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Phytochemical Analysis of *Catharanthus roseus* Plant Extract and Its Antimicrobial Activity: A Comprehensive Review

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Abstract: *Catharanthus roseus (L.) G. Don, commonly known as Madagascar Periwinkle or Vinca rosea, is one of the most extensively studied medicinal plants in the world. Belonging to the family Apocynaceae, this evergreen flowering shrub has been a cornerstone of traditional medicine systems across Asia, Africa, and Latin America for centuries. The plant is especially revered for its remarkably rich phytochemical profile, which includes over 100 monoterpenoid indole alkaloids (MIAs), the most notable being vinblastine and vincristine — two of the most clinically important anticancer compounds derived from plant sources. Beyond its oncological applications, C. roseus is a treasure trove of bioactive constituents including flavonoids, terpenoids, tannins, saponins, glycosides, and phenolic compounds, each contributing to a broad spectrum of pharmacological activities. This review comprehensively examines the botanical characteristics, phytochemical composition, extraction methodologies, and antimicrobial potential of C. roseus. Qualitative phytochemical screening of ethanolic extracts demonstrated the strongest overall presence of bioactive constituents, including alkaloids, glycosides, terpenoids, flavonoids, phenols, tannins, carbohydrates, and saponins. Antimicrobial assays revealed significant inhibitory activity against pathogens such as Pseudomonas aeruginosa, Staphylococcus aureus, Salmonella typhimurium, Candida albicans, and Bacillus subtilis. This article also draws upon a decade-long body of literature to place these findings within the broader context of evolving phytomedicine and the urgent need for novel natural antimicrobial agents in an era of rising antibiotic resistance.*

Keywords: Catharanthus roseus, phytochemical screening, antimicrobial activity, alkaloids, vincristine, vinblastine, medicinal plants, ethnobotany

I. INTRODUCTION

The relationship between plants and human health stretches back to the very origins of civilization. Long before the advent of modern synthetic pharmaceuticals, people across cultures relied on botanical preparations to manage and treat illness. Among the many thousands of medicinal plants documented worldwide, Catharanthus roseus occupies a position of extraordinary scientific and therapeutic significance. Known by several common names including Madagascar Periwinkle, Bright Eyes, Old Maid, and Cape Periwinkle, this ornamental yet profoundly medicinal plant has been at the center of pharmaceutical discovery for over half a century.

The story of C. roseus in modern medicine began dramatically in the 1950s when researchers, while investigating its purported antidiabetic effects, stumbled upon two powerful alkaloids — vinblastine and vincristine — that would go on to revolutionize cancer chemotherapy. These two compounds remain among the most widely used plant-derived anticancer agents in the world today, employed in the treatment of leukaemia, Hodgkin's lymphoma, neuroblastoma, and several other malignancies. This serendipitous discovery not only transformed our understanding of plant-based

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medicine but also underscored the immense untapped potential lying within the phytochemical arsenal of medicinal plants.

Beyond its landmark contribution to oncology, C. roseus has demonstrated an impressive range of additional biological activities. Traditional practitioners in India, China, the Philippines, the Caribbean, and various parts of Africa have long used this plant to manage diabetes, hypertension, bleeding disorders, and infections. Contemporary scientific investigation has validated many of these traditional claims, revealing that the plant's diverse array of chemical constituents — alkaloids, flavonoids, tannins, saponins, terpenoids, and phenolic acids — contributes to its multifaceted pharmacological profile.

In an era marked by escalating concerns over antimicrobial resistance, the search for effective natural alternatives to conventional antibiotics has become increasingly urgent. C. roseus represents a particularly promising candidate in this regard. Numerous studies have documented its inhibitory effects against a broad spectrum of bacterial and fungal pathogens, including drug-resistant strains. This review synthesizes the available literature on the phytochemical composition, extraction strategies, and antimicrobial activity of C. roseus, aiming to provide a comprehensive and accessible account of what is currently known about this remarkable plant and where future research might be most productively directed.

II. BOTANICAL DESCRIPTION AND TAXONOMY

Catharanthus roseus (L.) G. Don is an evergreen perennial sub-shrub or herb belonging to the family Apocynaceae (formerly placed in Vincaceae). It typically grows erect to a height of 30 to 100 cm and may become somewhat woody toward the base, though it can also adopt a sprawling growth habit under certain environmental conditions. Two botanical varieties have been formally recognized: C. roseus var. roseus and C. roseus var. angustus, the latter being considerably rarer and endemic to a more restricted range within Madagascar.

Table 1: Scientific Classification of Catharanthus roseus

Taxonomic Rank	Classification
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Gentianales
Family	Apocynaceae
Genus	Catharanthus
Species	C. roseus
Common Name	Madagascar Periwinkle

The leaves of C. roseus are simple, petiolate, ovate to oblong in shape, with a characteristic glossy appearance and acute margin. The colour is a deep, lustrous green, and the taste is notably bitter due to the high alkaloid content. Flowers are borne in leaf axils, either singly or in pairs on short pedicels. The corolla consists of five lobes ranging in colour from pink to white or pinkish-purple, with the corolla tube being greenish and typically exceeding 2.2 cm in length. Five anthers are attached within the upper portion of the corolla tube. The fruit is a follicle measuring 2.0 to 4.7 cm in length, containing numerous small, black seeds.

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Figure 1: Catharanthus roseus (Madagascar Periwinkle) in flower

The plant thrives in subtropical and tropical climates, showing remarkable hardiness in dry and nutritionally poor soils. It is widely cultivated as an ornamental bedding plant in temperate regions and remains in continuous bloom throughout the tropical year. Numerous cultivars have been developed for horticultural purposes, varying in flower colour (white, mauve, peach, scarlet, and reddish-orange) and cold tolerance. The plant is native to Madagascar but has been introduced and naturalized across much of the tropics and subtropics, and can be commonly found growing along roadsides in warm regions.

III. TRADITIONAL USES AND ETHNOPHARMACOLOGICAL SIGNIFICANCE

The medicinal use of Catharanthus roseus can be traced back at least to 2600 BCE in Mesopotamian records, making it one of the most ancient documented medicinal plants in human history. Its therapeutic applications span multiple traditional medicine systems, each utilizing the plant in distinctly different ways while converging on certain common indications such as diabetes, infection, and cancer.

In the Ayurvedic tradition of India, extracts derived from the plant's roots and shoots — though recognized as potentially toxic in high doses — have been employed to treat conditions ranging from muscle pain and central nervous system depression to wasp stings, nose bleeds, bleeding gums, mouth ulcers, sore throats, hypertension, cystitis, gastritis, enteritis, diarrhoea, and elevated blood sugar. Traditional Chinese medicine practitioners used C. roseus to treat malaria, diabetes, and Hodgkin's lymphoma long before Western science confirmed any of these applications.

In the Philippines, the plant is infused and consumed daily as a folk remedy to manage insulin levels and control high blood pressure. Across various parts of Africa, it has been used topically for treating wounds, eczema, cancerous sores, neck pain, and haemorrhage. In the Caribbean, it has a history of use in treating diabetes and childhood leukaemia. The leaves and seeds, rich in vincamine — an alkaloid associated with improved cerebral circulation — have been used to enhance memory and cognitive function, and to prevent age-related cognitive decline including Alzheimer's disease and dementia.

The depth and breadth of these traditional applications, drawn from independent cultures across multiple continents, constitute strong circumstantial evidence for the plant's genuine therapeutic value — and have historically provided the initial impetus for scientific investigation. At the same time, the discovery of modern pharmaceutical derivatives from C. roseus without appropriate benefit-sharing with the communities that first developed these uses has sparked important discussions about biopiracy and intellectual property in traditional knowledge systems.

IV. PHYTOCHEMICAL COMPOSITION

4.1 Alkaloids

Alkaloids represent the most pharmacologically significant class of compounds in C. roseus. The plant has been reported to contain over 100 monoterpenoid indole alkaloids (MIAs), with vinblastine and vincristine being the most commercially and clinically important. These dimeric alkaloids are formed by the coupling of vindoline and catharanthine, two monomeric alkaloids biosynthesized through a complex, multi-step pathway involving the shikimate and MEP pathways. The biosynthetic machinery involved is intricate enough that the plant remains the primary commercial source for these compounds, despite decades of efforts at total synthesis.

Other notable alkaloids include ajmalicine (used as an antihypertensive), serpentine, catharanthamine (with antitumour properties), vincamine (a cerebral vasodilator), vinpocetine (used in neurological conditions), lochnerine, and tetrahydroalstonine, among many others. Alkaloids in C. roseus are found to be hypotensive, sedative, and to possess tranquilizing and anticancerous properties. Vincristine has also been identified in biosynthetic amounts produced by the endophytic fungus Fusarium oxysporum associated with this plant, an intriguing finding with implications for biotechnological production strategies.

4.2 Flavonoids and Phenolic Compounds

Flavonoids and phenolic acids constitute another important category of bioactive compounds in C. roseus. These compounds are known to contribute significantly to the plant's antioxidant capacity and anti-inflammatory properties. Research has demonstrated that the total phenolic and flavonoid content in C. roseus tends to increase during winter months, suggesting seasonal variation in phytochemical accumulation. Additionally, studies have found that exposure to environmental pollution tends to elevate the levels of these compounds, possibly as part of a plant stress response. The presence of tannins — a type of polyphenol — has also been confirmed through qualitative screening of ethanolic extracts.

4.3 Terpenoids, Saponins, and Other Constituents

Terpenoids identified in C. roseus include several monoterpenes and sesquiterpenes that contribute to the plant's characteristic aroma and to its antimicrobial and anti-inflammatory effects. Saponins have been detected in ethanolic extracts, and these compounds are known to disrupt microbial cell membranes, contributing to the plant's antimicrobial activity. Carbohydrates, proteins, amino acids, and phytosterols have also been identified. The alkaloid reserpine, present in C. roseus, is well known for its blood-pressure-lowering properties and contributes to the plant's cardiovascular applications.

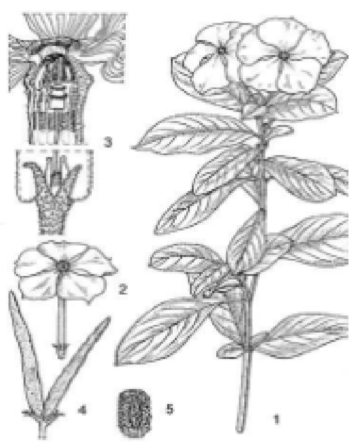

Figure 2: Botanical illustration of Catharanthus roseus showing morphological features

V. EXTRACTION METHODOLOGY

The nature and composition of plant extracts are critically dependent on the extraction method employed, as different solvents and procedures selectively solubilize different classes of phytochemicals. In systematic studies of C. roseus, four primary modes of extraction have been employed and compared: hot water extraction, cold water extraction, organic solvent extraction (using ethanol and methanol), and dry powder extraction.

5.1 Hot Water Extraction

In hot water extraction, 10 g of plant material (leaves, stems, roots, or flowers) is boiled in 100 mL of distilled water with continuous stirring for 30 minutes. After cooling to room temperature, the solution is filtered through muslin cloth and then through Whatman No. 1 filter paper under aseptic conditions. The filtered extract is centrifuged at 5000 rpm for 15 minutes and stored at 4°C. This method is effective at extracting water-soluble constituents such as certain alkaloids, saponins, and carbohydrates, and approximates traditional preparation methods such as decoctions.

5.2 Cold Water and Organic Solvent Extraction

Cold water extraction involves maceration of plant material at room temperature, which preserves heat-labile compounds that might be degraded by boiling. For organic solvent extraction, 10 g of plant material is mixed thoroughly with 100 mL of ethanol or methanol. After double filtration, the solvent is completely evaporated at room temperature to yield a concentrated crude extract. Stock solutions at 100 mg/mL are prepared for biological testing. Organic solvent extracts, particularly ethanolic extracts, have consistently demonstrated the broadest spectrum of phytochemical constituents and antimicrobial activity, making them the preferred extraction medium in most C. roseus studies.

VI. QUALITATIVE PHYTOCHEMICAL SCREENING

Qualitative phytochemical screening was conducted to assess the presence or absence of major classes of bioactive compounds across different solvent extracts — petroleum ether, acetone, chloroform, and ethanol. The following standard colorimetric and precipitation tests were applied..

For alkaloids, Mayer's reagent and iodine solution were used; yellow precipitate formation indicates a positive result. Terpenoids were detected using concentrated H_2SO_4, with a grayish colour indicating their presence. Phenols and tannins were identified using $FeCl_3$, where blue-green or black colouration confirms their presence. Reducing sugars were detected using Fehling's A and B solution; red precipitate formation is a positive indicator. Saponins were identified by the foam test — persistent foam formation upon shaking with distilled water indicates their presence. Flavonoids were confirmed by a magnesium ribbon and HCl test, where a pink-scarlet colour indicates positivity. Quinones were detected using 1% NaOH, and steroids using the Liebermann-Burchard test with chloroform and H_2SO_4.

Table 2: Phytochemical Screening of C. roseus Extracts

Phytochemical	Pet. Ether	Acetone	Chloroform	Ethanol
Alkaloids	+	+	+	+
Glycosides	–	–	–	+
Terpenoids	–	+	+	+
Flavonoids	–	–	–	+
Phenols	–	–	–	+
Tannins	–	–	–	+
Carbohydrates	–	–	–	+

The results clearly indicate that ethanolic extracts contain the richest and most comprehensive phytochemical profile. Alkaloids were the only class detected across all four solvents, reflecting their relatively broad solubility, while

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glycosides, flavonoids, phenols, tannins, and carbohydrates were exclusively detected in ethanol extracts. This underscores ethanol as the solvent of choice for maximum phytochemical yield from C. roseus and is consistent with findings from independent laboratories worldwide.

VII. ANTIMICROBIAL ACTIVITY

7.1 Mechanisms of Antimicrobial Action

Plants have been recognized as reservoirs of novel antimicrobial compounds ever since ancient healers first applied poultices of various herbs to infected wounds. The interest in plant-derived antimicrobials has been renewed and intensified by the global crisis of antibiotic resistance, in which conventional antibiotics are increasingly ineffective against a growing number of pathogenic organisms. C. roseus offers a particularly compelling case for investigation in this context, given its well-characterized phytochemical diversity and long history of use against infections.

The antimicrobial effects of C. roseus are attributed to several classes of compounds acting through distinct mechanisms. Alkaloids disrupt bacterial DNA replication and interfere with protein synthesis pathways. Flavonoids and phenolic compounds impair cell membrane integrity and inhibit key bacterial enzymes. Tannins precipitate bacterial proteins and form complexes that disrupt cellular metabolism. Saponins permeabilize microbial membranes through amphiphilic interactions, leading to leakage of intracellular contents. The synergistic effect of multiple compounds acting simultaneously may contribute to the broad-spectrum activity observed.

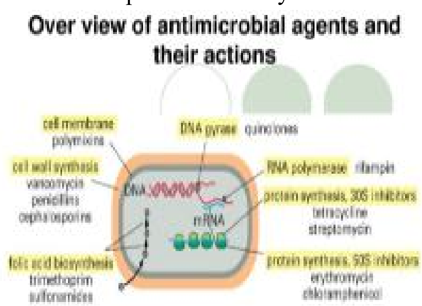

Figure 3: Overview of antimicrobial agents and their cellular mechanisms of action

7.2 Activity Against Bacterial Pathogens

Studies examining the antibacterial properties of C. roseus have tested extracts against a wide panel of both gram-positive and gram-negative organisms. Significant inhibitory activity has been documented against Pseudomonas aeruginosa (NCIM 2036), Staphylococcus aureus (NCIM 5021), Salmonella typhimurium (NCIM 2501), Escherichia coli, Klebsiella pneumoniae, Bacillus subtilis, Bacillus licheniformis, Shigella dysenteriae, and Bacillus anthraces.

Ethanolic leaf extracts have generally shown the highest levels of antibacterial activity across studies. One study using agar well diffusion demonstrated zones of inhibition against Candida albicans, Pseudomonas aeruginosa, and Aspergillus niger measuring 14, 13, and 8 mm respectively. In another study, in vitro leaf callus extracts at a concentration of 2.0 mg/mL showed a maximum zone of inhibition of 30.3 mm against Bacillus licheniformis — a particularly striking result that suggests callus cultures might be an even more potent source of antimicrobial constituents than whole plant material.

7.3 Activity Against Fungi and Nanoparticle Applications

Antifungal activity has also been demonstrated against Candida albicans, Aspergillus niger, Alternaria solani, Aspergillus fumigatus, and Rhizopus oryzae. Interestingly, in vitro-derived extracts (from tissue-cultured plants) consistently outperformed extracts from conventionally grown plants in both antibacterial and antifungal assays, raising intriguing possibilities for controlled production of high-potency antimicrobial preparations.

A particularly innovative line of research has involved the use of C. roseus extracts as bioreducing agents for the green synthesis of silver nanoparticles (AgNPs) and zinc oxide nanoparticles (ZnO NPs). These biogenic nanoparticles have demonstrated potent antimicrobial activity, with AgNPs synthesized from C. roseus showing high inhibitory zones against Shigella dysenteriae, Klebsiella pneumoniae, Bacillus anthraces, Staphylococcus aureus, and Pseudomonas aeruginosa. This intersection of phytochemistry, nanotechnology, and antimicrobial medicine represents one of the most exciting frontiers in C. roseus research.

VIII. OTHER NOTABLE PHARMACOLOGICAL ACTIVITIES

8.1 Anticancer Properties

The anticancer applications of C. roseus are its most celebrated contribution to modern medicine. Vincristine and vinblastine, the plant's signature alkaloids, belong to the vinca alkaloid class and function as microtubule-disrupting agents that interfere with the mitotic spindle, effectively halting cell division. They are used in chemotherapy regimens for acute lymphoblastic leukaemia, Hodgkin's lymphoma, non-Hodgkin's lymphoma, neuroblastoma, Wilms' tumour, Kaposi's sarcoma, and rhabdomyosarcoma. Derivatives such as vinflunine and vinorelbine have been developed to improve on the pharmacokinetic and adverse-effect profiles of the parent compounds. Beyond these well-established alkaloids, more recent research has identified additional compounds in C. roseus — including catharanthamine — with antitumour properties, and has documented the plant's ability to inhibit tumour angiogenesis by preventing the growth of new blood vessels that support tumour progression
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8.2 Antidiabetic and Cardiovascular Effects

The plant has long been used as a traditional antidiabetic agent, and scientific studies have provided partial validation for this use. C. roseus extracts have been shown to influence insulin production and to improve the body's utilization of glucose in animal models. The alkaloid reserpine, present in the plant, is a known antihypertensive compound that acts by depleting catecholamines from sympathetic nerve terminals. Vincamine, another alkaloid, is used pharmaceutically for its vasodilatory and nootropic effects, increasing cerebral blood flow and improving cerebral oxygenation — making it useful in the management of hypertension and age-related cognitive decline.

8.3 Antioxidant and Anti-inflammatory Activities

Catharanthus roseus has been identified as a good source of both enzymatic and non-enzymatic antioxidants. The flavonoid and phenolic content of the plant contributes substantially to its free-radical scavenging capacity, which in turn may underlie anti-inflammatory effects. The plant's traditional use for treating bleeding conditions and promoting wound healing aligns with its documented astringent (tannin-mediated) and anti-inflammatory properties.

IX. REVIEW OF KEY STUDIES

The scientific literature on C. roseus has grown substantially over the past two decades, building a comprehensive evidence base for its diverse pharmacological properties. The following synthesis draws from major studies that have shaped current understanding.

Nayak and Pinto Pereira (2006) conducted an evaluation of the antimicrobial and wound-healing activity of C. roseus flower extract in rats, providing early evidence for its efficacy in infection management. Patil and Ghosh (2010) demonstrated antimicrobial properties in C. roseus extracts against multiple bacterial pathogens and highlighted the growing concern over bacterial resistance to existing antibiotics as a key motivation for exploring plant-based alternatives.

Khalil et al. (2012) evaluated ethanolic leaf extracts from plants collected in Saudi Arabia against Staphylococcus aureus, Escherichia coli, and Candida albicans using the disc diffusion method, reporting very strong inhibitory activity against all tested organisms. Gajalakshmi, Vijayalakshmi, and Devi (2013) compiled a comprehensive review of the pharmacological activities of C. roseus, with particular emphasis on alkaloids as the primary bioactive constituents, and systematically catalogued activities ranging from antimicrobial to antineoplastic.

Naz et al. (2015) and Kabesh et al. (2015) independently reported phytochemical and antimicrobial studies, with Naz's group highlighting superior activity in in vitro-derived extracts and callus cultures. Hanasy et al. (2016) investigated Agrobacterium rhizogenes-mediated hairy root transformation of C. roseus as a biotechnological strategy to enhance production of vincristine and other valuable alkaloids. Gupta et al. (2018) reported the biosynthesis of ZnO nanoparticles using C. roseus leaf extract, characterizing them through advanced spectroscopic and microscopic techniques and documenting their antimicrobial efficacy.

Van, Bowyer, and Scarlett (2020) provided a comprehensive review of C. roseus phytochemicals and their biological activities, emphasizing antioxidant, antibacterial, antifungal, antidiabetic, and anticancer properties, and affirming vinblastine and vincristine as the first plant-derived anticancer agents to reach clinical use. Ahmad et al. (2020) synthesized silver nanoparticles from C. roseus leaves and silver nitrate, reporting high antimicrobial efficacy against multiple resistant bacterial strains. Collectively, this body of work confirms the breadth and depth of C. roseus's pharmacological potential and points toward a robust and expanding future for this medicinal plant in pharmaceutical research.

X. PHYSICOCHEMICAL PARAMETERS

Physicochemical characterization of C. roseus leaf material provides standardization data that are important for quality control in both research and pharmaceutical applications. Studies have established the following values within WHO-prescribed limits.

Table 3: Physicochemical Constants of C. roseus Leaf

Parameter	Value
Total Ash	0.4% w/w
Acid Insoluble Ash	0.68% w/w
Water Soluble Ash	1.68% w/w
Sulphated Ash	4.12% w/w
Water Soluble Extractive	6.34% w/w
Alcohol Soluble Extractive	4.8% w/w
Moisture Content	10.09% w/w
Loss on Drying	5.01% w/w

Fluorescence analysis of the leaf powder under various reagent treatments and UV conditions has also been documented, providing additional fingerprinting data useful for authentication. Powder microscopy reveals the characteristic cruciferous stomata and unicellular covering trichomes of this species, while calcium oxalate crystals are notably absent — a useful distinguishing feature. Transverse section microscopy confirms a single-layered epidermis covered with thick cuticle, a well-defined palisade parenchyma layer below the upper epidermis, and prominently developed vascular bundles of xylem and phloem in the midrib region.

XI. SAFETY PROFILE AND CONTRAINDICATIONS

While Catharanthus roseus offers a remarkable range of therapeutic benefits, it is important to acknowledge that the same alkaloids responsible for its pharmacological activity can also produce significant adverse effects when consumed or administered improperly. Vinca alkaloids, in particular, carry a well-documented toxicity profile. Side effects associated with excessive consumption include nausea, vomiting, hair loss, hearing loss, dizziness, haemorrhage, peripheral nerve problems, liver damage, and hypoglycaemia. The drug vincristine, when administered clinically at high doses, is associated with peripheral neuropathy as a dose-limiting toxicity.

The use of C. roseus preparations is strongly contraindicated in pregnant women and breastfeeding mothers, given the potential for teratogenic or toxic effects. Topical applications have generally been considered safer, though there is insufficient evidence to confirm their complete safety. Any therapeutic use of this plant should ideally be undertaken under appropriate medical supervision, particularly given that the concentration of active alkaloids can vary considerably depending on the plant's geographic origin, season of harvest, and method of preparation.

XII. CONCLUSION

Catharanthus roseus stands as one of the most pharmacologically significant plants in the history of medicine — a living testament to the extraordinary potential hidden within the natural world. Its contributions to modern oncology through the alkaloids vinblastine and vincristine have saved or extended countless lives, and its broader phytochemical arsenal continues to offer promising leads for drug discovery in antimicrobial therapy, metabolic disease management, and neuroprotection.

This review has demonstrated that ethanolic extracts yield the richest phytochemical profile, exhibiting the presence of alkaloids, glycosides, terpenoids, flavonoids, phenols, tannins, carbohydrates, and saponins. These constituents collectively account for the plant's broad-spectrum antimicrobial activity against bacterial pathogens including Pseudomonas aeruginosa, Staphylococcus aureus, Bacillus subtilis, and Salmonella typhimurium, as well as fungal organisms such as Candida albicans and Aspergillus species. The application of C. roseus in green nanotechnology for the biosynthesis of antimicrobial nanoparticles represents an especially exciting development at the interface of phytomedicine and materials science.

Looking ahead, there remains substantial scope for more rigorous clinical evaluation of C. roseus extracts, further exploration of its endophytic microbiome as a source of bioactive compounds, and biotechnological approaches to scale up the production of high-value alkaloids. As antibiotic resistance continues to threaten global public health, the urgency of developing effective plant-based antimicrobials has never been greater — and Catharanthus roseus, with its centuries-long track record in traditional medicine and its impressive scientific validation, is uniquely positioned to contribute meaningful solutions to this challenge.

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