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GREEN SYNTHESIS AND CHARACTERIZATION OF SILVER NANOPARTICLES USING *COLEUS AROMATICUS* LEAF EXTRACT

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***Abstract* -** The production and characterization of nanoparticles have garnered significant attention in the field of nanotechnology in recent times. Using *Coleus aromaticus* in the green synthesis of AgNPs offers many advantages over conventional synthesis methods. Gathering plant material, preparing plant extract, synthesizing silver nanoparticles, optimizing reaction parameters, and characterizing the resultant product. XRD observed intensity peaks at 28.5, 31.8, and 38.6 degrees, corresponding to planes 220, 311, and 240, respectively. FTIR spectrum peaks of 3000.48, 2888.89, 2825.30, 1622.33, 1417.58, 1132.81, 901.99, and 583.04 were observed. The SEM image revealed the component parts to be non-uniform, spherical, agglomerated, and having an average size of 28.5 nm. Silver nanoparticles (AgNPs) are produced from *Coleus aromaticus* extract by use of the phytochemicals in the plant extract, which function as stabilising and reducing agents. AgNPs are successfully synthesized, and their potential applications are supported by their characterization using a variety of analytical methods.

Keywords - Human Health, Well-Being, Silver Nanoparticles, *Coleus aromaticus*, Green Synthesis, XRD, Scanning Electron Microscope.

I. INTRODUCTION

The synthesis and characterization of nanoparticles have garnered a lot of interest recently in the realm of nanotechnology. Due to their distinct optical, electrical, and antibacterial capabilities, silver nanoparticles (AgNPs) have emerged as potential candidates among various types of nanoparticles [1]. The use of dangerous chemicals and energy-intensive procedures in conventional silver nanoparticle synthesis methods, however, raises questions about the sustainability of the environment and public health. As a result, developing green synthesis methods that make use of safe surroundings and natural resources is becoming more and more popular. [2]. The medicinal plant *Coleus aromaticus*, typically found in tropical areas, is one example of a natural resource. It has a long history of therapeutic usage in conventional medicine. The bioactive substances phenolic compounds, flavonoids, and terpenoids, which have antioxidant and antibacterial properties, are among those found in *Coleus aromaticus* leaves [3]. These bioactive substances might function as reducing and stabilizing agents during the environmentally friendly synthesis of AgNPs [4].

The term "green synthesis" describes the creation of nanoparticles using techniques that are less harmful to the environment and require less energy [5]. It has several benefits, including affordability, scalability, and environmental friendliness. By utilizing renewable resources and minimizing the production of hazardous byproducts, green synthesis using plant extracts offers a sustainable method [6]. Silver ions (Ag^+) in a silver precursor solution are reduced to create metallic silver nanoparticles during the production of AgNPs utilizing *Coleus aromaticus*. To stop the agglomeration and development of nanoparticles, the plant extract works as a reducing agent, while the phytochemicals in the plant function as stabilizing agents. There is no requirement for high-energy inputs because the synthesis process is normally carried out at ambient temperature and pressure [7]. Compared to traditional synthesis techniques, the green synthesis of AgNPs using *Coleus aromaticus* has several benefits. First and foremost, it is a cost-effective strategy since it does away with the need for expensive and hazardous chemicals. The plant extract's function as a natural supply of stabilizing and lowering agents lowers the overall cost of synthesis [8]. Because green synthesis creates less hazardous waste and has a smaller carbon footprint than conventional processes, it is also better for the environment. Furthermore, it is possible to perform the synthesis process at room temperature and pressure, which uses less energy and increases energy efficiency [9]. Following their synthesis, the stability of the *Coleus aromaticus* AgNPs is observed by a variety of characterization methods. AgNPs are preferable over traditional metallic nanoparticles in a number of ways, including their notable anti-inflammatory, antiviral, antibacterial, and antifungal characteristics [10]. Fibre composite materials, cryogenic superconductivity materials, electrical components, and the food and cosmetics sectors may all include them. Thus, there is always a need for them. Furthermore, due to the broad-spectrum biocidal properties of silver and silver-based compounds against bacteria, topical lotions, antiseptic sprays, and wound dressings have all used silver. Positive results have been shown when AgNPs are included in these products with regard to wound healing and anti-diabetic properties [11]. Silver nanoparticles, or AgNPs, are available in diameters between 5 and 100 nm. Their unique physical, chemical, and biological characteristics have garnered significant interest in science and technology. Chemical reduction, laser ablation, or green synthesis employing plant extracts are frequently used to create nanoparticles [12]. Their high reactivity and surface area make them effective catalysts and adsorbents for the purification of water. Because silver nanoparticles have excellent electrical and optical capabilities, they are used in conductive inks, printed electronics, and sensors [13]. They are frequently found in flexible electronics, RFID tags, and touchscreens. Silver is a low-toxicity, potent antibacterial agent that is especially helpful for treating burn injuries. Because of their unique properties, such as their high drug-loading capacity, biodegradability, site-specific delivery mechanism, and non-toxicity to healthy cells and tissues, nanocarriers are useful as drug delivery vehicles [14, 15, 16].

Due to their variable levels of in vitro toxicity, silver nanoparticles have been investigated for their potential cytotoxicity. Particularly, nanoparticles are widely used in the therapeutic domains of drug delivery systems, targeted therapy, and gene therapy because of their properties and ease of control, which are obtained via dynamic medication with an emphasis on parenteral organisation. Green nanoparticle production using plants with therapeutic properties provides us with new forms of medications that have been successfully employed in traditional medicine. Plant-based medications offer fewer side effects while also being more inexpensive and feasible. Numerous studies have detailed the synthesis of metal nanoparticles, including composites, gold, silver, and copper, using plants. Because of the overuse of antibiotics and the development of drug-resistant bacteria, antimicrobial resistance (AMR) is becoming a major worldwide problem. The creation of innovative and potent antibacterial drugs is now urgently needed as a result [17]. Traditional medicine has historically used medicinal plants to treat a wide range of illnesses, including bacterial infections. Plant extracts have been demonstrated in several studies to possess antibacterial properties against a diverse range of microbes. Compared to synthetic antibiotics, plant-based antimicrobial drugs have a number of benefits, including a reduced toxicity profile, fewer side effects, and a wide variety of bioactive chemicals that can target different aspects of bacterial growth and survival. [18].

II. MATERIALS AND METHODS

A. Mechanism of Green Synthesis:

A complex interplay of several phytochemicals found in the plant is involved in the green synthesis of AgNPs using *Coleus aromaticus* extract. The bioactive substances found in the plant extract reduce silver ions ($Ag+$) to silver atoms ($Ag0$), which is the main mechanism. By giving electrons to the silver ions, these substances—which include phenolic compounds, flavonoids, and terpenoids—act as reducing agents. AgNPs are created during the reduction process and are stabilized by phytochemicals, which keep them from aggregating and uphold their stability [19].

The size, shape, content, and stability of the synthesized AgNPs can be studied utilizing a variety of analytical techniques for characterization. Typical characterization strategies include the following:

B. Green Synthesis Steps:

Plant material: Collecting *Coleus aromaticus* leaves from a dependable source, they were completely cleaned of any contaminants using distilled water.

C. Plant Extract Preparation

To make the plant extract, cleaned *Coleus aromaticus* leaves were mashed in a mortar and pestle with an appropriate solvent (such as ethanol or water). The grinding procedure releases the phytochemicals from the leaves into the solvent. The resultant mixture was filtered through fine mesh or filter paper to get a clear plant extract.

D. Synthesis of Silver Nanoparticles:

By mixing a silver precursor solution, such as silver nitrate ($AgNO_3$), with the plant extract, silver nanoparticles (AgNPs) were created. As a reducing agent, the plant extract breaks down the silver ions (Ag^+) in the solution to create silver nanoparticles. Normally, the reaction takes place in ambient settings at room temperature.

E. Optimization of Reaction Parameters:

The concentration of the plant extract, the concentration of the silver precursor, the pH, and the reaction time may all need to be optimized for the best synthesis conditions. The stability, size, and form of the synthesized nanoparticles can all be affected by these variables. Characterization of Silver Nanoparticles: Precipitate is used for further characterization like XRD, FTIR, and SEM and is used for biomedical applications [20, 21].

AgNPs are investigated using XRD to determine their crystallinity. It offers details on the nanoparticles' crystal structure, lattice spacing, and particle size. FTIR: The functional groups present in the plant extract and their interactions with the AgNPs are identified using FTIR spectroscopy. It aids in comprehending the position phytochemicals play in the stabilization and reduction of nanoparticles. Scanning Electron Microscopy (SEM): High-resolution imaging methods like Sem make it possible to see synthesized AgNPs directly. It offers details on the distribution, size, and shape of nanoparticles at the nanoscale.

III. RESULTS

A. Synthesis of Silver Nanoparticles:

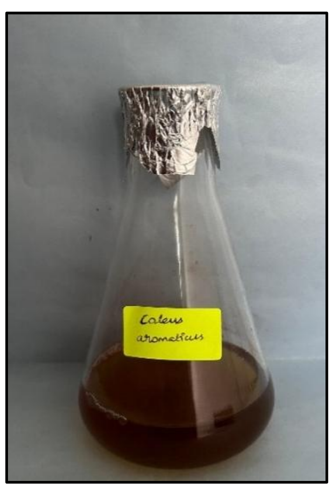

Fig.1. Aqueous extract of *Coleus aromaticus*

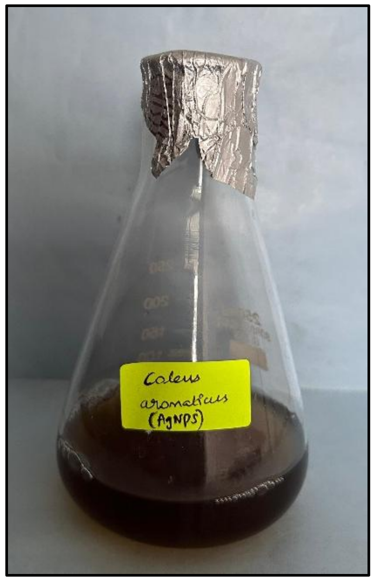

Fig.2. Green synthesis of *Coleus aromaticus* mediated silver nanoparticles.

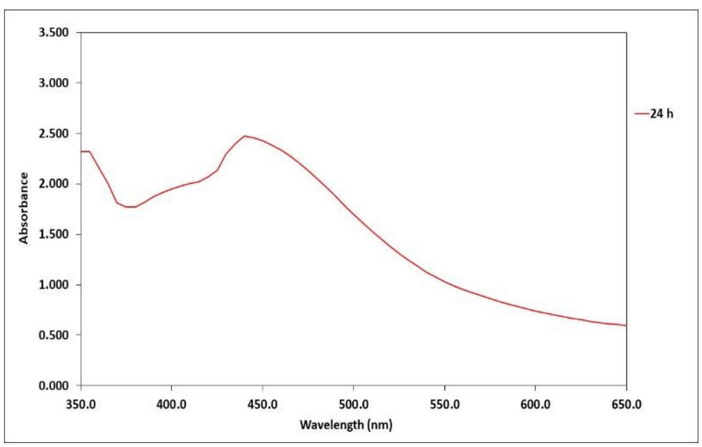

Fig.3. UV spectra analysis of AgNPs synthesized using *Coleus aromaticus*

B. UV spectra analysis of silver nanoparticles using *Coleus aromaticus*

The preparation was shown in Fig 1 & 2. The UV-Vis absorption spectra of the generated silver nanoparticles revealed a distinct surface plasmon resonance (SPR) peak at 440 nm was shown on Fig 3. The synthesis is visually confirmed when the hue of the silver nanoparticle solution changes from brown to dark brown.

C. XRD:

XRD analysis was used to investigate the crystalline nature and structural characteristics of the silver nanoparticles mediated by *Coleus aromaticus*. The AgNO3 nanoparticles made from *Coleus aromaticus* leaf extract are displayed in their XRD pattern. Planes 220, 311, and 240 correspond to the measured intensity maxima at 28.5, 31.8, and 38.6

degrees, respectively as shown in Fig 4. The *Coleus aromaticus* mediated silver nanoparticle values are by the standard database.

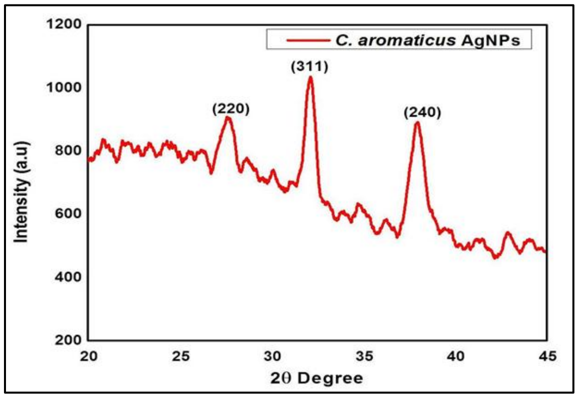

Fig.4. XRD spectrum of green-synthesized AgNO3 nanoparticles from *Coleus aromaticus*

D. FTIR Analysis:

It was applied to examine the existence of multifunctional groups in green synthesized *Coleus aromaticus-mediated* silver nanoparticles and *Coleus aromaticus* extract. The infrared spectrum peaks that were recorded were 3000.48, 2888.89, 2825.30, 1622.33, 1417.58, 1132.81, 901.99, and 583.04 was shown in Fig 5.

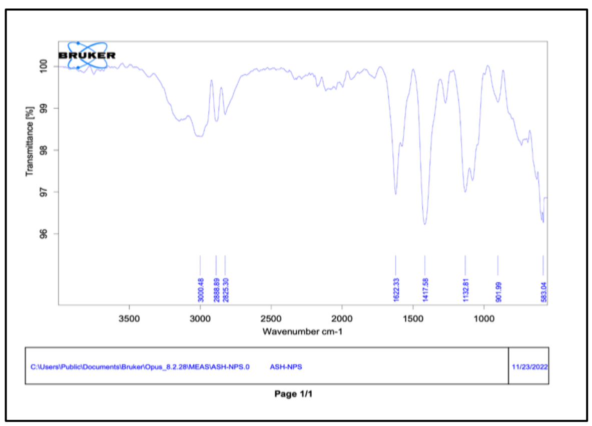

Fig.5. FTIR Spectrum of green-synthesized AgNO3 nanoparticles from *Coleus aromaticus*

E. SEM:

SEM was used to analyse the surface morphology of *Coleus aromaticus-mediated* silver nanoparticles, and the findings are presented. The *Coleus aromaticus* leaf extract's secondary metabolites and chemical constituents affect particle aggregation because bioactive molecules enclose and stabilize each particle. The SEM picture makes it evident that the constituent portions had an average size of 28.5 nm, and were agglomerated, spherical, and non-uniform as represented in Fig 6.

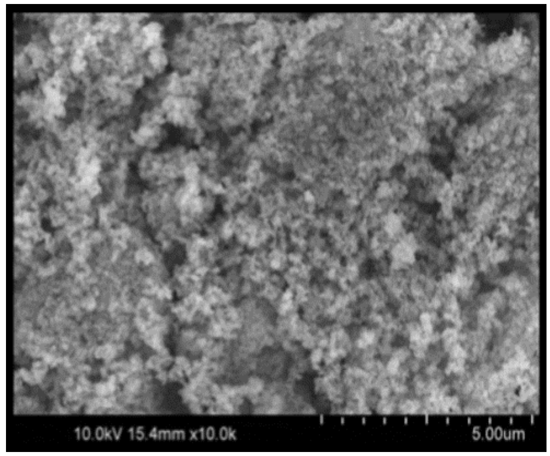

Fig.6. SEM analysis of green-synthesized AgNO3 nanoparticles from *Coleus aromaticus*

VI. DISCUSSION

Numerous studies have shown the effective green synthesis of AgNPs using an extract from *Coleus aromaticus*. *Coleus aromaticus* leaf extract was used to create AgNPs, and the nanoparticles were examined using TEM, UV-vis, X-ray diffraction (XRD), and Fourier-transform infrared spectroscopy (FTIR) [22]. The findings demonstrated the production of spherical AgNPs with an average size range of 10–30 nm. Additionally, the synthesised AgNPs' strong antibacterial activity effectively inhibited both gram-positive and gram-negative microorganisms [23]. [24] reported the green synthesis of AgNPs and evaluated their cytotoxicity against cancer cell lines using leaf extract from *Coleus aromaticus*. The produced AgNPs had strong cytotoxic effects, indicating a possible application in cancer therapy [25]. Research with UV–visible spectroscopy was done to look into how nanoparticles were made. The formation of a dark brown hue, which is corroborated by surface plasmon resonance and the oscillation of free electrons inside the silver nanoparticles, is indicative of the synthesis of silver nanoparticles. Silver nanoparticles' UV–visible spectra were captured across a range of periods, from 0 to 24 hours.

The findings showed that spherical AgNPs with an average size range of 10–30 nm was formed. Additionally, both gram-positive and gram-negative bacteria were effectively suppressed by the synthesised AgNPs' strong antibacterial activity. An examination was conducted for five minutes at a rate of 200 nm per minute with a resolution of 1 nm in the 200–1000 nm range utilising a systolic UV–visible absorption spectrophotometer type 117. A 0.5 ml sample of the solution was taken and analysed in equal amounts at room temperature. [26]. The material composition and crystalline phase of the decreased SNPs were determined by means of X-ray diffractometer measurements. Under Cu K (α) radiation, the device ran at a voltage of 20 kV and a current of 30 mA. Upon extracting the lids, the samples were positioned beneath the analytical instrument. The SNPs were compressed onto an almost transparent disc and evenly distributed across the dry KBr matrix to create the sample. KBr was the standard used for the sample analysis [27]. Using a Multi Skan Go spectrophotometer with a resolution The synthesised AgNPs were confirmed using a Multi Skan Go spectrophotometer, which has a resolution of one nm and a wavelength range of 300 to 800 nm. The UV reveals the UV-visible absorbance spectra of the Hc-AgNPs, with a λmax of 429 nm. Using an aqueous extract of the plant Houttuynia cordata, AgNO3 was reduced to Ag0. Spectral examination of the extract revealed a colour shift from transparent yellow to reddish brown, confirming the decrease. Hc-AgNPs were examined using scanning electron microscopy (SEM), and the findings revealed that the particles ranged in size from 15 nm to 100 nm and were polydisperse, spherical, and densely packed. The FTIR spectra revealed potential interactions between capping agents and silver nanoparticles. Analysing the FTIR spectraof extracts from *H. cordata* [28].

V. CONCLUSION

In conclusion, the phytochemicals in the plant extract serve as reducing and stabilizing agents in the environmentally friendly and sustainable process of producing silver nanoparticles from *Coleus aromaticus* extract. This results in well-defined and stable AgNPs. Several analytical approaches are used to characterize AgNPs, confirming their successful production and their applications. Further research in this area might lead to the development of novel, eco-friendly nanomaterials with a variety of uses.

CONFLICT OF INTEREST:

The authors did not have any conflict of interest.

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