

Pharmaceutical Preparation, FTIR Spectroscopic Characterisation, and Systemic Insights into the Immunomodulatory Potential of Guduchi Satva (*Tinospora cordifolia*)

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Abstract

In Ayurveda, *Tinospora cordifolia* (*Guduchi*) is an important *Rasayana* drug, indicated for promoting *Vyadhikshamtva* (disease resistance) and maintaining immune homeostasis. *Guduchi Satva* is a classical starch-based preparation of the stem and is widely used therapeutically. However, a comprehensive pharmaceutical characterisation and spectroscopic evaluation of this formulation remain limited. The present study focused on preparing *Guduchi Satva*, characterising its pharmaceutical attributes, analysing its FTIR spectroscopic profile, and correlating analytical findings with the reported immunomodulatory phytochemical profile of *T.cordifolia*.

Fresh mature stems of *Tinospora cordifolia* were collected, authenticated, and processed according to the method described in Bhavaprakasha Nighantu for *Guduchi Satva* preparation. The formulation was evaluated for percentage yield and organoleptic characteristics. Fourier Transform Infrared (FTIR) spectroscopy was used to identify characteristic functional groups. The observed spectral features were compared with published literature, and the detected functional groups were correlated with reported phytochemical constituents and their documented immunomodulatory relevance.

Guduchi satva was successfully prepared as a fine, creamish-white powder with characteristic pharmaceutical properties. FTIR analysis demonstrated characteristic absorption bands corresponding to hydroxyl, aliphatic, carbonyl/amide, and carbohydrate-associated functional groups. These functional groups were tentatively correlated with phytochemical classes previously reported in *Tinospora cordifolia*, including polysaccharides, glycosides, phenolic compounds, and diterpenoids.

The FTIR profile of *Guduchi satva* was consistent with the reported phytochemical composition of *Tinospora cordifolia* and supports the presence of functional groups associated with bioactive phytochemical classes implicated in immunomodulatory activity. Although FTIR cannot definitely identify individual compounds, the present findings establish baseline analytical evidence supporting the traditional

use of *Guduchi satva* and offer a scientific foundation for future chromatographic characterisation and biological investigations.

Keywords: Guduchi Satva, *Tinospora Cordifolia*, Immunomodulation, FTIR profiling, Vyadhikshamatva.

Introduction

The immune system is essential for maintaining host homeostasis by defending the body against a constantly changing universe of pathogenic microorganisms and neutralising harmful, toxic or allergenic substances(1). Immune homeostasis balances pathogen defence with tissue repair by using pattern recognition receptors to differentiate between external infections and internal cellular damage(2). Autoimmune disorders comprise a wide range of illnesses marked by abnormal B and T lymphocyte responses targeted at the body's own healthy components. Typically, the development of an autoimmune condition is triggered by the complex interaction of an individual's hereditary susceptibility and external environmental elements(3). Traditional treatments for autoimmune conditions rely predominantly on non-specific immunomodulators that trigger a widespread suppression of the patient's immune system. Consequently, these medications frequently cause severe adverse complications, including an elevated risk of infection, allergies, and malignant diseases(4). There is an expanding scientific focus on utilising multi-component herbal medicines to regulate the intricate human immune system, primarily to prevent infections rather than solely treating active immune-related diseases. This shift is largely driven by the major limitations and severe side effects associated with standard synthetic immune drugs, which are often highly cytotoxic. Consequently, researchers are heavily prioritising the exploration of natural, plant-derived products to identify safer and more effective lead compounds for developing new immunostimulants and immunosuppressants(5).

Tinospora cordifolia is a widespread, hairless, and separate sex perennial climber that drops its leaves seasonally and produces distinct male and female flowers. When the plant is fresh, its succulent green stems are wrapped in a delicate brown outer layer, but as they dry out, the stems contract, the bark detaches from the wood, and they become dotted with rough, pimple-like structures called lenticels. Its thin, heart-shaped leaves measure roughly 5-10 cm in length, while the small, yellow or green male blossoms emerge during the summer season in clusters(6). Ancient Ayurvedic literature documents *Tinospora cordifolia*, commonly known as *Guduchi*, as a versatile therapeutic herb credited with body-rejuvenating, tonic, and digestive-boosting qualities. It is classically indicated for managing an array of medical conditions, including respiratory issues like asthma, metabolic disorders like diabetes, and various systemic diseases such as jaundice, fever, and gout. Additionally, Ayurvedic pharmacology recognises its noticeable capacity to improve mental faculties, serving as a natural enhancer for memory and cognitive performance(7). Current research indicates *Guduchi* as a well-researched immunomodulator capable of mitigating inflammation, thereby acting as an essential therapeutic agent for enhancing the body's natural defence mechanisms and purging systemic toxins(8). The herb acts as a potent natural immune booster by activating non-specific immune mechanisms, stimulating macrophage functions, and boosting the proliferation of lymphocytes. It aids in tissue defence mechanisms by working as a non-microbial TLR4 agonist, accelerating antibody production, and enhancing protective Th1-type cytokine responses(9).

Satva is the active, starchy essence of an herb extracted as a solid sediment through water extraction. It is routinely prescribed to treat fevers, burning sensations, and *Pitta*-predominant disorders. Relative to the crude stem, *Satva* offers a significantly higher water-soluble extractive yield due to its processing, while converting a naturally bitter raw material into a palatable, completely flavourless medicine. Despite its widespread clinical use, it has previously seen limited scientific investigation, with fewer analytical standards published prior(10).

Executing strict testing and quality assurance measures helps reduce inherent risks like contamination, adulteration, and toxic ingredients, thereby guaranteeing that herbal therapies are safe to use(11). Beyond quickening the initial biological screening of drug candidates, it is highly critical to refine and select the

most viable molecules based on their practical pharmaceutical development potential(12). Because traditional visual fingerprint mappings carry a high rate of error and frequently produce ambiguous outcomes, it has become essential to execute analytical methods that extract informative data directly from the chemical constituents left within the print. Integrating FTIR is highly advantageous because it serves as a non-damaging approach that simultaneously delivers detailed chemical composition profiles and visual mapping of the fingerprint.

Comprehensive studies have investigated the phytochemistry and pharmacological activities of *Tinospora cordifolia* extracts. Pharmaceutical characterisation and spectroscopic profiling of *Guduchi Satva* preparation are deficient. Therefore, the present study aimed to prepare *Guduchi Satva* according to classical Ayurvedic procedures, document its pharmaceutical characteristics, analyse its FTIR spectroscopic profile, and discuss the possible mechanistic relevance of the identified functional groups with respect to the reported immunomodulatory potential of *Guduchi*.

Materials and Methods

Plant Material

Fresh *Tinospora cordifolia* (*Guduchi*), from the family Menispermaceae, was collected from the Varanasi region. The drug was authenticated by the Department of Botany, Banaras Hindu University (BHU).

Preparation of *Guduchi Satva*

A total of 500g of collected *Guduchi* stems was thoroughly washed with water, then cut into small pieces of 5-7 cm. These pieces were then crushed in a *khalwa yantra*. In compliance with the classical guidelines of the Bhavaprakasha Nighantu, the crushed mass was mixed with 4 times its volume of water in a stainless-steel vessel and thoroughly macerated by hand. This was kept overnight. The following morning, the mixture was stirred and macerated again for approximately 1 hour. The liquid was then filtered through a clean cotton cloth. The filtrate was left undisturbed for 6 hours to allow the starch to settle. After complete sedimentation, the supernatant liquid was carefully decanted. The sediment settled at the bottom was transferred to a tray, sun-dried, and the resulting *Guduchi Satva* was collected and stored in airtight jars. The prepared sample was evaluated for its organoleptic characteristics.



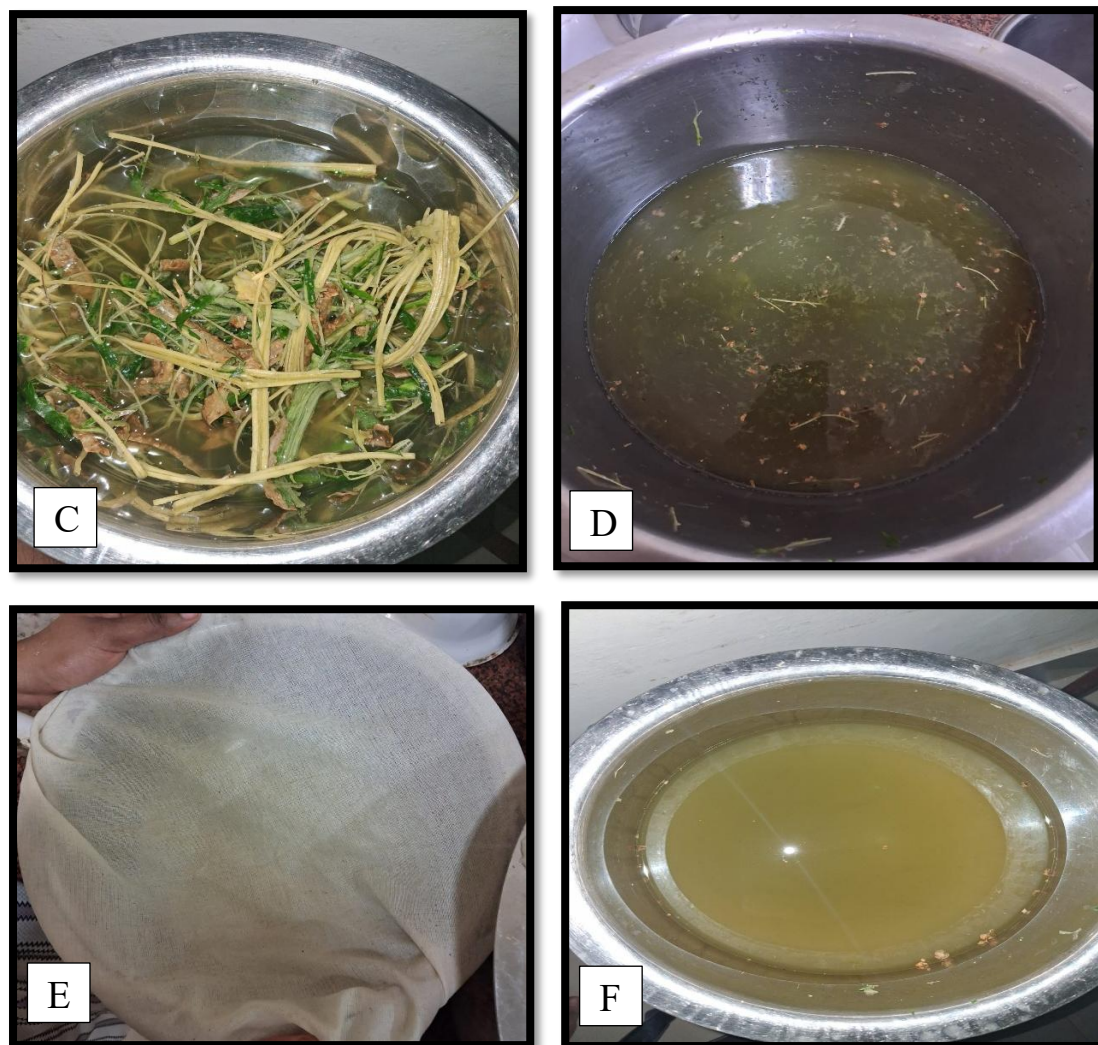


Figure: A-Fresh Guduchi Stems, B-Crushed Guduchi Stems, C&D-Macerated in water, E&F-Filtration and sediment.

FTIR Spectroscopic Analysis

Fourier-transform infrared(FTIR) spectroscopic analysis of the sample was performed at the Department of Physics, BHU, to identify the characteristic functional groups. The analysis was performed using a PerkinElmer Spectrum DW02 spectrophotometer. Approximately 2 mg of the dried *Guduchi Satva* powder was uniformly blended with spectroscopic-grade potassium bromide (KBr) to prepare a translucent pellet. The spectrum was recorded in the transmission mode under a scanned wavenumber range of 4000- 400 cm^{-1} at a spectral resolution of 4 cm^{-1} . A total of 20 scans were collected to optimise the signal-to-noise ratio. Data acquisition and subsequent baseline corrections were processed using the Spectrum 10 software.

Data Interpretation

The raw FTIR spectral data were plotted and analysed using OriginPro 2026b. The functional groups corresponding to these characteristic peaks were identified by systematically comparing the observed wavenumbers with values reported in the literature. These specific vibrational bands were correlated with major reported phytochemical classes of *Tinospora cordifolia*, such as alkaloids, glycosides, diterpenoid lactones, and steroids. A systemic interpretation of the structural bonds was performed using previously documented evidence.

Results

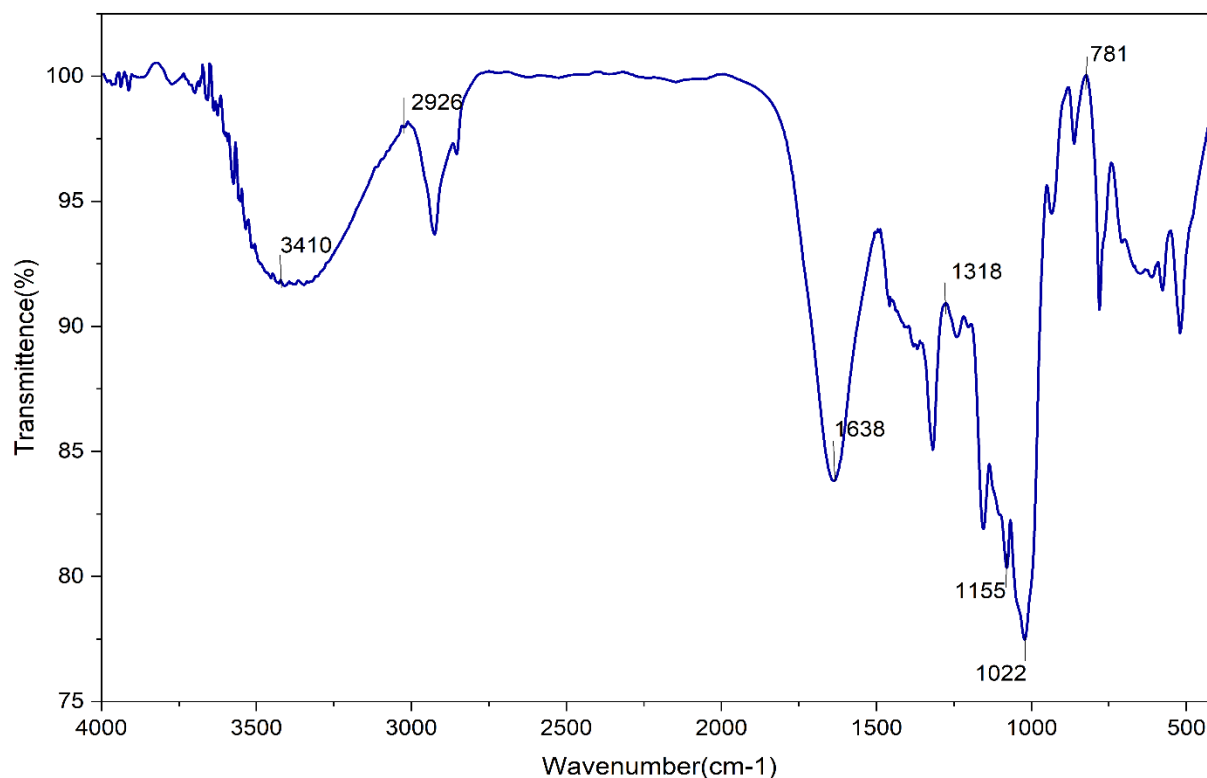
Pharmaceutical Characteristics of *Guduchi Satva*

Guduchi Satva was prepared following the classical procedure. A creamish white sediment was obtained after sedimentation. The sediment was dried to obtain a fine powder. The final product was free from visible impurities.

Parameter	Observation
Percentage yield	2.35%
Colour	Creamish white
Odour	Not specific
Taste	Slightly Bitter
Texture	Smooth



FTIR Spectroscopic Profile of *Guduchi Satva*



The FTIR spectrum of *Guduchi Satva* demonstrated multiple characteristic absorption bands distributed between 4000 cm⁻¹ and 400 cm⁻¹. Prominent peaks were observed at 3410, 2926, 1638, 1318, 1155, 1022 and 781 cm⁻¹.

FTIR peak Assignment^(13,14)

Peak position	Functional group
3410	O-H Stretch
2926	C-H Stretch
1638	N-H Stretch
1318	C-O Stretch
1155	C-H Stretch
1022	C-O Stretch
781	C-H Stretch

Discussion

Guduchi Satva was prepared from fresh stems of *Tinospora cordifolia* following the classical pharmaceutical procedure described. Strictly following traditional manufacturing guidelines is essential for authenticity and genuine physical traits of an herbal extract. By closely mirroring the classical instructions such as harvesting the plant during specific winter months, selecting medium, thumb-sized stem diameters, and utilising proper water maceration, the researchers were able to create a final product that perfectly matched historical benchmarks. Ultimately, replicating these time-tested methodologies provides a reliable framework for standard manufacturing procedures, ensuring consistent pharmaceutical quality that can be validated by modern analytical profiling⁽¹⁵⁾.

Bhavaprakasha Nighantu under *Guduchyadi Varga* explained the preparation of *Guduchi Satva* as follows: collect *Guduchi* stems before the rainy season. Peel off the outer bark, wash them thoroughly, and crush them into a fine paste in a stone mortar. Add four times the amount of water and let it sit for 12 to 24 hours. Afterwards, rub the mixture well and strain it through a cloth. Allow the liquid to stand until the sediment settles at the bottom. Carefully pour off the top water, then dry the remaining sediment and store it in bottles. Some people boil the residue in water again, strain it, and dry the liquid in the sun. Others use strained liquid directly after boiling it down⁽¹⁶⁾.

While comparing the percentage yield of *Guduchi Satva* to published literature, variability in the final output is highly anticipated due to the inherent nature of herbal preparations. The extraction yield is heavily influenced by biological and environmental factors, most notably the season of collection and the maturity of the stem, with peak starch accumulation naturally occurring during the late winter months(*Shishira Ritu*). Beyond these seasonal and plant-specific variables, differences in yield across studies can also be attributed to geographical variations of the raw material, the inherent water content of the fresh stems, extraction efficiency, the specific drying method utilised, and variations in operator technique during manual processing. Therefore, fluctuating yield percentages remain a standard characteristic when benchmarking custom extractions against established classical or contemporary data⁽¹⁷⁾.

The preparation process involved washing, crushing, filtration, sedimentation, decantation, and drying, resulting in the formation of a fine starchy fraction. During sedimentation, a distinct creamish white deposit was observed at the bottom of the container, while the supernatant became comparatively clear, indicating successful separation of the *Satva* fraction. The collected sediment was carefully separated and dried in the sun to obtain the final product.

The prepared *Guduchi Satva* was obtained as a fine, creamish white powder possessing a slightly bitter taste, smooth texture, and soft consistency. The formulation was free from visible foreign matter and exhibited a uniform physical appearance after drying. The final yield of *Guduchi Satva* obtained from the processed stem material was 11.75g, corresponding to a percentage yield of 2.35%. The prepared sample was stored in an airtight container until further analytical evaluation.

FTIR provides information regarding the presence of functional groups such as Hydroxyl, Methyl, Amine, and Carbonyl groups. Arabinogalactan is a stem-derived polysaccharide that helps protect the body against endotoxic shock by regulating cytokines and nitric oxide. It also acts as a polyclonal mitogenically active

compound and shields the brain tissue from iron-mediated lipid damage. (1,4)- α -D-glucan acts as an immune system stimulant. It achieves this by activating macrophages through TLR6 signalling, NF-kappa B translocation, and the production of cytokines(18).

Tinospora cordifolia, from which *Guduchi Satva* is prepared, contains alkaloids such as jatrorrhizine, palmatine, berberine, tembeterine and choline(19). Glycosidic compounds such as 18-norclerodane glucoside, tinocordiside, tinocordifolioside, cordioside, syringin, and various cordifolisides are important constituents found in the stem of *Guduchi*(20). Phenolic compounds such as tannic acid and quercetin are effective antioxidants because of their proven ability to function as efficient hydrogen donors(21). The stem of *Tinospora cordifolia* is a source of specialised clerodane furonoditerpene glucosides, which include amritosides A, B, C, and D. Key active terpenoid components identified in the herb include various diterpene forms, such as tinosporide, furanoid diterpenes, and furanolactone clerodane diterpenes(22). The correlation remains tentative. Many of these reported phytochemical classes have been associated with immunomodulatory properties.

Guduchi is one of the best Ayurvedic immunomodulators. Preclinical laboratory tests demonstrate that the plant triggers macrophage and NK cell activity, manages cytokine signalling, and displays antioxidant and cytotoxic properties. In rodent and mouse models, research shows that *Tinospora cordifolia* successfully lowers liver enzyme levels, mitigates swelling, and improves both glucose tolerance and insulin sensitivity. Human trials indicate that *Guduchi* provides therapeutic advantages for individuals managing recurrent infections, allergic rhinitis, and type 2 diabetes. Even though small and varied clinical trials show promise for immune and metabolic health, larger standardised studies are required to confirm these outcomes and firmly establish their safety(23).

Innate immunity involves macrophage activation, in which cellular communication loops between immune cells, such as the signalling pathway where neutrophils activate tissue-resident macrophages, are highly susceptible to age-related functional decline. When macrophages are activated in elderly individuals, they generate elevated levels of Prostaglandin E2, which directly impairs their ability to display MHC class 2 molecules appropriately. Natural killer cells constitute roughly 10 to 15 % of the body's peripheral blood lymphocytes and specialise in controlling early-stage tumour cells and intracellular infections. As humans age, the overall population of NK cells undergoes a compositional shift marked by a drop in immunoregulatory CD56bright cells and an increase in highly mature CD56dim cytotoxic cells. Acting as highly efficient antigen-presenting cells, dendritic cells are vital for activating and priming specific T lymphocytes to launch adaptive immune reactions. Ageing has a notable impact on these cells, often reducing their endocytic processes, migratory capabilities, and ability to generate essential chemical signals such as IL-12(24).

Adaptive immunity relies on a tightly controlled synchronisation between antigen-presenting cells, T lymphocytes, and B lymphocytes to provide highly tailored antigen recognition and create long-lived immunologic memory. T lymphocytes originate in the bone marrow but develop in the thymus, where their unique receptors undergo strict selection processes before migrating to secondary lymphoid organs to be activated by specific peptide MHC complexes. B lymphocytes undergo antigen-independent development in the bone marrow to express surface receptors, later activating in the periphery via T-independent or T-dependent interactions to differentiate into memory cells or antibody-secreting plasma cells. Efficient antibody production evolves from a slow, low-affinity primary IGM response into a rapid, high-affinity secondary response driven by germinal centre mechanisms like somatic hypermutation and class switching, which refine antigen affinity and alter antibody isotopes. This entire adaptive system is directed and regulated by cytokines, which function as critical signalling molecules that dictate the helper T cell lineage differentiation (such as T_H1 , T_H2 , or T_H17 subsets), coordinate distinct inflammatory effector paths, and directly control B cell immunoglobulin class switching to specific isotopes like IgE or IgA(25). Inflammation is an adaptive response to tissue injury, infection, or malfunction aimed at restoring homeostasis. This pathway is initiated when sensors activate tissue-resident cells to release mediators, including the critical pro-inflammatory cytokines TNF- α , IL-1 β , and IL-6, which activate the local endothelium and leukocytes. In sustained or chronic states, the cellular infiltrate can shift to include T cells, introducing cytokines such as IFN- γ . At the intracellular level, genetic programs such as the stress-

inducible NF- κ B pathway operate to maintain cell survival and inhibit premature apoptosis during tissue distress. Neutrophils generate oxidative stress via reactive oxygen species(ROS) to kill pathogens and modify the extracellular matrix(26).

Guduchi offers therapeutic benefits for individuals suffering from recurrent infections, highlighting its potential for primary care integration, particularly as a preventive intervention against recurrent respiratory infections(23). *Guduchi* stem phytoconstituents can regulate or suppress specific chemical triggers, such as histamine and serotonin, that drive the body's inflammatory response, thereby demonstrating noticeable anti-inflammatory effects by significantly reducing acute swelling and fluid buildup in experimental animal models (27). When administered alongside *Sunti churna* and purgation therapy, *Guduchi ghan vati* effectively manages the autoimmune disorder rheumatoid arthritis by significantly mitigating physical joint symptoms like pain, stiffness, and swelling. This combined Ayurvedic intervention demonstrates strong therapeutic value by successfully reducing critical biochemical autoimmune and inflammatory markers, including RA factor, CRP, and Anti-CCP titers(28). The reported pharmacological activities may be related to the phytochemical classes tentatively identified through FTIR analysis.

The present FTIR findings suggest hydroxyl compounds, carbohydrates, phenolics, etc are present in *Guduchi Satva*. Hydroxyl-rich polysaccharides act on immune receptors, causing the release of macrophages and cytokines, and leading to immune balance. While phenolics, being antioxidants, help in ROS reduction, leading to inflammatory control and immune regulation. Alkaloids, due to their anti-inflammatory potential, cause signal modulation and result in immune homeostasis. This proposed mechanism is based on published evidence. Further studies should validate these mechanisms experimentally.

Rasayana is a foundational branch of Ayurveda centred on rejuvenation and nutritional dynamics to revitalise both the body and mind. These herbal therapies act as immunostimulants that help obstruct the onset of various illnesses, delay premature ageing, boost intellect, enhance physical strength, and extend longevity. Experimentally, *Guduchi* has validated this traditional concept by significantly prolonging the lifespan of the experimental model across both parent and first generations, a benefit potentially linked to its robust antioxidant and immunomodulatory traits(29). The *Rasayana* effect maintains homeostasis, immune regulation, and adaptive resilience. The *Guduchi Satva* may represent the concentrated *Rasayana* fraction.

Conclusion

Guduchi satva is prepared as per the classical literature-mentioned methodology and analysed for functional groups present through FTIR. The identified functional groups support the reported presence of bioactive phytochemical classes associated with immunomodulatory properties of *T.cordifolia*. Further chromatographic characterisation and experimental pharmacological studies are warranted to validate these findings and elucidate the specific bioactive constituents responsible for its therapeutic effects.

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