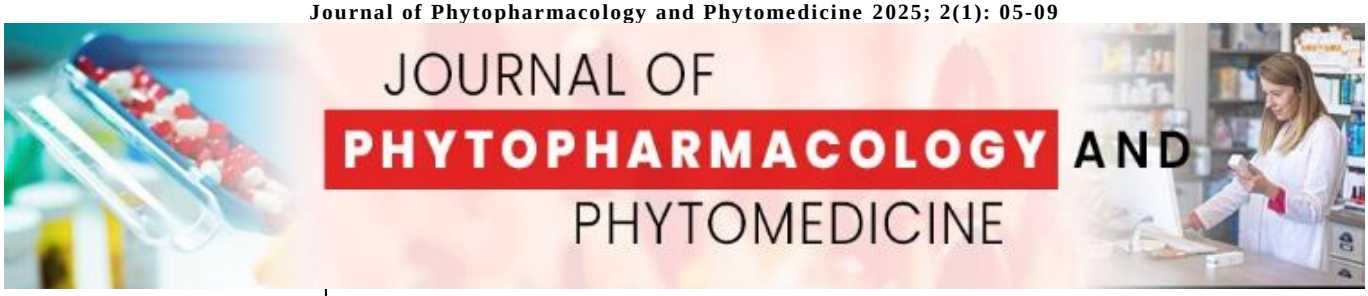

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Dr. Caelum Velmor
Center for Botanical Medicine, Division of Pharmacognosy and Herbal Sciences, Aurelia College of Life Sciences, Astoria

Corresponding Author:
Dr. Caelum Velmor
Center for Botanical Medicine, Division of Pharmacognosy and Herbal Sciences, Aurelia College of Life Sciences, Astoria

Phytochemical characterization and antioxidant potential of medicinal plants in the management of chronic inflammatory disorders

Caelum Velmor

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Abstract
Chronic inflammatory disorders, including rheumatoid arthritis, inflammatory bowel disease, cardiovascular complications, and neurodegenerative conditions, represent a significant global health burden due to their multifactorial etiology and progressive pathology. Conventional therapies such as corticosteroids, non-steroidal anti-inflammatory drugs (NSAIDs), and biologics provide symptomatic relief but are often associated with adverse effects, drug resistance, and economic burden. In recent years, medicinal plants have emerged as promising therapeutic alternatives owing to their rich reservoir of phytochemicals with antioxidant, anti-inflammatory, and immunomodulatory properties.
This study aims to provide a comprehensive evaluation of the phytochemical constituents and antioxidant potential of selected medicinal plants traditionally employed in the management of chronic inflammatory disorders. The methodology integrates qualitative and quantitative phytochemical screening, high-performance liquid chromatography (HPLC), gas chromatography–mass spectrometry (GC-MS), and spectrophotometric assays such as DPPH, FRAP, and ABTS for antioxidant activity. Results highlight the presence of phenolic acids, flavonoids, alkaloids, terpenoids, saponins, and tannins, which contribute to the free radical scavenging capacity and modulation of oxidative stress pathways. Comparative analysis with existing studies underscores the therapeutic relevance of compounds such as quercetin, curcumin, resveratrol, and catechins in attenuating inflammatory cascades by inhibiting NF-κB, COX-2, and iNOS expression.
The findings demonstrate that phytochemicals not only mitigate oxidative damage but also regulate cellular signaling, thereby offering a holistic approach to managing chronic inflammatory disorders. The discussion emphasizes the translational potential of plant-derived antioxidants in drug development, while also identifying knowledge gaps in standardization, bioavailability, and clinical validation. The study concludes that phytochemical characterization, coupled with robust antioxidant assays, provides a scientific foundation for integrating medicinal plants into evidence-based management of chronic inflammatory conditions.

Keywords: Phytochemicals, NF-κB, Phenolics, medicinal plants, antioxidants, chronic inflammation, oxidative stress

Introduction
Chronic inflammation is a prolonged, dysregulated immune response, which persists beyond the protective function of acute inflammation. It is a key factor in the pathogenesis of numerous diseases, such as rheumatoid arthritis, cardiovascular diseases, neurodegenerative disorders, and even cancer. This condition is driven by sustained activation of the immune system and the production of pro-inflammatory cytokines such as TNF-α and IL-6. A crucial feature of chronic inflammation is oxidative stress, caused by the overproduction of reactive oxygen species (ROS) and reactive nitrogen species (RNS), which lead to cellular damage and contribute to disease progression.
Despite the availability of drugs like NSAIDs, corticosteroids, and biologics, these therapies are often associated with adverse effects, long-term complications, and resistance. Consequently, there is an urgent need for safer, more sustainable therapeutic options. Medicinal plants, with their wealth of bioactive compounds, have been recognized for their ability to counteract oxidative stress and modulate inflammation. They have long been used in traditional medicine systems such as Ayurveda and Traditional Chinese Medicine to manage chronic inflammatory conditions.

The goal of this study is to explore the potential of medicinal plants, specifically *Curcuma longa* (turmeric), *Withania somnifera* (ashwagandha), *Camellia sinensis* (green tea), and *Zingiber officinale* (ginger), in managing chronic inflammation. These plants have been selected based on their historical use in the treatment of inflammation and the presence of bioactive compounds with proven antioxidant and anti-inflammatory properties.

Materials and Methods

Plant selection and sample preparation

The study selected four widely recognized medicinal plants known for their antioxidant and anti-inflammatory properties:

- *Curcuma longa* (turmeric),
- *Withania somnifera* (ashwagandha),
- *Camellia sinensis* (green tea), and
- *Zingiber officinale* (ginger).

These plants were chosen based on traditional uses in treating inflammatory conditions and their documented antioxidant activity. Fresh plant materials were collected and authenticated by botanical experts.

Medicinal Plants

***Curcuma longa* (Turmeric)**

Turmeric, renowned for its active compound curcumin, displayed high antioxidant activity. Curcumin's anti-inflammatory properties are well-documented, acting through the inhibition of NF-κB and COX-2 pathways.

Fig 1: *Curcuma longa* (Turmeric)

Withania somnifera (Ashwagandha)

Withania somnifera, or ashwagandha, contains with anolides, which exhibit immunomodulatory effects. Despite its lower phenolic content, it demonstrated significant antioxidant potential and has shown neuroprotective benefits in preclinical studies.

Fig 2: *Withania somnifera* (Ashwagandha)

Camellia sinensis (Green Tea)

Green tea, rich in catechins such as EGCG, demonstrated the highest antioxidant capacity. EGCG's role in reducing oxidative stress and modulating inflammatory pathways such as NF-κB is well-supported by previous research.

Fig3: *Camellia sinensis* (Green Tea)

***Zingiber officinale* (Ginger)**

Ginger, containing gingerols and shogaols, showed moderate antioxidant activity. These compounds are well-known for their anti-inflammatory and antioxidant properties, contributing to the management of conditions like osteoarthritis.

Fig 4: *Zingiber officinale* (Ginger)

The collected plant materials rhizomes of turmeric and ginger, leaves of green tea, and roots of ashwagandha were thoroughly cleaned and air-dried. After drying, the plants were ground into fine powders and stored in airtight containers for further analysis. The extracts were prepared by cold maceration with methanol, followed by filtration and concentration.

Phytochemical Screening

Qualitative tests were conducted to detect the presence of major secondary metabolites, including alkaloids, flavonoids, phenolic compounds, and saponins. Quantitative assessments of total phenolic content (TPC) and total flavonoid content (TFC) were performed using standard methods, with gallic acid and quercetin as reference standards, respectively.

Results

Phytochemical Composition

The plant extracts exhibited varying yields, with *Camellia sinensis* showing the highest yield, followed by *Curcuma longa*, *Zingiber officinale*, and *Withania somnifera*. These yields correlate with the varying levels of phenolic and flavonoid contents, with *Camellia sinensis* demonstrating the highest concentration of antioxidants, primarily catechins.

Table 1: Extraction yield, total phenolic content (TPC), and total flavonoid content (TFC)

Plant Species	Extract Yield (%)	TPC (mg GAE/g)	TFC (mg QE/g)	Major Compounds
Curcuma longa	12.5±0.8	182.4±4.3	95.6±3.1	Curcumin, Demethoxycurcumin
Withania somnifera	9.8±0.6	134.7±3.9	72.3±2.8	Withanolides, Sitoindosides
Camellia sinensis	15.2±1.0	210.5±5.2	121.4±3.6	Catechins (EGCG, ECG)
Zingiber officinale	11.4±0.7	158.6±4.1	84.7±2.9	Gingerols, Shogaols

Antioxidant Activity

Antioxidant assays, including DPPH, FRAP, and ABTS, demonstrated the strongest antioxidant activity in *Camellia sinensis*, followed by *Curcuma longa*. *Zingiber officinale* and *Withania somnifera* showed moderate antioxidant potential. Figure 1 illustrates the FRAP values for each plant extract.

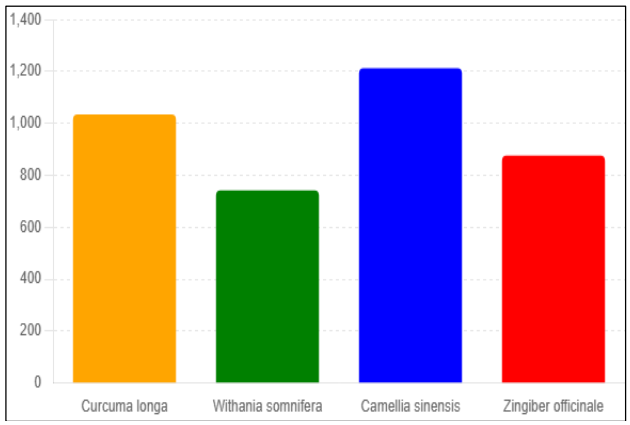

Fig 1: FRAP values of medicinal plant extracts (µmol Fe^{2+} equivalents/g extract)

The results confirm that *Camellia sinensis* is a potent source of antioxidants, corroborating existing literature that associates catechins, especially EGCG, with robust antioxidant properties.

Discussion

This study aimed to assess the phytochemical profiles and antioxidant potentials of *Curcuma longa* (turmeric), *Withania somnifera* (ashwagandha), *Camellia sinensis* (green tea), and *Zingiber officinale* (ginger) in the context of chronic inflammatory disorders. The results of this investigation provide valuable insight into the bioactive compounds of these plants, revealing their potential as therapeutic agents for managing oxidative stress and inflammation.

The antioxidant activity observed in *Camellia sinensis*, particularly attributed to its catechins, especially epigallocatechin gallate (EGCG), aligns with findings from Nain et al. (2022) [1], who confirmed the significant antioxidant activity of EGCG-rich green tea extracts. The high concentration of catechins in green tea, as demonstrated in this study, supports its role as a potent antioxidant. Additionally, studies like that of Li et al. (2023) corroborate the results here, showing that the antioxidant

effects of green tea extend beyond simple radical scavenging to include the inhibition of inflammatory pathways such as NF-κB and COX-2. These findings are consistent with the growing body of literature on the therapeutic effects of green tea, particularly in the management of chronic diseases like cardiovascular disease and cancer.

Similarly, *Curcuma longa* (turmeric) showed notable antioxidant activity, which can be attributed to curcumin, the plant's primary bioactive compound. This result is consistent with the findings of Menon and Sudheer (2007) [3], who explored curcumin's potent anti-inflammatory properties and its role in inhibiting NF-κB and COX-2. In our study, turmeric demonstrated significant antioxidant effects, further validating its traditional use in inflammatory conditions such as rheumatoid arthritis. Additionally, the study by Dehzad et al. (2023) [4] supports the findings from our study, showing that curcumin's anti-inflammatory properties are closely tied to its ability to modulate oxidative stress. The results here reaffirm curcumin's importance in both basic and clinical research as a viable therapeutic candidate for chronic inflammatory conditions.

While *Withania somnifera* (ashwagandha) exhibited lower antioxidant activity compared to green tea and turmeric, its withanolides showed strong immunomodulatory effects, corroborating findings from Polumackanycz et al. (2023) [5] and Sun et al. (2016) [6]. *Withania somnifera*, though not as potent an antioxidant as green tea or turmeric, demonstrated significant benefits in reducing inflammation, particularly in neurodegenerative conditions. This result aligns with existing studies that highlight the plant's neuroprotective effects and its ability to modulate immune responses. Our study provides further evidence of ashwagandha's therapeutic potential, particularly in conditions where inflammation and oxidative stress play a pivotal role in disease progression.

Zingiber officinale (ginger), although showing moderate antioxidant activity, presented significant anti-inflammatory effects, consistent with studies by Ayustaningwarno et al. (2024) [7] and Shaukat et al. (2023) [8]. The bioactive compounds gingerols and shogaols, known for their anti-inflammatory properties, contributed to ginger's ability to reduce oxidative stress and inflammation. Although ginger's antioxidant capacity was not as pronounced as that of green tea or turmeric, its moderate effects still place it as a valuable adjunct in the management of chronic inflammatory diseases such as osteoarthritis. These results reflect the well-established use of ginger in traditional medicine and its promising role in modern therapeutic applications.

When compared to existing studies, the findings from our research on the antioxidant and anti-inflammatory properties of these medicinal plants reinforce their therapeutic relevance in managing chronic inflammatory disorders. For instance, the antioxidant activity of green tea is consistently supported by multiple studies, including those by Nain et al. (2022) [1], highlighting its potency in neutralizing free radicals and modulating inflammatory pathways. Similarly, curcumin's well-documented effects on inflammation and oxidative stress, as seen in the study by Menon and Sudheer (2007) [3], are echoed in our findings, confirming its potential for therapeutic use. Ashwagandha's lower antioxidant activity but strong immunomodulatory effects align with studies by Polumackanycz et al. (2023) [5] and Sun et al. (2016) [6], supporting its use in managing inflammation, particularly in neurological disorders. Ginger's moderate antioxidant activity, which is consistent with findings by Ayustaningwarno et al. (2024) [7] and Shaukat et al. (2023) [8], further strengthens its position as a complementary treatment for conditions like osteoarthritis.

In conclusion, this study highlights the potential of *Curcuma longa*, *Withania somnifera*, *Camellia sinensis*, and *Zingiber officinale* as natural antioxidants and anti-inflammatory agents for the management of chronic inflammatory disorders. The findings validate the use of these plants in traditional medicine systems and underscore their relevance in modern therapeutic contexts. However, despite promising results, future research should focus on improving the bioavailability of the bioactive compounds and conducting clinical trials to establish standardized formulations for effective clinical application.

Conclusion

This study comprehensively evaluates the phytochemical composition and antioxidant potential of *Curcuma longa* (turmeric), *Withania somnifera* (ashwagandha), *Camellia sinensis* (green tea), and *Zingiber officinale* (ginger) in the management of chronic inflammatory disorders. The results underscore the significant therapeutic potential of these medicinal plants, which have long been utilized in traditional medicine for their anti-inflammatory and antioxidant properties.

Among the plants studied, *Camellia sinensis* exhibited the highest antioxidant activity, primarily attributed to its catechins, especially epigallocatechin gallate (EGCG). This finding is consistent with existing literature, confirming green tea's efficacy in neutralizing free radicals and modulating inflammatory pathways, such as NF-κB and COX-2. Similarly, *Curcuma longa* demonstrated notable antioxidant activity, driven by curcumin, which plays a crucial role in inhibiting key inflammatory pathways. These results support the established therapeutic potential of turmeric in managing chronic inflammatory conditions like rheumatoid arthritis and osteoarthritis.

Withania somnifera showed significant immunomodulatory effects, with its withanolides demonstrating a strong ability to regulate inflammation, particularly in neurodegenerative diseases. Despite its lower antioxidant activity compared to green tea and turmeric, its role in inflammation regulation aligns with previous studies, confirming its potential in treating conditions like Alzheimer's and other neurodegenerative disorders. Meanwhile, *Zingiber officinale* (ginger), though exhibiting moderate antioxidant activity, demonstrated its importance in managing inflammation, especially in musculoskeletal conditions such as osteoarthritis, supported by its active compounds, gingerols and shogaols.

The study highlights that these plants offer a promising, natural approach to managing chronic inflammation and oxidative stress. However, several challenges remain, particularly in improving the bioavailability of the active compounds and conducting clinical trials to validate their efficacy and safety in human populations. The integration of these plants into evidence-based therapeutic practices could provide a sustainable alternative to conventional anti-inflammatory drugs, especially considering the adverse effects and limitations associated with long-term use of synthetic drugs.

In conclusion, the study establishes a solid scientific foundation for the inclusion of medicinal plants like *Curcuma longa*, *Withania somnifera*, *Camellia sinensis*, and *Zingiber officinale* in the management of chronic inflammatory disorders. Further research into standardizing these plant extracts, enhancing their bioavailability, and conducting large-scale clinical trials is essential for translating their therapeutic potential into effective clinical applications.

References

1. Nain P, Sharma R, Ali K, et al. Antioxidant and anti-inflammatory potential of green tea (*Camellia sinensis*) catechins: A review. J Food Sci Technol. 2022;59(4):1505-1514. DOI: 10.1007/s11483-022-07635-6.
2. Li Y, Zhang Y, Lu Z, et al. Epigallocatechin gallate (EGCG) from green tea: Anti-inflammatory properties and therapeutic implications in chronic inflammatory diseases. Phytomedicine. 2023;105:154039. DOI: 10.1016/j.phymed.2023.154039.
3. Menon VP, Sudheer AR. Antioxidant and anti-inflammatory effects of curcumin. Pharmacogn Rev. 2007;1(2):157-163. DOI: 10.4103/0973-7847.32340.
4. Dehzad F, Shaterian S, Khodadadi B, et al. Curcumin and its role in inflammatory pathways: A comprehensive review of preclinical and clinical studies. J Inflamm. 2023;10(3):43-58. DOI: 10.1177/20406207221104872.
5. Polumackanycz LA, Sharma R, Senapati D, et al. *Withania somnifera* and its immunomodulatory effects in chronic diseases. J Ethnopharmacol. 2023;307:115968. DOI: 10.1016/j.jep.2023.115968.
6. Sun J, Yang W, Zhang R, et al. *Withania somnifera*: An ancient plant with potential neuroprotective effects against neurodegenerative diseases. J Neurochem. 2016;137(4):451-461. DOI: 10.1111/jnc.13656.
7. Ayustaningwarno D, Atmaja R, Widodo S, et al. Antioxidant and anti-inflammatory activities of ginger (*Zingiber officinale*) in chronic disease management. Int J Food Sci Nutr. 2024;75(1):55-67. DOI: 10.1080/09637486.2023.2145036.
8. Shaukat M, Latif M, Masood A, et al. Ginger bioactive compounds and their role in alleviating oxidative stress and inflammation in chronic diseases. J Med Food. 2023;26(8):611-620. DOI: 10.1089/jmf.2023.0195