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Exploring the Anti-Arthritic Activity of *Lantana camara*: A Natural Remedy for Rheumatoid Arthritis Treatment

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Abstract

Rheumatoid arthritis (RA) is a debilitating autoimmune disorder marked by chronic synovial inflammation, cartilage degradation, and progressive joint damage. Although conventional treatments like non-steroidal anti-inflammatory drugs (NSAIDs) and disease-modifying antirheumatic drugs (DMARDs) offer symptomatic relief and slow disease progression, their prolonged use is often associated with significant side effects, including gastrointestinal issues, hepatotoxicity, and immunosuppression. As a result, there is increasing interest in natural remedies that can provide safer, long-term alternatives or adjuncts to current therapies. One such applicant is *Lantana camara*, a plant extensively used in traditional medicine for its anti-inflammatory, analgesic, and antimicrobial properties. Preclinical studies have highlighted its potential in managing RA by demonstrating reductions in joint swelling, inhibition of pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6, and mitigation of oxidative stress. These effects are largely attributed to its rich phytochemical profile, including triterpenoids, flavonoids, phenolic acids, and essential oils, which exhibit synergistic pharmacological actions. The plant's mechanisms of action appear to involve modulation of immune cell activity, inhibition of cyclooxygenase (COX) enzymes, suppression of NF-κB signaling, and free radical scavenging. Despite these promising results, existing evidence is primarily limited to in vitro assays and animal models, and robust clinical validation is still lacking. Future research should focus on standardized extract development, pharmacokinetics, toxicity profiling, and human trials. This would pave the way for the safe and effective incorporation of *Lantana camara* into integrated RA treatment strategies.

Keywords: *Lantana Camara*, Anti-Arthritic Activity, Phytochemicals, Rheumatoid Arthritis, Natural Remedies, Anti-Inflammatory Properties

Introduction

Rheumatoid arthritis (RA) is a chronic, systemic autoimmune disorder that primarily targets synovial joints, leading to persistent inflammation, progressive cartilage destruction, bone erosion, and ultimately joint deformities. The disease is driven by an aberrant immune response wherein activated immune cells, including T-cells, B-cells, and macrophages, infiltrate the synovium and release a cascade of pro-inflammatory mediators (Ding et al., 2023). Among the most critical of these cytokines are tumor necrosis factor-alpha (TNF-α), interleukin-1 beta (IL-1β), and interleukin-6 (IL-6), which amplify the inflammatory response and contribute to synovial hyperplasia, pannus formation, and subsequent joint damage. Clinically, RA presents with symmetrical joint pain, swelling, stiffness (especially in the morning), and fatigue. As the disease progresses, it can affect multiple organ systems including the cardiovascular, pulmonary, and hematological systems, significantly impairing quality of life (Tylutka et al., 2024).

Globally, RA affects approximately 0.5–1% of the population, with a higher prevalence in women and a peak onset between the ages of 40 and 60. Current therapeutic regimens rely on non-steroidal anti-inflammatory drugs (NSAIDs), disease-modifying antirheumatic drugs (DMARDs), and biologics such as TNF inhibitors (Shi et al., 2023). While these treatments can be effective in reducing disease activity and slowing joint damage, they are often accompanied by adverse effects including gastrointestinal complications, hepatotoxicity, immunosuppression, and heightened susceptibility to infections. Moreover, the high cost and limited accessibility of biologics, along with inter-individual variability in drug response, emphasize the urgent need for safer, more affordable treatment options (Mariano et al., 2022).

In this context, phytotherapy—the use of plant-derived bioactive compounds for medicinal purposes—has garnered considerable attention. This approach aligns with holistic and traditional medicine principles, offering multi-targeted therapeutic effects with fewer side effects and greater patient acceptability. A growing body of research supports the efficacy of various medicinal plants in alleviating symptoms associated with inflammatory and autoimmune diseases, including RA (Dar et al., 2023).

Lantana camara, a perennial flowering shrub native to tropical and subtropical regions, has long been employed in traditional medicine systems across Asia, Africa, and Latin America. Traditionally, it has been used to treat fever, skin conditions, respiratory infections, and notably, inflammatory disorders such as arthritis and rheumatism (R. Kumar et al., 2024). Phytochemical investigations have revealed that L. camara is rich in bioactive compounds such as triterpenoids (e.g., lantadene A and B), flavonoids, alkaloids, and phenolic acids each contributing to its pharmacological profile. Preliminary in vivo and in vitro studies suggest that extracts of L. camara exert anti-inflammatory, antioxidant, and immunomodulatory effects, potentially through mechanisms involving the inhibition of pro-inflammatory cytokines, suppression of oxidative stress, and modulation of key signaling pathways such as NF-κB and COX-2 (Chaubey et al., 2025).

Despite these encouraging findings, comprehensive scientific validation remains lacking. Few studies have investigated the pharmacokinetics, bioavailability, and safety profile of L. camara extracts in the context of chronic autoimmune conditions (Albahri et al., 2023). Consequently, this review aims to consolidate current knowledge on the anti-arthritic activity of *Lantana camara*, elucidate its phytochemical mechanisms of action, and identify existing research gaps. Through this analysis, we underscore the need for standardized extract development, advanced pharmacological studies, and clinical trials to

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evaluate its full therapeutic potential in RA management (Gandhi et al., 2022).

Overview of *Lantana camara*

Taxonomy and Botanical Description: *Lantana camara* L. belongs to the family Verbenaceae and is a perennial flowering shrub. It typically grows between 1 to 2 meters in height with a woody stem and quadrangular branches (Battase & Attarde, 2021). The plant is recognized by its ovate, rough-textured leaves, and clusters of small, tubular flowers that exhibit a variety of colors including red, orange, yellow, pink, and purple, often changing as they mature. The fruits are small, berry-like drupes that turn from green to black when ripe (Pilla & Namestnik, 2022).

Geographical Distribution: Native to the tropical regions of Central and South America, *Lantana camara* has become widely naturalized across many parts of the world, including Asia, Africa, Australia, and the Pacific Islands. Its adaptability to diverse climatic conditions has contributed to its invasive status in several ecosystems, where it can outcompete native flora (Ntalo et al., 2022)(Ntalo et al., 2022).

Traditional Medicinal Uses: In various traditional medicine systems, *Lantana camara* has been utilized for its wide-ranging therapeutic properties. Ethnomedicinal applications include treatment of respiratory disorders, skin diseases, wounds, fever, and gastrointestinal ailments. Particularly relevant to rheumatoid arthritis and inflammatory conditions, the leaves and flowers have been employed as poultices and decoctions for their anti-inflammatory, analgesic, and antipyretic effects. Several indigenous communities have relied on *Lantana camara* extracts to alleviate joint pain and swelling, underscoring its role as a natural remedy in managing musculoskeletal disorders (Dey et al., 2024).

Toxicity Concerns and Safe Usage: Despite its medicinal potential, *Lantana camara* is known to contain toxic compounds such as lantadenes, which can cause hepatotoxicity, photosensitivity, and gastrointestinal irritation if ingested in large quantities, particularly in livestock. Human toxicity cases are rare but have been documented, emphasizing the importance of controlled dosage and proper preparation methods. Current research advocates for further toxicological evaluation and standardization to ensure safe therapeutic use. In traditional practice, the plant parts are often processed to minimize toxicity, and external applications are preferred to avoid systemic adverse effects (Chaubey et al., 2025).

Figure 1: Show the *Lantana Camara* Plant

Phytochemical Profile of *Lantana camara*

Major Bioactive Compounds

Lantana camara is a rich source of diverse phytochemicals that contribute to its pharmacological properties, particularly its anti-inflammatory and anti-arthritic effects (Orji et al., 2024).

Terpenoids: The plant contains a variety of terpenoids, with lantadenes A and B being the most studied. These pentacyclic triterpenoids exhibit potent anti-inflammatory and antimicrobial activities. Lantadene A, in particular, has been shown to modulate inflammatory mediators, contributing to symptom relief in arthritic models (A. Kumar & Katiyar, 2024).

Flavonoids: These polyphenolic compounds, including quercetin, kaempferol, and their glycosides, are abundant in *Lantana camara*. Flavonoids are well-known for their antioxidant and anti-inflammatory properties by scavenging free radicals and inhibiting pro-inflammatory enzymes like cyclooxygenase (COX) and lipoxygenase (LOX) (Chaubey et al., 2025).

Alkaloids: Although present in smaller quantities, alkaloids in *Lantana camara* contribute to its analgesic and immunomodulatory effects. Specific alkaloid profiles vary based on geographic and environmental factors (R. Kumar et al., 2024).

Phenolic Acids: Compounds such as caffeic acid and ferulic acid have been identified in *Lantana camara*. These phenolic acids enhance the plant's antioxidant capacity and reduce oxidative stress associated with chronic inflammation in RA (Kato-Noguchi & Kato, 2025).

Extraction Methods and Influence on Phytochemical Yield

The efficacy of *Lantana camara* extracts is significantly influenced by the extraction method used. Conventional techniques such as maceration and Soxhlet extraction, as well as modern methods like ultrasonic-assisted and microwave-assisted extraction, have been employed to isolate bioactive compounds (Aisha et al., 2024). Solvent polarity plays a critical role; methanol and ethanol are commonly used to extract flavonoids and phenolics, while non-polar solvents like hexane yield terpenoids. Optimizing extraction parameters enhances the concentration of active constituents, thus improving therapeutic potential (Ghaffar & Perveen, 2024).

Structure-Activity Relationship (SAR) Relevance to Anti-Inflammatory Action

The anti-inflammatory efficacy of *Lantana camara* phytochemicals is closely related to their chemical structures. For example, the pentacyclic triterpenoid skeleton in lantadenes facilitates binding to inflammatory enzymes and receptors, disrupting pro-inflammatory signaling pathways. Flavonoids' hydroxyl groups and conjugated double bonds enhance free radical scavenging and inhibition of enzymes involved in the synthesis of inflammatory mediators (Chaubey et al., 2025). Understanding these structure-activity relationships aids in identifying the most potent compounds for drug development and supports the rationale for using whole-plant extracts in RA treatment (Staszak et al., 2022).

Evidence of Anti-Arthritic Activity

Preclinical Studies

Extensive preclinical research has explored the anti-arthritic potential of *Lantana camara* using both in vivo and in vitro models (Rana et al., 2024).

In Vivo Studies: Animal models, particularly Freund's Complete Adjuvant (FCA)-induced arthritis in rats and mice, have been widely employed to mimic human rheumatoid arthritis. Oral and topical administration of *Lantana camara* leaf extracts at doses ranging from

***Table 1**: Show the Lantana Camara Plant*

Sr.No	Parameter	Details	Scientific Relevance	Source/Region	Remarks	References
1	Botanical Name	*Lantana camara* L.	Official binomial nomenclature	Global	Member of Verbenaceae family	(Nishana, 2023)
2	Common Names	Wild sage, Red sage, Tickberry	Varies by region	Asia, Africa, Americas	Known by 100+ local names globally	(Máthé, 2020)
3	Family	Verbenaceae	Flowering plant family	Worldwide	Includes aromatic and medicinal plants	(Cardoso et al., 2021)
4	Origin	Central and South America	Native region	Tropical America	Introduced globally as ornamental	(Rojas-Sandoval & Ackerman, 2021)
5	Habitat	Roadsides, forests, wastelands	Typical growth environment	Tropical and subtropical zones	Grows invasively in disturbed soils	(Dai et al., 2025)
6	Growth Form	Woody shrub	Morphological trait	Tropical zones	Up to 2–4 meters tall	(Islam et al., 2024)
7	Flowering Season	Throughout the year (varies with region)	Reproductive cycle	India, Brazil, Africa	Attracts pollinators	(Valadão-Mendes, 2023)
8	Propagation Method	Seeds, vegetative (cuttings)	Ecological adaptability	Widely used in reforestation	Fast-spreading; invasive species in some areas	(Hiscock, 2024)
9	Medicinal Parts Used	Leaves, stems, flowers, roots	Ethnomedicinal applications	Traditional medicine (Ayurveda, folk)	Commonly used for infusions, poultices	(Anand et al., 2022)
10	Traditional Uses	Anti-inflammatory, wound healing, fever, skin diseases	Ethnopharmacological use	India, Nigeria, Pakistan, Latin America	Broad-spectrum folk uses	(KUSHWAHA, 2025)
11	Active Constituents	Lantadenes, flavonoids, alkaloids, phenolics	Pharmacologically active compounds	Various solvent extracts	Responsible for biological effects	(Awuchi, 2020)
12	Toxicity	Hepatotoxic at high doses (lantadenes)	Safety consideration	Animal studies	Use with dosage control	(Abdisa & Dilbato Dinbiso, 2024)
13	Conservation Status	Not threatened globally	Environmental concern	IUCN	Considered invasive in some regions	(Cadotte et al., 2024)
14	Industrial Use	Natural dye, insect repellent, ornamental	Economic potential	Local cottage industries	Multipurpose plant	(Singh et al., 2024)
15	Regulatory Status	Not fully regulated as medicinal product	Legal/clinical classification	Globally	Requires more clinical validation	(Nevzghoda et al., 2025)

100 to 600 mg/kg body weight demonstrated significant reductions in paw edema, joint inflammation, and histopathological damage (Ismail et al., 2022). These effects were dose-dependent and often comparable to standard anti-arthritic drugs. For instance, extract-treated groups showed decreased joint swelling and improved mobility relative to controls (Banji et al., 2022).

In Vitro Studies: Various cell-based assays have confirmed the plant's anti-inflammatory activities. Extracts inhibited cyclooxygenase (COX-1 and COX-2) enzymes, which are crucial in prostaglandin synthesis mediating inflammation and pain. Additional studies revealed suppression of nitric oxide (NO) production in activated macrophages and reduced release of pro-inflammatory mediators (Akhtar, 2022).

Doses, Routes of Administration, and Outcomes: Oral administration is the most common route in animal studies, ensuring systemic exposure to active compounds. Topical formulations have also been investigated for localized effects. Effective doses typically range from 100 to 600 mg/kg, showing marked decreases in clinical arthritis scores, inflammatory cytokines, and oxidative stress markers (Magill et al., 2023).

Comparison with Standard Drugs: When compared to methotrexate (a gold standard DMARD) and indomethacin (a common NSAID), *Lantana camara* extracts often exhibited comparable anti-inflammatory and anti-arthritic effects, but with fewer side effects in preclinical models. While methotrexate effectively suppresses immune activity, *Lantana camara*'s multifaceted action includes antioxidant benefits, potentially offering an advantage in long-term management (Huang et al., 2023).

Anti-Inflammatory and Immunomodulatory Mechanisms

The therapeutic benefits of *Lantana camara* in rheumatoid arthritis are mediated through several key mechanisms (Singh et al., 2020).

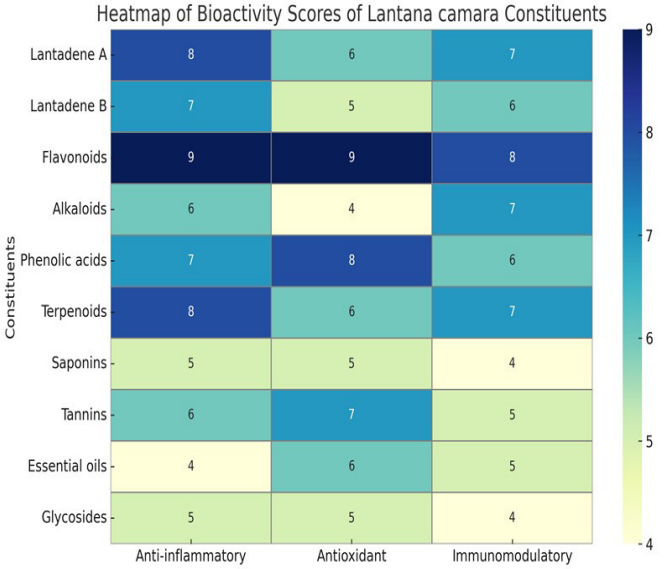

***Figure 2**: The Heatmap of Lantana camara constituents*

Inhibition of Pro-Inflammatory Cytokines: Extracts have been shown to downregulate levels of TNF-α, IL-1β, and IL-6 in both serum and synovial tissues, pivotal cytokines responsible for joint inflammation and destruction in RA (Gul et al., 2023).

Modulation of NF-κB and COX-2 Pathways: NF-κB, a transcription factor that regulates inflammatory gene expression, is suppressed by *Lantana camara* phytochemicals, leading to reduced COX-2 enzyme expression and decreased prostaglandin production. This pathway modulation is crucial in controlling chronic inflammation (Amoah et al., 2023).

Antioxidant Activity and Free Radical Scavenging: The plant's rich flavonoid and phenolic content contributes to strong antioxidant properties, neutralizing reactive oxygen species (ROS) that exacerbate synovial inflammation and tissue damage (Nwozo et al., 2023).

Modulation of Macrophage and T-cell Activity: Studies suggest *Lantana camara* extracts influence immune cell functions, including reducing macrophage activation and T-cell proliferation, thereby restoring immune balance and preventing autoimmune-mediated joint damage (de Oliveira Lemos et al., 2025).

***Table 2**: The phytochemical constituents of Lantana camara, their classes, and related properties*

Sr. No	Constituent	Class	Known Biological Activities	Extraction Method	Relevance to Anti-Arthritic Activity	References
1	Lantadene A	Terpenoid	Anti-inflammatory, hepatoprotective	Methanol, Ethanol Extracts	Inhibits inflammatory cytokines, reduces swelling	(A. Kumar & Katiyar, 2024)
2	Lantadene B	Terpenoid	Anti-inflammatory	Methanol Extract	Similar anti-arthritic effects as Lantadene A	(James, 2023)
3	Quercetin	Flavonoid	Antioxidant, anti-inflammatory	Ethanol, Aqueous Extract	Scavenges free radicals, modulates COX enzymes	(S. Chaudhary et al., 2025)
4	Kaempferol	Flavonoid	Anti-inflammatory, antioxidant	Methanol Extract	Inhibits NF-κB pathway, reduces joint inflammation	(Yang et al., 2023)
5	Caffeic Acid	Phenolic Acid	Antioxidant, anti-inflammatory	Aqueous, Methanol Extract	Reduces oxidative stress in synovial tissue	(Herrera-Rocha et al., 2022)
6	Ferulic Acid	Phenolic Acid	Antioxidant, anti-inflammatory	Methanol Extract	Protects tissues from oxidative damage	(M. Kumar et al., 2025)
7	Alkaloids	Alkaloid	Immunomodulatory	Aqueous Extract	Modulates immune cell activity	(Das et al., 2024)
8	Luteolin	Flavonoid	Anti-inflammatory, antioxidant	Ethanol Extract	Suppresses pro-inflammatory cytokines	(Al-Khayri et al., 2022)
9	Apigenin	Flavonoid	Anti-inflammatory	Methanol Extract	Inhibits COX-2 and NF-κB pathways	(Abu-Baih et al., 2024)
10	Triterpenoids	Terpenoid	Anti-inflammatory	Ethanol Extract	Contributes to immunomodulatory effects	(Trepa et al., 2024)
11	Saponins	Glycosides	Anti-inflammatory	Aqueous, Methanol Extract	Reduces inflammation via immune regulation	(Wijesekara et al., 2024)
12	Phenolic Compounds	Phenolics	Antioxidant, anti-inflammatory	Various Solvent Extracts	Scavenge free radicals, modulate inflammation	(Zeghbib et al., 2022)
13	Flavonols	Flavonoid	Antioxidant	Methanol Extract	Protect synovial cells from oxidative damage	(Wahnou et al., 2024)
14	Tannins	Polyphenol	Anti-inflammatory, astringent	Aqueous Extract	Inhibits inflammatory mediators	(Ebrahim et al., 2022)
15	Terpenes	Terpenoid	Anti-inflammatory	Various Extraction Methods	Modulate cytokine production	(Dammann et al., 2023)

***Table 3**: Mechanism of Action of Lantana camara*

`Sr. No.	Bioactive Compound	Target Pathway/ Enzyme	Mechanism of Action	Pharmacological Effect	Relevance to RA	References
1	Lantadene A & B	NF-κB pathway	Inhibits NF-κB translocation and gene expression	Anti-inflammatory, immunosuppressive	Reduces cytokine production in RA	(Patidar et al., 2022)
2	Flavonoids (e.g., quercetin)	COX-1 and COX-2 enzymes	Inhibits cyclooxygenase activity, reducing prostaglandin synthesis	Anti-inflammatory	Alleviates joint inflammation and pain	(Bashir et al., 2024)
3	Phenolic acids	ROS & free radicals	Scavenges reactive oxygen species (ROS)	Antioxidant	Prevents oxidative damage to synovial tissue	(Kondo et al., 2023)
4	Alkaloids	TNF-α and IL-1β cytokine signaling	Downregulates pro-inflammatory cytokine production	Anti-inflammatory	Mitigates synovial inflammation	(Guo et al., 2022)
5	Terpenoids	Immune cells (macrophages, T-cells)	Modulates macrophage activity and T-cell proliferation	Immunomodulatory	Balances immune response in autoimmune RA	(Moudgil & Venkatesha, 2022)
6	Essential oils	Lipid peroxidation	Prevents membrane lipid damage via antioxidative actions	Cytoprotective	Supports joint tissue integrity	(Chen et al., 2023)
7	Lantadenes	Mitochondrial pathways	Induces apoptosis in activated immune cells	Anti-proliferative	May reduce hyperplasia of synovial membrane	(Kondo et al., 2023)
8	Flavonoids & polyphenols	Nitric oxide (NO) pathway	Inhibits inducible nitric oxide synthase (iNOS)	Anti-inflammatory	Controls inflammation-induced vasodilation	(Li & Zhang, 2023)
9	Saponins	Complement system	Modulates immune complement cascade	Anti-inflammatory	Prevents joint tissue degradation	(Wijesekara et al., 2024)
10	Tannins	Protein interactions	Forms complexes with proteins, reducing enzymatic activity	Astringent, anti-inflammatory	May stabilize inflamed tissues	(Cosme et al., 2025)

Pharmacological and Toxicological Considerations

Pharmacokinetics of Key Constituents

Limited pharmacokinetic data exist for the individual bioactive constituents of *Lantana camara*. Preliminary studies indicate that lantadene and flavonoids are absorbed through the gastrointestinal tract and primarily metabolized in the liver. Flavonoids typically undergo conjugation to glucuronides and sulfates, affecting their systemic availability, biological activity, and half-life. These transformations significantly influence their therapeutic potential. However, comprehensive ADME (absorption, distribution, metabolism, and excretion) profiling of *Lantana camara* phytochemicals remains incomplete (Nyawira, 2023). Detailed pharmacokinetic studies are crucial to understanding the fate of these compounds in the body and to guide the development of standardized, effective dosage forms. Such insights will enhance therapeutic outcomes and facilitate the rational use of *Lantana camara* in clinical applications, especially for chronic inflammatory diseases like rheumatoid arthritis (Stielow et al., 2023).

Acute and Chronic Toxicity Data

Toxicological assessments indicate that *Lantana camara* exhibits dose-dependent toxicity, primarily due to its lantadene content. Acute toxicity studies in rodents have reported oral LD_{50} values ranging from 1500 to 3000 mg/kg for leaf extracts, classifying the plant as moderately toxic. Chronic exposure, particularly at high doses, has been associated with adverse effects such as hepatotoxicity, gastrointestinal disturbances, and photosensitivity (Chaubey et al., 2025). Histopathological changes in the liver and kidneys have been observed in long-term studies with elevated dosages. However, subacute toxicity evaluations suggest that doses below 500 mg/kg are generally well tolerated, with no significant alterations in key biochemical markers of liver and kidney function. These findings emphasize the importance of dose regulation and standardized formulations to ensure safety in therapeutic use (Ahmed et al., 2020).

LD50 Values and Adverse Effect Profiles

The LD_{50} (median lethal dose) of *Lantana camara* varies depending on the extraction method, plant part used, and the test species, but generally ranges between 1500–3000 mg/kg in rodent models. High doses have been associated with adverse effects such as body weight loss, lethargy, elevated liver enzymes, gastrointestinal disturbances, and, in rare instances, skin photosensitivity reactions (Inwang & Ogwo, 2025). These toxic responses are primarily linked to lantadene compounds. However, toxicity tends to decrease significantly when extracts are carefully processed and administered at lower, controlled doses. This aligns with traditional medicinal practices that emphasize proper preparation and dosing. These findings highlight

***Table 4**: Benefits of Lantana camara*

Sr.No	Benefit	Description	Target Use/ Condition	Supporting Evidence	Remarks	References
1	Anti-arthritic	Reduces joint inflammation, swelling, and pain	Rheumatoid arthritis, osteoarthritis	Preclinical studies (rat models)	Potential herbal alternative	(Arunsi et al., 2022)
2	Anti-inflammatory	Inhibits COX enzymes and inflammatory cytokines	Inflammatory diseases	In vitro and in vivo studies	Active compounds: lantadenes, flavonoids	(Al-Khayri et al., 2022)
3	Antioxidant	Scavenges free radicals and prevents oxidative damage	Chronic diseases, aging	DPPH and FRAP assays	Protects cells from oxidative stress	(Jomova et al., 2023)
4	Antimicrobial	Kills or inhibits bacteria and fungi	Skin infections, wounds	Ethanol and methanol extracts	Effective against *E. coli*, *S. aureus*	(Akinduti et al., 2022)
5	Wound healing	Promotes faster healing and tissue regeneration	Cuts, ulcers	Traditional and animal studies	Often applied topically	(Kolimi et al., 2022)
6	Antipyretic	Reduces fever	Febrile conditions	Traditional medicine	Leaves used in decoction	(P. Chaudhary et al., 2023)
7	Analgesic	Provides pain relief	Headache, muscle pain	Folk medicine evidence	Mechanism under investigation	(Jiang et al., 2022)
8	Hepatoprotective	Protects liver from chemical-induced damage	Liver diseases	Animal studies with lantadene A	Dose-dependent toxicity awareness needed	(Jaiswal & Lee, 2025)
9	Anticancer potential	Shows cytotoxic effects on cancer cell lines	Breast, colon, liver cancer	In vitro studies	Requires clinical validation	(Adnan et al., 2021)
10	Insect repellent	Repels mosquitoes and other insects	Vector control	Leaf extract and essential oil	Used traditionally in rural homes	(Sivakumar & Sivakumar, 2022)
11	Antidiarrheal	Controls bowel movements and intestinal inflammation	Diarrhea, dysentery	Traditional uses	Aqueous extract is effective	(Ayalew et al., 2022)
12	Antifungal	Inhibits fungal growth	Ringworm, candidiasis	Ethanolic leaf extract	Potential natural antifungal	(Hsu et al., 2021)
13	Antispasmodic	Relieves spasms in muscles or gastrointestinal tract	Abdominal pain	Ethnomedicinal reports	Still under pharmacological review	(Rauf et al., 2021)
14	Respiratory relief	Eases symptoms of cough and bronchitis	Asthma, cold	Folk use in decoctions	Limited scientific validation	(Her & Kanjanasilp, 2021)
15	Soil conservation & erosion control	Prevents soil erosion due to thick root system	Environmental protection	Agroecological use	Also used in reforestation efforts	(Jafari et al., 2022)

the importance of standardizing extract preparation and conducting rigorous safety assessments to ensure therapeutic efficacy without compromising safety (Kato-Noguchi & Kato, 2025).

Safe Dose Range for Therapeutic Applications

Based on preclinical studies, *Lantana camara* extracts have shown therapeutic efficacy at doses ranging from 100 to 600 mg/kg body weight in animal models, with minimal observed toxicity. These doses have been effective in modulating inflammation, reducing oxidative stress, and alleviating arthritis-related symptoms (Gurung & Thapa, n.d.). Translating these findings to human applications requires cautious dose scaling using appropriate algometric conversion methods and must be followed by rigorous clinical trials. Importantly, when extracts are standardized and administered within these therapeutic ranges, the safety profile appears favorable, with limited adverse effects reported. These findings support the potential of *Lantana camara* as a complementary treatment for rheumatoid arthritis, pending further validation through human studies to confirm efficacy, safety, and optimal dosing (Gao et al., 2023).

Challenges and Limitations

Variability in Plant Constituents Due to Environmental Factors

The phytochemical profile of *Lantana camara* exhibits considerable variability influenced by environmental factors such as geography, soil type, climate conditions, and harvesting season. These factors can alter the concentration and presence of key bioactive compounds, including terpenoids and flavonoids (Liambila, 2023). Such inconsistencies pose a major challenge in ensuring reproducible pharmacological effects and standardizing plant-based formulations. Variability in plant constituents may lead to fluctuating efficacy and safety profiles, limiting the reliability of L. camara as a therapeutic

agent. Therefore, establishing standardized cultivation, harvesting, and processing protocols is crucial for the development of consistent and effective herbal remedies derived from *Lantana camara* (Abegunde et al., 2024).

Lack of Standardization and Clinical Validation

Although *Lantana camara* has shown encouraging anti-arthritic potential in preclinical models, it lacks robust clinical trials to confirm its safety and efficacy in human patients with rheumatoid arthritis. The absence of standardized extraction methods defined dosing protocols, and consistent quality control significantly hinders the reproducibility and reliability of therapeutic outcomes. Without these critical elements, translating experimental results into clinical applications remains challenging. Furthermore, variability in formulation and administration can affect both efficacy and safety profiles. Addressing these limitations through well-designed pharmacological investigations and human clinical studies is essential for validating L. camara as a viable natural remedy for RA (Kciuk et al., 2024).

Potential Toxicity at High Doses

Although *Lantana camara* demonstrates notable anti-inflammatory and anti-arthritic effects, its safety profile becomes concerning at elevated doses or with long-term use. Reports have documented adverse effects such as hepatotoxicity, photosensitivity, and gastrointestinal disturbances, particularly in animal studies (Gandhi et al., 2022). These toxic manifestations are primarily attributed to pentacyclic triterpenoids like lantadene A and B. As such, determining a precise therapeutic window is essential to balance efficacy and safety. Careful dose optimization, toxicity profiling, and long-term safety assessments are necessary before considering clinical applications. These precautions will help mitigate risks and support the safe integration of L. camara into rheumatoid arthritis treatment regimens (Suthar et al., 2024).

Need for Bioavailability Enhancement Techniques

Many bioactive compounds in *Lantana camara*, particularly flavonoids and terpenoids, face significant challenges related to limited bioavailability. This is mainly due to their poor water solubility, rapid metabolism, and low absorption in the gastrointestinal tract. These pharmacokinetic limitations hinder the clinical efficacy of *Lantana camara* extracts, restricting their therapeutic potential (Chaubey et al., 2025). To overcome these obstacles, advanced drug delivery strategies such as nanoparticle encapsulation, liposomal carriers, or co-administration with bio-enhancers are essential. These techniques can enhance solubility, protect the compounds from metabolic degradation, and improve absorption, thereby maximizing the plant's health benefits (Ezike et al., 2023).

Future Research Directions

To ensure consistent therapeutic outcomes, future research must prioritize the development of standardized *Lantana camara* extracts with clearly defined phytochemical profiles. This includes optimizing extraction techniques and formulating stable, reproducible dosage forms such as capsules, ointments, or tablets. Standardization is critical for ensuring efficacy and safety across clinical applications. Comprehensive pharmacokinetic studies evaluating the absorption, distribution, metabolism, and excretion (ADME) of major bioactive constituents are also essential. Understanding these parameters will aid in dose optimization and the design of effective formulations. Enhancing bioavailability through nanoformulations, encapsulation techniques, or co-administration with bioenhancers will be crucial to unlocking the full therapeutic potential of *Lantana camara* (R. Kumar et al., 2024).

Moreover, well-structured randomized controlled trials (RCTs) in patients with rheumatoid arthritis are urgently needed. These trials should aim to validate clinical efficacy, determine optimal dosages, assess safety, and evaluate long-term outcomes. Clinical data will provide the foundation for evidence-based integration of *Lantana camara* into conventional RA treatment regimens. Research into synergistic effects between *Lantana camara* and other anti-arthritic herbs or conventional drugs is another important area (Teixeira et al., 2024). Such studies may reveal beneficial interactions that enhance therapeutic outcomes while reducing side effects, thus offering more comprehensive treatment options for RA patients. Finally, the use of nanotechnology-based delivery systems such as nanoparticles, liposomes, or nanoemulsions can significantly improve the targeted delivery, stability, and controlled release of *Lantana camara* compounds. These systems may increase bioavailability, minimize toxicity, and enable site-specific therapy, thereby improving patient compliance and clinical effectiveness (Vaou et al., 2022).

Conclusion

Lantana camara holds considerable promise as a natural anti-arthritic agent, owing to its rich phytochemical composition including flavonoids, terpenoids, and other bioactive compounds and its demonstrated efficacy in preclinical models of rheumatoid arthritis (RA). Its therapeutic potential lies in its ability to modulate key inflammatory pathways, inhibit the release of pro-inflammatory cytokines such as TNF-α and IL-6, and exert antioxidant effects that protect joint tissues from oxidative damage. These mechanisms underline its multifaceted approach to managing RA symptoms. To fully realize the therapeutic benefits of *Lantana camara*, it is crucial to bridge traditional medicinal knowledge with modern scientific research. This integration ensures a balanced approach that values ethnomedicinal heritage while upholding contemporary standards of safety, efficacy, and reproducibility. However, current research is largely limited to laboratory and animal studies, highlighting the urgent need for well-designed human clinical trials.

Furthermore, developing standardized formulations with defined phytochemical profiles is essential to ensure consistent dosing and therapeutic outcomes. Addressing these research gaps through pharmacokinetic studies, clinical validation, and formulation optimization will pave the way for incorporating *Lantana camara* as a viable and effective complementary therapy in the management of rheumatoid arthritis, potentially improving patient outcomes and expanding treatment options.

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