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Muntingia Calabura Stem Extract-Mediated Green Synthesis of Iron Nanoparticles and its Anti-Inflammatory Action

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ABSTRACT

This study reports the green synthesis of iron nanoparticles (Fe-NPs) using *Muntingia calabura* stem extract as a natural reducing and stabilizing agent. The phytochemical analysis of the extract revealed the presence of several bioactive compounds, including flavonoids, alkaloids, and terpenoids, which facilitate nanoparticle formation. The synthesized Fe-NPs were characterized by UV-Visible spectroscopy, XRD, and FTIR, confirming their structural and chemical properties. Acute toxicity studies on rats confirmed the safety of the extract with an LD50 above 2000 mg/kg. The anti-inflammatory potential of the Fe-NPs was assessed using the carrageenan-induced paw edema model in rats, and significant anti-inflammatory effects were observed, comparable to the standard drug Diclofenac. These results indicate that *Muntingia calabura* stem extract can be a sustainable alternative for nanoparticle synthesis with promising biomedical applications.

1. Introduction:

Nanotechnology offers vast potential in various fields, including medicine and environmental remediation. However, conventional methods of nanoparticle synthesis involve toxic chemicals, leading to environmental hazards. Green synthesis, using plant extracts, provides a safer alternative that is eco-friendly and sustainable. Plants are rich in bioactive compounds that can reduce metal ions into nanoparticles without harmful by-products.

Muntingia calabura (Jamaican cherry) is a tropical plant known for its medicinal properties. Its stem extract contains a variety of phytochemicals, such as flavonoids, terpenoids, and alkaloids, which have been documented for their antioxidant and anti-inflammatory activities. This study focuses on utilizing *Muntingia calabura* stem extract for the green synthesis of iron nanoparticles and evaluating their anti-inflammatory efficacy.

2. Materials and Methods:

2.1. Phytochemical Screening:

The phytochemical constituents of *Muntingia calabura* stem extract were analyzed using standard qualitative methods. The solvent extracts (ethanol, methanol, chloroform, and distilled water) were screened for carbohydrates, alkaloids, flavonoids, terpenoids, proteins, tannins, saponins, and steroids. Ethanol extract was found to contain the highest diversity of phytochemicals.

2.2. Green Synthesis of Iron Nanoparticles:

An aqueous solution of *Muntingia calabura* stem extract was mixed with an iron sulfate solution ($FeSO_4$). The appearance of a color change from brown to black indicated the formation of iron nanoparticles. The reaction was monitored using UV-Visible spectroscopy, and the nanoparticles were separated by centrifugation, followed by drying for further analysis.

2.3. Characterization of Synthesized Fe-NPs:

UV-Visible Spectroscopy: The absorption peaks were observed at 225 nm and 297 nm, indicating the presence of phytochemicals attached to the Fe-NPs.

X-ray Diffraction (XRD): XRD analysis showed distinct peaks at 2θ values corresponding to the magnetite phase (Fe_3O_4) of the synthesized nanoparticles.

FTIR Analysis: FTIR spectroscopy identified functional groups involved in the synthesis and stabilization of nanoparticles, with key peaks around 1634 cm^{-1} (H-O bending) and 3383 cm^{-1} (O-H stretching), indicating the role of hydroxyl groups from the extract in nanoparticle stabilization.

2.4. Acute Toxicity Studies:

The acute toxicity of the ethanolic extract was assessed using the OECD guidelines. Rats were administered varying doses of the extract, and the absence of mortality or adverse effects at doses up to 2000 mg/kg confirmed the extract's safety.

2.5. Anti-Inflammatory Activity:

The anti-inflammatory effects of the synthesized Fe-NPs were evaluated using the carrageenan-induced paw edema model in rats. Rats were treated with 1 mg/kg and 2 mg/kg doses of Fe-NPs, with Diclofenac (5 mg/kg) serving as the standard control. Paw volumes were measured at 1, 2, 3, and 4 hours post-carrageenan injection to determine the degree of inflammation reduction.

3. Results:

3.1. Phytochemical Screening:

Phytochemical analysis of the ethanol extract of *Muntingia calabura* stem revealed the presence of carbohydrates, alkaloids, flavonoids, terpenoids, tannins, saponins, and proteins, which played a crucial role in the reduction and stabilization of Fe-NPs.

3.2. Characterization of Fe-NPs:

UV-Visible Spectroscopy: Peaks observed at 225 nm and 297 nm confirmed the formation of Fe-NPs and indicated the presence of bioactive compounds from the extract on the nanoparticle surface.

XRD: The XRD patterns showed distinct peaks corresponding to the magnetite (Fe_3O_4) phase, confirming the crystalline nature of the nanoparticles.

FTIR: The FTIR spectra indicated the presence of hydroxyl and amine groups from the extract, which contributed to nanoparticle capping and stabilization.

3.3. Acute Toxicity Studies

No toxic effects were observed up to a dose of 2000 mg/kg in rats, confirming the safety of ***Muntingia calabura*** stem extract.

3.4. Anti-Inflammatory Activity

The Fe-NPs exhibited significant anti-inflammatory effects in the carrageenan-induced paw edema model. At a dose of 2 mg/kg, Fe-NPs showed 85.7% inhibition of paw edema, compared to 99.6% inhibition by Diclofenac. These results were statistically significant ($p < 0.05$) and indicate the potential of Fe-NPs as an anti-inflammatory agent.

4. Discussion:

The green synthesis of Fe-NPs using ***Muntingia calabura*** stem extract offers an eco-friendly approach to nanoparticle synthesis. The phytochemicals in the extract act as reducing agents, facilitating the formation of stable nanoparticles without the need for hazardous chemicals. The synthesized Fe-NPs exhibited potent anti-inflammatory activity, with effects comparable to Diclofenac, a commonly used anti-inflammatory drug.

The acute toxicity studies confirm the safety of the stem extract, making it suitable for biomedical applications. The presence of bioactive compounds, such as flavonoids and terpenoids, not only aids in nanoparticle synthesis but also enhances their therapeutic potential. Future studies should focus on optimizing the synthesis conditions and exploring additional biomedical applications of Fe-NPs, such as antimicrobial and anticancer activities.

5. Conclusion:

This study successfully demonstrates the green synthesis of iron nanoparticles using *Muntingia calabura* stem extract. The Fe-NPs exhibit significant anti-inflammatory activity, highlighting their potential for use in therapeutic applications. The use of plant-based synthesis methods offers a sustainable and environmentally friendly alternative to conventional chemical methods.

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