Biogenic Synthesis of Silver Nanoparticles Using Caesalpinia Bonducella Seed Extract: Characterization and Antimicrobial Evaluation

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REVIEW OF LITERATURE

CAESALPINIA BONDUCELLA AND ITS MEDICINAL USES:

Plants have played a significant role in maintaining human health and improving the quality of human life for thousands of years and have served humans well as valuable components of medicines, seasonings, beverages, cosmetics and dyes. Herbal medicine is based on the premise that plants contain natural substances that can promote health and alleviate illness. In Recent times, focus on plant research has increased all over the world and a large body of evidence has collected to show immense potential of medicinal plants used in various systems modern medicine uses active constituents that are isolated from various plant parts, with 80% of these active components being effective in treating particular diseases with their anticancer, hepatoprotective, antioxidant, antimalarial, antibacterial, antipyretic, antifertility, and anti-inflammatory qualities (Kannur Et al., 2006; Moon *et al*., 2010).

In India, the traditional Ayurvedic medical system is used by 76% of the rural population. With over 20,000 medicinal plants and 2,50,000 registered Ayurvedic practitioners, India is the world's greatest produce medicinal systems. Plants are now occupying important position in allopathic medicine, herbal medicine, homoeopathy and aromatherapy. Medicinal plants are the sources of many important drugs of the modern world. Many of these indigenous medicinal plants are used As spices and food plants; they are also sometimes added to foods meant for pregnant mothers for medicinal purposes. (Ajayi I 2011).

C. bonducella is an Indian herb reported in Ayurveda, the ancient Hindi medicine system of India.*Caesalpinia bonducella F.,* commonly known as Nata Karanja, a prickly shrub found throughout the hotter parts of India, Myanmar and Sri Lanka, has grey, hard, globular shaped seeds with a smooth shining surface. *Caesalpinia bonducella* belongs to the Family: *Caesalpiniaceae* found all over the world specially, in India, Sri Lanka and Andaman and Nicobar Islands, in India especially present in tropical regions. "*Bonducella*" the name of the species is derived from the Arabic word "Bonduce" meaning 'a little ball" which indicated the globular shape of the seed (Desh Deepak Pandey *et al.*, 2018).

The common name of *Caesalpinia Bonducella* plant seed is Bonduc nut, fever nut. It belongs to the family of *Fabaceae/Caesalpiniacea*e. .It Is referred to as Kazhanchikkuru Kalechikai, Kazharchikkaai in Tamil (Arindam et al., 2007). This Bonduc nut is useful to cure a variety of symptoms and afflictions, including diabetes mellitus, malaria, colic, fever, edema, Leprosy,

And abdominal pain. Although this plant has several medical properties (Dipsikha PATRA 2024). Its seeds are used In Ayurvedic medicine, and the plant grows To 10 meters tall and has sharp spines (Billah *et al*., 2013).

Seeds consist of a thick, brittle shell with a yellowish white bitter fatty kernel (Nadkarni, 1954). Plant is reported to have multiple therapeutic properties like, antidiuretic, anthelmintic and antibacterial (Neogi and Nayak, 1958), anti-anaphylactic and antiviral (Dhar *et al*., 1968), antiasthmatic (Gayaraja *et al.*, 1978), antiamebic and anti-estrogenic (Raghunathan and Mitra, 1982). Blood sugar lowering activity of *C.bonducella* has been primarily evaluated with

significant result in rabbit (Rao et al., 1994) and rat models (Biswas *et al.,* 1997, Sharma *et al*., 1997).

The major uses and benefits of fever nut are to suppress fever and malaria. Leaf and twig paste were used to relieve toothaches, as well as boiled leaves are used for gargling to alleviate sore throat and also used to treat Abdominal pain, ruminant liver fluke. Fresh juice of tender leaves is administered to avoid mucous secretions along with the honey. Leaves and twigs are historically used in tumour therapy, inflammation11and liver disorders. Elephantiasis and smallpox have traditionally been treated with leaf juice. (S. Sivakrishnan 2021).

The leaves are around 30- to 60 Binnates with small yellow flowers and clusters of leaflets. The calyx has lobes That are obovate-oblong and obtuse, and it is 6–8 mm long, fulvous, and hairy. The petals have declinate, Flattened filaments at the base, and are yellow and oblanceolate. The pods of fruits with 10 seeds are Hard and brown with a bitter taste. The treated seeds are extracted from 1–1.25 mm testa in a dry state and have a firm, glossy coat. Their colour is pale yellowish white, their texture is ridged, and their Flavour is bitter (Sundare *et al.,* 2007; Kakade *et al.,* 2017).

Plants which have been selected for medicinal use over thousands of years constitute the most obvious choice of examining the current search for therapeutically effective new drugs such as anticancer drugs, antimicrobial drugs , antihepatotoxic compounds. According to World Health Organization (WHO), medicinal plants would be the best source to obtain variety of drugs. About 80% of Individuals from developed countries use traditional medicines, which has compounds derived from medicinal plants. However, such plants should be investigated to better understand their properties, safety, And efficiency. Bioactive substances include tannins, alkaloids, carbohydrates, terpenoids, steroids and flavonoids are synthesized by primary or rather secondary metabolism of living organisms. Secondary metabolites are chemically and taxonomically extremely diverse compounds with obscure function. They are widely used in the human therapy, veterinary, agriculture, scientific research.

Phytochemicals that may lead to the development of novel drugs. Most of the phytochemicals from plant sources such as phenolics and flavonoids have been reported to have positive impact on health and phytochemicals that may lead to the development of novel drugs. Cancer prevention. Modern mediterranean and DASH (Dietary Approaches to Stop Hypertension) incorporate a phytochemicals rich diet from fruit and vegetable sources as the plant based diet has shown to extend life span in Okinawan people, that has the highest number of centenarians. High content of phenolic and flavonoids in medicinal plants have been associated with their antioxidant activities that play a role in the prevention of the development of age-related disease, Particularly cause by oxidative stress. With regards to the beneficial phytochemicals in medicinal plants and the shift towards natural products in pharmaceuticals and cosmeceuticals industry (Azwanida 2015)

SILVER NANOPARTICLES :

Silver nanoparticles (AgNPs) have been extensively studied due to their unique nanoscale properties and wide-ranging applications in various fields. This review aims to explore the definition and characteristics of AgNPs, as described by researchers, highlighting their significance In scientific and industrial advancements. According to various studies, AgNPs are typically defined as silver particles with a size range of 1 to 100 nanometers, exhibiting remarkable physicochemical properties that distinguish them from bulk silver (Marambio-Jones *et al.,* 2010).

These nanoparticles possess a high surface area-to-volume ratio, which enhances their reactivity and functional capabilities, making them highly effective in antimicrobial, optical, and catalytic applications (Song & Kim, 2009). According to this review, researchers have emphasized that the definition of AgNPs extends beyond their size, incorporating their morphology, surface charge, and synthesis methods. The shape of AgNPs whether spherical, triangular, rod-shaped, or cubic significantly influences their optical and biological behavior (Iravani et al., 2013). Additionally, studies suggest that the surface properties of AgNPs, including functionalization with biomolecules or polymers, can further enhance their stability and interaction with biological systems The growing interest in AgNPs has led researchers to refine their definition based on their diverse applications, from antimicrobial coatings to drug delivery systems. As research progresses, the characterization and understanding of AgNPs continue to evolve, emphasizing their potential in

nanotechnology-driven innovations.(Kumar *et al.,* 2021).

SYNTHESIS OF SILVER NANOPARTICLES :

Silver nanoparticles (NPs) have been the subjects of researchers because of their unique properties (e.g., size and shape depending optical, antimicrobial, and electrical properties). A variety of preparation techniques have been reported for the synthesis of silver NPs; notable examples include, laser ablation, gamma irradiation, electron irradiation, chemical reduction, photochemical methods, microwave processing, and biological synthetic methods. This review presents an overview of silver nanoparticle preparation by physical, chemical, and biological synthesis. The aim of this review article is, therefore, to reflect on the current state and future prospects, especially the potentials and limitations of the above mentioned techniques for industries (S. Iravani *et.al.,*2013) .

Over the past few decades, nanoparticles of noble metals such as silver exhibited significantly distinct physical, chemical and biological properties from their bulk counterparts. Nano-size particles of less than 100 nm in diameter are currently attracting increasing attention for the wide range of new applications in various fields of industry. Such powders can exhibit properties that differ substantially from those of bulk materials, as a result of small particle dimension, high surface area, quantum confinement and other effects. Most of the unique properties of nanoparticles require not only the particles to be of nano-sized, but also the particles be dispersed without agglomeration. Discoveries in the past decade have clearly demonstrated that the electromagnetic, optical and catalytic properties of silver nanoparticles are strongly influenced by shape, size and size distribution, which are often varied by varying the synthetic methods, reducing agents and stabilizers. Accordingly, this review presents different methods of preparation silver nanoparticles and application of these nanoparticles in different fields (Kholoud M.M. Abou El-Nour 2013).

APPLICATION OF SILVER NANOPARTICLES:

Research on silver nanoparticles (AgNPs) has been extensively conducted due to their nanoscale size and high surface area, which contribute to their broad-spectrum applications in medicine, pharmaceuticals, environmental science, and various industries. The increasing use of AgNPs in these fields has driven scientific investigations into their mechanisms of action, safety, and future developments. This review provides a comprehensive overview of AgNP applications across different sectors, highlighting their benefits, challenges, and future prospects.In the medical field, AgNPs have been widely investigated for their antimicrobial activity.

In medical field, studies have demonstrated their effectiveness in wound dressings, surgical masks, and medical coatings, contributing to infection prevention and faster wound healing. Their incorporation into medical devices such as catheters, implants, and sutures has been explored to prevent microbial colonization and biofilm formation, reducing healthcare-associated infections and improving patient outcomes (Rai et al., 2009). Furthermore, AgNPs exhibit strong antibacterial activity against multidrug-resistant bacteria, enhancing their significance in combating resistant pathogens in hospital settings (Chen *et al.,* 2010).

In pharmaceuticals, research has highlighted their role in drug delivery systems, particularly in crossing biological barriers, including the blood-brain barrier, allowing for targeted drug delivery in neurological disorders and cancer treatment. Studies also indicate their potential as carriers for antimicrobial, anticancer, and anti-inflammatory drugs, improving therapeutic efficiency while minimizing side effects (Yin *et al.,* 2020).

Beyond biomedical applications, AgNPs have been extensively studied for their role in environmental and industrial sectors. Research has emphasized their potential in water purification and wastewater treatment due to their strong antimicrobial and catalytic properties, effectively removing pathogens and toxic pollutants from contaminated water sources (Zhang *et al.,* 2016). In the food industry, AgNPs have been explored for food preservation and safety, particularly in antimicrobial packaging and nanosensors for spoilage detection, though concerns about their toxicity have led to further safety evaluations (Singh et al., 2014). Studies in textiles highlight their use in antibacterial and odor-resistant fabrics for healthcare and sportswear applications, enhancing hygiene and reducing infection risks (Simoncic *et al*., 2010). In electronics, AgNPs have been investigated for their excellent conductivity, contributing to the development of conductive inks, flexible circuits, and nanosensors (Marambio-Jones *et al.,* 2010). Additionally, research in cosmetics has

shown their antimicrobial and anti-inflammatory effects in skincare formulations, particularly in reducing acne-causing bacteria Overall, the growing body of research on AgNPs underscores their significant potential in medicine and pharmaceuticals. However, ongoing studies continue to assess their long-term safety, mechanisms of action, and regulatory implications to ensure their sustainable and effective application. (Vigneshwaran *et al.,* 2007).

GREEN SYNTHESIS:

Green synthesis of silver nanoparticles (AgNPs) has gained considerable interest due to its eco-friendly nature and alignment with green chemistry principles. Various studies have explored plant-mediated synthesis as an alternative to conventional chemical and physical methods, utilizing bioactive compounds from plant extracts for the reduction and stabilization of silver ions. Phytochemicals such as polyphenols, flavonoids, alkaloids, and terpenoids play a crucial role in determining nanoparticle size, stability, and bioactivity. This review presents an overview of the green synthesis of AgNPs, emphasizing the mechanisms involved and the influence of plant metabolites on nanoparticle formation (Ahmed *et al.,* 2016; Khatami *et al.,* 2023).

The objective of this review is to highlight the current advancements in plant-mediated AgNP synthesis, focusing on its biomedical applications, including antimicrobial, anticancer, and wound-healing properties. Additionally, it examines the challenges associated with the standardization and scalability of green synthesis for industrial applications. While green synthesis offers a sustainable and cost-effective alternative, variations in plant metabolites pose challenges in ensuring reproducibility. This review aims to provide insights into optimizing synthesis protocols and future prospects for integrating green-synthesized AgNPs into pharmaceuticals, medicine, and environmental applications (Singh *et al.,* 2021).

CHARACTERIZATION OF AGNPs:

The characterization of silver nanoparticles (AgNPs) synthesized using green methods is crucial for understanding their structural, optical, and antimicrobial properties. Various spectroscopic and microscopic techniques have been employed to analyze their morphology, size distribution, crystallinity, and surface properties.

UV-Vis Spectroscopy Analysis:

UV-Vis spectroscopy is one of the primary techniques used to confirm the synthesis of silver nanoparticles. The surface plasmon resonance (SPR) band of AgNPs typically appears between 400–450 nm, depending on their shape and size. Researchers have reported that plant extracts influence the SPR peak due to variations in capping agents and reducing agents present in natural extracts. For instance, silver nanoparticles synthesized using *Azadirachta indica* extract exhibited an absorption peak at 420 nm, confirming nanoparticle formation (Kumar et al., 2020). Similarly, green synthesis using *Moringa oleifera* showed an SPR peak at 425 nm, indicating stable AgNPs formation (Sharma *et al.,* 2021).

Fourier-Transform Infrared Spectroscopy (FTIR) Analysis:

FTIR spectroscopy is widely used to identify functional groups responsible for reducing and stabilizing AgNPs. Studies indicate that biomolecules such as phenols, flavonoids, proteins, and terpenoids act as capping agents in green synthesis. An FTIR spectrum of AgNPs synthesized from Ocimum sanctum showed peaks at 3,400 cm□¹ (O-H stretch), 1,635 cm□¹ (C=O stretch), and 1,072 cm□¹ (C-O stretch), confirming the presence of bioactive compounds involved in the reduction process (Raghunandan et al., 2019). Similarly, AgNPs synthesized from Allium sativum extract exhibited characteristic FTIR peaks corresponding to proteins and sulfur-containing compounds, indicating effective stabilization (Verma *et al.,* 2022).

ANTIMICROBIAL ACTIVITY:

The AgNPs have been found to exhibit promising anti-micribial activity. Researchers have used several novel techniques. The disc diffusion method, a most commonly used technique to access the antimicrobial activity of a liquid, has been employed by many researchers to confirm antimicrobial action of the AgNPs solution. In this method, uniform sized disc of adsorbent material are dipped in the increasing concentration of AgNP and placed over surface of the targeted microbe inoculated on the nutrient medium plates. An inhibition zone formation around the disc reflects antimicrobial action of the nanomaterials and well diffusion In the Well diffusion method instead of using discs, small disc shaped pits are created on the agar plate for filling the test solution. In both the techniques, the microbe inoculated plates are

incubated under standard condition for the formation of clear inhibition zone. The inhibition zone diameter around the disc or well, directly relates the effects of AgNPs on the chosen microbe. (Kharissova *et al*.2013).

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