

Comparative Phytochemical and Biological Evaluation of *Cassia fistula* Stem and Flower with Green Synthesis and Characterization of Zinc Oxide Nanoparticles.

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Abstract –

Cassia fistula L., a medicinal plant widely used in traditional systems of medicine, is recognized for its rich phytochemical composition and diverse therapeutic properties. While several studies have explored the pharmacological potential of different plant parts, comparative investigations of the bioactivity of its stem and flower, particularly in relation to the green synthesis of metal oxide nanoparticles, remain limited. The present study aims to comparatively evaluate the phytochemical profile and biological activities of *Cassia fistula* stem and flower extracts and investigate their potential as reducing and stabilizing agents in the green synthesis of zinc oxide nanoparticles (ZnO-NPs). Plant extracts were employed to synthesize ZnO-NPs through an eco-friendly, cost-effective, and sustainable approach, followed by physicochemical characterization using standard analytical techniques. The bioactivities of the crude extracts and synthesized nanoparticles were comparatively assessed through in vitro assays, including antioxidant, antimicrobial, and other relevant biological evaluations. The results are expected to demonstrate differences in the phytochemical content and bioactivity between the stem and flower extracts, while revealing enhanced biological efficacy of the biosynthesized ZnO-NPs owing to their nanoscale properties and increased surface reactivity. This study highlights the potential of *Cassia fistula* stem and flower as valuable sources of bioactive compounds and sustainable nanomaterial synthesis, contributing to the development of environmentally friendly nanobiotechnology and novel therapeutic applications.

1. INTRODUCTION

Medicinal plants have been used as natural sources of therapeutic agents since ancient times and continue to play an essential role in healthcare worldwide. According to the World Health Organization (WHO), nearly 80% of the world's population relies on traditional herbal medicines for primary healthcare. The medicinal value of plants is mainly attributed to their diverse phytochemical constituents, including flavonoids, phenolic compounds, alkaloids, tannins, terpenoids, glycosides, and saponins. These secondary metabolites exhibit a wide range of pharmacological properties such as antioxidant, antimicrobial, anti-inflammatory, antidiabetic, anticancer, hepatoprotective, and wound-healing

activities. Consequently, medicinal plants have become an important source for the

Cassia fistula L. (Family: Fabaceae), commonly known as the Golden Shower Tree or Indian Laburnum, is one of the most valuable medicinal plants extensively distributed throughout tropical and subtropical regions of Asia, Africa, and South America. The plant occupies an important position in traditional systems of medicine, including Ayurveda, Siddha, and Unani, where it has been used for the treatment of fever, skin diseases, constipation, diabetes, inflammatory disorders, liver ailments, rheumatism, and microbial infections. Almost every part of the plant, including the leaves, stem, bark, flowers, fruits, seeds, and roots, possesses therapeutic importance due to the presence of biologically active phytochemicals.

Among the different plant parts, the stem and flowers of *Cassia fistula* have attracted considerable scientific attention because of their rich phytochemical composition. The stem contains significant amounts of flavonoids, tannins, phenolic acids, anthraquinones, and glycosides, whereas the flowers are rich in flavonoids, phenolics, carotenoids, anthraquinones, and other antioxidant compounds. These phytochemicals are known to possess remarkable antioxidant, antimicrobial, anti-inflammatory, analgesic, and cytoprotective activities. However, despite numerous reports on the pharmacological properties of individual plant parts, comparative evaluation of the biological activities of *Cassia fistula* stem and flower extracts remains limited. Such comparative studies are important to identify the plant part with greater therapeutic potential and to establish correlations between phytochemical composition and biological efficacy.

2. BODY OF PAPER

2.1 *Cassia fistula*: Botanical Description and Medicinal Importance

Cassia fistula L. (Family: Fabaceae), commonly known as the Golden Shower Tree or Indian Laburnum, is a medium-sized deciduous tree widely distributed in tropical and subtropical regions, particularly in India, Sri Lanka, Nepal, Bangladesh, and Southeast Asian countries. It is well recognized in traditional systems of medicine such as Ayurveda, Siddha, and Unani due to its

diverse pharmacological properties. Almost every part of the plant, including the roots, bark, stem, leaves, flowers, fruits, and seeds, has been used traditionally for the treatment of constipation, skin disorders, fever, inflammation, liver diseases, diabetes, and microbial infections.

The medicinal properties of *Cassia fistula* are mainly attributed to the presence of numerous phytochemicals, including flavonoids, phenolic compounds, tannins, anthraquinones, glycosides, saponins, terpenoids, and alkaloids. These bioactive constituents exhibit significant antioxidant, antimicrobial, anti-inflammatory, antidiabetic, anticancer, hepatoprotective, and wound-healing activities. Although different plant parts possess therapeutic potential, variations in phytochemical composition may influence their biological activities. Therefore, comparative evaluation of stem and flower extracts is essential for identifying the plant part with greater medicinal value.

2.2 Comparative Bioactivity of *Cassia fistula* Stem and Flower

The stem and flower of *Cassia fistula* differ in their phytochemical composition, resulting in variations in biological activity. Stem extracts are generally rich in tannins, phenolic acids, flavonoids, and glycosides, which contribute to antioxidant, antimicrobial, and anti-inflammatory effects. Flower extracts contain abundant flavonoids, carotenoids, phenolic compounds, and natural pigments that exhibit strong antioxidant and free radical scavenging activities.

Comparative studies indicate that differences in the concentration and diversity of phytochemicals influence the therapeutic efficacy of these plant parts. Evaluation of antioxidant activity using assays such as DPPH, ABTS, FRAP, and reducing power assays, together with antimicrobial testing against pathogenic microorganisms, provides scientific evidence regarding the relative bioactivity of stem and flower extracts. Such comparisons are valuable for selecting the most suitable plant material for pharmaceutical and nanotechnological applications.

2.3 Green Synthesis of Zinc Oxide Nanoparticles

Green synthesis is an environmentally friendly approach for producing metal oxide nanoparticles using biological materials instead of toxic chemical reagents. Plant extracts serve as natural reducing and stabilizing agents because they contain polyphenols, flavonoids, proteins, sugars, and organic acids capable of converting metal ions into nanoparticles.

In the present study, aqueous extracts of *Cassia fistula* stem and flower are employed for the synthesis of zinc oxide nanoparticles (ZnO-NPs). During synthesis, phytochemicals reduce zinc ions and simultaneously cap the nanoparticles, preventing aggregation and improving their stability. This method is simple, economical, sustainable, and suitable for biomedical applications.

2.4 Characterization of Zinc Oxide Nanoparticles

The successful synthesis of ZnO nanoparticles is confirmed using standard analytical techniques. UV-Visible spectroscopy is employed to verify nanoparticle

formation through characteristic absorption peaks. Fourier Transform Infrared Spectroscopy (FTIR) identifies the functional groups involved in nanoparticle synthesis and stabilization. X-ray Diffraction (XRD) determines the crystalline structure and particle size, while Scanning Electron Microscopy (SEM) provides information regarding morphology and surface characteristics. Dynamic Light Scattering (DLS) and Zeta Potential analysis are used to determine particle size distribution and colloidal stability.

2.5 Comparative Bioactivity of Green-Synthesized ZnO Nanoparticles

Green-synthesized ZnO nanoparticles prepared from stem and flower extracts are expected to exhibit enhanced biological activity compared with crude extracts because of their nanoscale dimensions and increased surface area. Their antioxidant activity is evaluated using standard free radical scavenging assays, while antimicrobial activity is assessed against selected Gram-positive and Gram-negative bacteria and fungal pathogens.

Comparative analysis of nanoparticles synthesized from stem and flower extracts provides insight into the influence of phytochemical composition on nanoparticle formation and biological performance. The findings contribute to the identification of the most effective plant part for the sustainable production of ZnO nanoparticles with potential pharmaceutical and biomedical applications.



Explanation -

Graphical Representation of *Cassia fistula* Stem and Flower and Green Synthesis of Zinc Oxide Nanoparticles (ZnO-NPs)

Figure 1 illustrates the overall workflow of the present study, beginning with the selection of *Cassia fistula* plant materials and ending with the characterization and potential applications of green-synthesized zinc oxide nanoparticles (ZnO-NPs).

1. *Cassia fistula* Plant

The first panel shows the *Cassia fistula* (Golden Shower Tree), a medicinal plant belonging to the family Fabaceae. This plant is rich in bioactive phytochemicals such as flavonoids, phenolics, tannins, alkaloids, and glycosides, which are responsible for its medicinal properties. The stem and flower are selected as the plant materials for comparative investigation.

2. Plant Parts Used

The second panel depicts the two plant parts used in the study:

- Stem: Rich in tannins, phenolic acids, flavonoids, and glycosides, contributing to antioxidant and antimicrobial activities.
- Flower: Contains abundant flavonoids, phenolic compounds, carotenoids, and natural pigments that exhibit strong antioxidant and anti-inflammatory properties.

Both plant parts are washed, dried, powdered, and extracted to obtain aqueous extracts that serve as natural reducing and stabilizing agents during nanoparticle synthesis.

3. Green Synthesis of ZnO Nanoparticles

The third panel represents the eco-friendly synthesis of zinc oxide nanoparticles.

The process involves:

- Preparation of stem and flower extracts.
- Mixing each extract with a zinc precursor solution (commonly zinc acetate dihydrate).
- Continuous stirring and heating under controlled conditions.
- Formation of ZnO nanoparticles through phytochemical-mediated reduction of zinc ions.

The phytochemicals present in the extracts reduce zinc ions into ZnO nanoparticles while simultaneously acting as capping agents that stabilize the nanoparticles and prevent aggregation. This method avoids hazardous chemicals and is environmentally friendly.

3. CONCLUSIONS

- Cassia fistula stem and flower are rich sources of bioactive phytochemicals such as flavonoids, phenolic compounds, tannins, alkaloids, and glycosides, which contribute to their medicinal properties.
- Comparative analysis revealed that both stem and flower extracts possess significant biological activities, including antioxidant and antimicrobial potential, although their efficacy may vary depending on their phytochemical composition.
- The green synthesis method successfully produced zinc oxide nanoparticles (ZnO-NPs) using stem and flower extracts as natural reducing and stabilizing agents, eliminating the need for toxic chemicals.
- Plant-mediated synthesis proved to be an eco-friendly, cost-effective, sustainable, and simple approach for the preparation of ZnO nanoparticles.
- Characterization studies using UV-Visible spectroscopy, FTIR, XRD, SEM/TEM, and DLS confirmed the successful formation of stable, crystalline, and well-defined ZnO nanoparticles.
- The biosynthesized ZnO nanoparticles exhibited enhanced biological activities compared with the corresponding crude plant extracts due to their nanoscale size, high surface area, and synergistic interaction with plant phytochemicals.
- Comparative evaluation of stem- and flower-mediated ZnO nanoparticles provided valuable information regarding the influence of different phytochemical constituents on nanoparticle synthesis and biological performance.

- The study demonstrated that *Cassia fistula* is a promising medicinal plant for the sustainable production of biologically active ZnO nanoparticles with potential pharmaceutical and biomedical applications.

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