechanisms of polyphenols, notably ellagic acid are still unclear.[11] The chemical structure of phenol molecules is linked to their antibacterial function. It can easily infiltrate the pathogen's membrane and disrupt its enzymatic activity, resulting in cell death because it is lipophilic.[12]

P. cordifolia L. is an excellent source of bioactive components that have significant antibacterial effects on bacterial population growth, implying that the researched *P. cordifolia* L. plant could be an herbal remedy for minimising the formation of bacteria pathogen strains, which are frequently involved in food-borne illnesses. The polyphenol content of the fruits, roots, seeds and leaves varied according to the extraction methods, solvents used and dosage formulation. The MIC/MBC values of *P. cordifolia* L. Extract found in several studies differ significantly. The mechanism of antibacterial effects essentially involves damaging the cell membrane and bacterial cell wall to modify bacterial membrane permeability; effect on protein and nucleotide synthesis; and reduction of bacterial enzymatic activity.[13] Corylifolinin exhibited specific effects on bacterial cell membranes. The mechanism of antibacterial effects mostly included the destruction of the cell membrane and bacterial cell wall to alter bacterial membrane permeability; effect on protein and nucleotide synthesis; and suppression of bacterial enzymatic activity.[14] Even a study on seeds leaves and aerial parts of *P. cordifolia* L. showed antibacterial activity.[15,16]

Bakuchiol had equal antibacterial action against adhering bacterial cells within water-insoluble glucan with the addition of sucrose. Bakuchiol has been reported to have a cytotoxic effect against cells in culture, which has been connected to cell membrane disintegration using microscopy of electrons and haemolytic activity.

Bakuchiol's biological actions have lately been reported to include anti-inflammatory properties, inhibition of mitochondrial lipid peroxidation, immune system activation, inhibition of DNA polymerase, suppression of papilloma development and diabetes prevention. As a result, Bakuchiol could be a suitable lead chemical for the development of antibacterial drugs against human oral infections.[9,17] Psoralen inhibits the growth of bacteria such as *M canis, M gypseum, T rubrum, T. mentagrophytes, S. aureus, C. albicans* and *E. coli*.[18] The MIC of methanol extract of *P. corylifolia* L. seeds was reported to be in the 2.5 to 5 mg/mL range for the majority of pathogens.[10]

Table 1: Experimental study involving the antibacterial activity of *Psoralea cordifolia* Linn. on different gram-negative and positive bacteria pathogens.

Author	Part used	MIC/ MBC/ ZOI	Target pathogen	Compounds	Outcomes
1. Harumi *et al.*, 2001	Extract of seed	MIC	*S. mutans, E. faecalis, L. acidophilus, L. plantarum, P. gingivalis, S. sanguis, S. salivarius, S. salivarius, A. viscosus, L. plantarum, L. casei.*	Bakuchiol	Bakuchiol is potentially useful for the development of antibacterial agents.
2. Upadhyaya *et al.*, 2010	Essential oil	MIC MBC ZOI	*E. coli, B. cereus, L. acidophilus, M. luteus, S. aureus, K. pneumoniae, S. pneumoniae.*		This study focuses on the antibacterial capabilities of plant essential oils against human pathogenic microorganisms. When evaluated *in vitro*, all essential oils were found to have significantly stronger bacteriostatic and bactericidal activity than synthetic antibiotics.
3.Rajurkar *et al.*, 2011	Leaves Extract Petroleum ether and ethanol.	ZOI	*E. coli, Bacillus subtilis, S. aureus.*	Bavachinin, Bavachin, Corylin, Corylifol, Corylifolin Coumarins, Psoralidin, Psoralen, Bakuchiol.	When the three extracts were mixed in equal concentration it showed more inhibitory zone as compared to other individual extracts.
4. Chandra *et al.*, 2011	Seed, Leaf and stem Extract of aqueous and methanol.	ZOI	*S. coccus, P. morgan, S. epidermis, B. megatinium, Anterobacteria aerogenes, Alcaligene faecalis.*		*P. cordifolia* L. showed more potent and showed activity against bacterial strains studied.
5. Purkayastha *et al.*, 2012	Bakuchi oil	ZOI	*P. mirabilis, Acinetobacter, S. aureus, E.coli, K. pneumoniae, P. aeruginosa, Enterococcus, P. mirabilis.*		The antibacterial effects of *P. Corylifolia* L essential oil against human MDR bacteria are highlighted in this study.
6. Tiwari *et al.*, 2012	Leaves, seed and tender stem extract methanol, water, petroleum, ether.	ZOI	*P. vulgaris, S. typhi, K. pneumonia, P. aeruginosa.*	-	Different solvent extracts using different portions of *P. corylifolia* produced effective results, indicating the plant's potential against harmful bacterial populations.
7. Rao *et al.*, 2012	Extract of seed Methanol, hexane.	MIC	*S. sanguis, S. mutans, A. viscosus.*	γ-cadinene, Bakuchiol, Psoralen, Isopsoralen and Psoraledin.	It was found that the methanolic and acetone extract, hexane fractions and Bakuchiol showed significant antimicrobial activity against Oral care bacteria.
8. Suman *et al.*, 2013	Seed extract methanol.	ZOI	*S. aureus, E. coli, B. subtilis, B. megaterium, K. pneumonia, E. aerogenosa, Enterococci, C. albicans.*	Alkaloids, Saponins, Glycosides, Phenolics, Tannins, Flavonoids, Steroids.	The synergistic effect of *Psoralea corylifolia* and *Plumbago zeylanica* methanol extracts has never been described before.

Author	Part used	MIC/ MBC/ ZOI	Target pathogen	Compounds	Outcomes
9. Borate *et al.*, 2014	Extract of seed Methanol and diethyl ether.	MIC	*E. coli, Staphylococcus aureus, Staphylococcus epidermidis, K. pneumoniae, P. mirabilis, P. vulgaris and P. aeruginosa.*	Alkaloids, Carbohydrates, Flavonoids, Glycosides and Saponin.	*Bakuchi taila* and its various dose forms have antimicrobial efficacy against both gram-positive and gram-negative microorganisms.
10. Sung-Im Kim *et al.*, 2015	Extract of seed	MBC	*Streptococcus mutans*		According to the findings, the antibacterial activity of four distinct types of natural herbal extracts was comparable to that of synthetic chemical mouthwash solutions.
11. Acharya MJ *et al.*, 2015	Bakuchi taila, gel, siktha taila and ointment.	ZOI	*B. subtilis, S. aureus, E. coli, K. pneumonia.*	Psoralen, Angelicin and Bakuchiol.	When compared to mouth rinsing solutions containing a synthesised chemical component, four types of natural herbal extract demonstrated similar antibacterial efficacy.
12. Yanmei Cui *et al.*, 2015	Fruits extract	MIC	*S. aureus*	Flavone, Flavanones, Isoflavones chalcones meroterpenes Coumarins, Isobavachalcone, Bakuchiol, Corylifol C, Neobavaisoflavone, Corylifol B.	The isolated chemicals, isobavachalcone and bakuchiol, demonstrated substantial anti-MRSA properties. Corylifol C, neobavaisoflavone and corylifol B all showed significant antibacterial activity.
13. Sharath *et al.*, 2016	Seed Extract aerial part Methanol and hexane.	ZOI	*S. aureus*	-	The bactericidal activity of *P. corylifolea* seed extracts in hexane and methanol was demonstrated.
14. Chopra *et al.*, 2016	Extract of seed Methanol, ether, Water etc.	MIC	*S. aureus, E.coli, S. aureus, P. aeruginosa.*	Bakuchiol, Psoralen, Isopsoralen and Psolaridine.	The current study explored a methanol and petroleum ether extract of *Psoralea corylifolia* seeds against bacterial infections of the skin.
15. Vidya *et al.*, 2017	Leaves Stem and Seeds Hexane, Chloroform and Methanol.	ZOI	*E. coli*		The study showed that methanolic extract has the best suppression of pathogen activity.
16. Chitrangna *et al.*, 2017	Seeds Petroleum ether, ethane Chloroform.	ZOI	*B. licheniformis, E. coli.*	Flavanoids, Phenols.	All the seed extracts of *Psoralea corylifolia* have potent antibacterial activity.
17. Nan He *et al.*, 2018	Corylifolinin extract from powder	MIC MBC	*S. coccus, S. aureus.*	Corylifolinin	The results showed that corylifolinin had a powerful antibacterial action via bacteriolysis.

Author	Part used	MIC/ MBC/ ZOI	Target pathogen	Compounds	Outcomes
18. Xiaotian *et al.*, 2018	Psoralen and angelicin.	MIC, MAC	*S. aureus*	Psoralen and Angelicin.	Experiments showed that psoralen and angelicin exhibited antibacterial effects on planktonic bacteria and bacterial biofilms.
19. Siddiqui *et al.*, 2019	Roots Extract of methanol, aqeuous, ethanol.	ZOI	*B. subtilis, S. cereus, megaterium, E. coli, S. aureus, S. typhimurium, P. vulgaris, S. boydii, P. aeruginosa.*	Psoralen, Coumarins, Isopsorale, Neobavaisofoavone, Bovachin,	Ethanol extracts are efficient against Gram-positive bacteria under research, but methanol extracts are effective against Gram-positive and some Gram-negative bacteria.
20. Liqiong *et al.*, 2022	Seed Ethanol Extract	MIC	*S. aureus, S. coccus, E. shigella dysenteriae, P. geruginosa, E. coli.*	Bavachin, Corylin, Corylifol, Isobavachalcone,4-0-Methylbrousso, Isobavachin.	PCSs possessed potent activities against Gram (+) bacteria.

*MIC: Minimum inhibitory concentration, MBC: Minimum bacterial concentrations, ZOI: Zone of inhibition.

The marker compounds (bakuchiol, psoralen, isopsoralen and psolaridin) concluded that antimicrobial activity of the extracts of *P. corylifolia* L. was due to the presence of Bakuchiol.[19] Antimicrobial screening of *P. corylifolia* L. Leaf, Seed and Stem in different solvents such as hexane, chloroform and methanol against appropriate pathogens demonstrates that methanolic extraction has the best suppression of pathogen activity.[20] Bakuchiol's MIC range was determined to be 9.76-19.5 g/mL.[21] *P. cordifolia* L. seeds extracted in alcohol and diethyl ether have revealed wide-spectrum antibacterial action against cutaneous pathogens, with a maximum zone of inhibition against gram-negative and gram-positive pathogens and a zone of inhibition against gram-positive pathogens and a zone of inhibition against gram-positive pathogens inhibition 21mm in diameter and a Maximum Inhibitory Concentration (MIC) of 2.5-5mg/mL. Out of all the compounds examined, Bakuchiol was found to have significant antibacterial activity.

According to a specific concept, the two the coumarin chemicals might trigger cell disintegration and death by destroying the cell membrane. Because psoralen and angelicin are both liposoluble, they can pass the plasma membrane and disrupt the cytomembrane's integrity.[22] The presence of tannins in *P. cordifolia* L. oil is responsible for its antibacterial activity against *Enterococcus* sp., as demonstrated by a TLC bio autography experiment. *P. cordifolia* L. essential oil has demonstrated strong antibacterial activity against *Enterococcus* sp., *P. aeruginosa, E. coli* and *S. aureus*, making it a promising candidate for development into the next generation of antimicrobials to tackle Multidrug Resistance (MDR) in pathogenic bacteria.[23] Six Plant Essential Oils' Antibacterial Activity against Pathogenic Bacterial Strains, this study focuses on the antibacterial properties of plant essential oils against human pathogenic pathogens. When evaluated *in vitro*, all essential oils were found to have substantially stronger bacteriostatic and bactericidal activity than synthetic antibiotics. Other Gram (-) and Gram (+) bacteria may be affected by these essential oils. More importantly, because of their great antibacterial potential and few side effects, these might be included in the list of herbal medications. As a result, essential oils and their constituents might be prescribed for therapeutic purposes and utilised as an alternative medication.[24,25] Standard chemical compound analysis was performed on extracts from plants, which revealed the existence of a variety of secondary metabolites such as reducing sugars, tannins, flavonoids, terpenoids, glycosides and phenolics.[26,27]

Only corylifol (MIC 16 g/mL) showed an antibacterial effect on the two MRSA strains tested. Bavachin exhibited the lowest bactericidal impact (MIC 32 g/mL), while the other flavanones, bakuflavanone and bavachinin, did not have antibacterial characteristics at the levels tested. Except for neobavaisoflavone, which had a MIC of 16 g/mL, other isoflavones had little bactericidal activity (MICs>32 g/mL). Isobavachalcone and corylifol B, two chalcones, showed significant antibacterial activity against MRSA (Methicilin-Resistant *staphylococcus aureus*) (MIC 8 or 16 g/mL). Bakuchiol, a phenolic meroterpene, demonstrated a notable bactericidal activity (MIC, 8 g/mL), while the other meroterpenes and coumarins had minor effects. Corylifol C, neobavaisoflavone and corylifol B all showed significant antibacterial activity. The MIC value of 30 µg/mL of *P. cordifolia* L. seeds contains a considerable amount of polyphenols and has been demonstrated to produce the highest antibacterial activity.[28,29] According to the review's summary, the authors found extraordinary promise, notably in extracts produced from various components of *P. cordifolia* L., such as roots, seeds, fruits, leaves and dosage formulations. The separation of bioactive substances, especially those with antibacterial activity, might be used to produce medications and help combat resistant to antibiotics.

CONCLUSION

The research aims to determine the antibacterial activity of different portions of the *P. cordifolia* L. Plant, especially the phytochemical elements found in different kinds of compounds. A study of multiple studies showed that polyphenols, which include flavonoids and tannins are the most prevalent class of compounds found in many *P. cordifolia* L. The components, particularly the leaves, roots, fruits, seeds and dosage form formulations with antibacterial properties. Finally, the phytochemical components of *P. cordifolia* L. have antimicrobial activity. Among all investigations, Bavachin and Bakuchiol exhibit stronger antibacterial action than other chemical ingredients.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

***P. cordifolia* L.:** *Psoralea cordifolia* Linn.; **MDR:** Multi Drugs Resistance; **MRSA:** Methicilin resistant *Staphyllococcus aureus*; **ZOI:** Zone of inhibition; **MBC:** Minimum Bacterial Concentration; **MIC:** Minimum Inhibitory Concentration; **Gram negative:** Gram (-); **Gram positive:** Gram (+).

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