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# GREEN SYNTHESIS OF SILVER NANOPARTICLES FROM PLANT EXTRACTS: CHARACTERIZATION AND ANTICANCER APPLICATIONS

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**ABSTRACT**

Multiple methods exist for synthesizing silver nanoparticles. The process of producing nanoparticles using components derived from plants is referred to as "green synthesis." Due to its cost-effectiveness, ecological sustainability, and capacity for extensive manufacturing, this technology is experiencing a surge in popularity. In the present study, plant extract is used for the physiological synthesis of silver nanoparticles. The booming manufacturing of silver nanoparticles is evidenced by the dark brown color shift, which can be attributed to surface plasmon resonance. The silver nanoparticles were characterized using SEM and UV-vis spectroscopy. The investigation focused on examining the antimetastatic properties of silver nanoparticles on osteosarcoma cancer cell lines after the production and characterization of the particles. The application of silver nanoparticles to osteosarcoma cancer cell lines has been observed to induce anticancer activity and demonstrate notable efficacy in combating bacterial infections.



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## 1. INTRODUCTION

Nanoparticles serve as the fundamental constituents for numerous applications within the field of nanotechnology. The significance of nanotechnology and nanostructured materials is increasing in everyday life, scientific investigation, and advancement. Nanotechnology is primarily concerned with materials that possess nanoscale scale dimensions, sometimes called nanostructured materials. The advent of nanotechnology has recently engendered substantial advancements in research and technology. Nanotechnology refers to the scientific investigation of minuscule entities and their use across diverse fields such as chemistry, biology, physics, material science, and engineering. Nanoparticles, which are core particles, can operate as a unified entity for transportation and property. The term "nano" denotes a unit of measurement equivalent to one billionth or 10-9. Usually, its size varies between 1 and 100 nm [1]. Nanoparticles exhibit a remarkable degree of atypicality due to their elevated surface-to-volume ratio relative to bigger particles and their unique physical, chemical, and biological attributes. The broad scope of nanotechnology encompasses both theoretical advancements and empirical investigations.

The glass panes have been prepared using minuscule metal particles, specifically silver, which impart a shiny golden color. AgNps were synthesized by reducing silver nitrate using the fungus TrichodermaViride. Exposure of AquousAg(+) ions to T. Viride filtrate reduces their solution. Produced highly stable silver nanoparticles. The silver nanoparticles' apoptotic capabilities were confirmed using caspase-3 activation and DNA fragmentation tests at a

concentration of 100 g/mL [2]. Silver AgNPs were synthesized by reducing silver nitrate using aqueous fresh aerial parts of Alternanthera sessile. Silver nanoparticles (AgNPs) with a size range of 10-30 nm and a spherical shape. The UV range SPR band is located at a wavelength of 420 nm [3]. The rate of apoptosis in MCF-7 cell lines is observed to increase as the concentration of silver nanoparticles increases, which can be attributed to the cytotoxic effects of silver AgNPs in vitro. Nanoparticles were synthesized using the plant Indigofera Longeracemosa. The cytotoxicity of the nanoparticles was evaluated against the SK-MEL-28 cell line at different doses using the MTT assay. An absorption peak was seen in the UV-visible spectrum at 436 nm. Based on SEM measurements, the AgNPs exhibited predominantly spherical shapes and varied sizes between 30 nm and 110 nm. Compressed and fragmented DNA is a defining feature of apoptotic cells. The upregulation of the tumor suppressor gene p53 was seen, while the downregulation of the anti-apoptotic gene Bcl-2 was significantly observed [4].

Neem compounds were employed for the synthesis of AgNPs. Using Neem compounds as a synthesis and capping agent in vitro testing on stomach cancer cells has shown a highly notable anticancer effect [5]. The metal precursor employed in this study was aqueous silver nitrate. In contrast, the stem bark of Artocarpus elasticus served as both a stabilizer and a reductant in synthesizing silver nanoparticles. The nanoparticles increased in size with increased reaction time at ambient temperature [6]. The tropical shrub species Jatropha curcas was utilized to produce nanoparticles. The study showed that silver nanoparticles (AgNPs) derived from Jatropha species successfully inhibited the A549 lung cancer cell line's proliferation in a manner dependent on the dosage [7]. Silver nanoparticles with a size range of 1 to 20 nm were synthesized through the bioreduction of silver ions using Aspergillus niger. The silver nanoparticles that are created have the potential to efficiently inhibit a wide range of hazardous organisms, such as bacteria and fungi [8].

The production of silver nanoparticles involved the utilization of a Saliva officinalis extract, which was confirmed by a noticeable change in color from yellow to brown and subsequently detected using UV-visible spectroscopy. The decreased hemoglobin concentration in the treated samples indicated that the therapy had a suppressive impact on angiogenesis [9]. Silver nanoparticles within the 425–435 nm size were synthesized by employing plant extracts derived from Nelumba Lucifera, A. Indica, and Boswellia Ovalifoliolata. The antibacterial activity was investigated by examining the clearance zone of several pathogenic gram-positive and gram-negative bacteria [10]. The manufacture of silver nanoparticles involved the utilization of pineapple (Ananas comosus juice). The nanoparticles exhibited a peak in the optical absorption band at a wavelength of 430 nm [11]. Silver nanoparticles (AgNps) have garnered significant attention recently due to their exceptional ability to protect against various infections and the development of drug resistance to commonly used antibiotics [12]. Silver nanoparticles (AgNPs) possess unique qualities that make them highly valuable in several fields, such as biomedicine, pharmaceutical delivery, water treatment, and agriculture. AgNps are utilized in inks, adhesives, electrical devices, pastes, and other materials due to their exceptional conductivity [13]. AgNps have been synthesized using various physio-chemical techniques, including chemical reduction, gamma radiation, microemulsion, electrochemical approach [14], laser ablation, autoclave, microwave, and photochemical reduction. These approaches provide favorable outcomes; however, they are accompanied by several limitations, including using hazardous chemicals, elevated operational expenses, and energy demands. In response to the limitations of standard physio-chemical methods, there is growing interest in a novel, energy- and cost-effective strategy for synthesizing silver nanoparticles (AgNP). This approach involves the utilization of microorganisms, plant extracts, and natural polymers as reducing and capping agents. Integrating green chemistry and nanotechnology can enhance the diversity of metallic nanoparticles that exhibit compatibility with biological and cytological applications. There has been a scarcity of published reviews on the green synthesis of AgNPs in the past decade [15].

The evaluations primarily focused on a wide range of plant and microbial sources for synthesis, different methods for analysis based on characterization, particular tabular data indicating source, shape, and size, and information on various uses. In contrast to previous literature reviews, the present study provides a comprehensive account of the synthesis process, parameters, characterizations, applications, and anticipated antibacterial mechanism [16]. Notably, the study emphasizes several environmentally sustainable techniques for producing AgNPs. The green generation of silver nanoparticles (AgNPs) requires two primary components:

a solution containing silver metal ions and a reducing biological agent [17]. In most cases, reducing agents or other cellular constituents function as stabilizing and capping agents, thereby preventing the necessity of incorporating external capping and stabilizing agents. The primary constituent required to synthesize AgNPs is the Ag+ ion, which can be present in various water-soluble silver salts. However, most research has employed aqueous solutions of AgNO3 with concentrations of Ag+ ions ranging from 0.1 to 10 mm, with a standard concentration of 1 mm.

There exists a broad range of reducing agents inside biological systems. The synthesis of AgNPs has been influenced by four out of the five kingdoms of living organisms, namely Monera (prokaryotic organisms lacking a genuine nucleus), Protista (unicellular organisms possessing a true nucleus), Fungi (eukaryotic as saprophytes or parasites), Plantae (eukaryotic as autotrophs), and Animalia (eukaryotic as heterotrophs). Based on the available information, more data on the utilization of animal products in the synthesis of AgNP [18]. This limitation has sparked debates over the environmentally friendly production of AgNPs using microorganisms, plants, and bio-polymers. Silver nanoparticles (AgNPs) have been synthesized using biopolymers, microbial cell biomass, or cell-free growth conditions in conjunction with plant extracts. The plants used to produce AgNps range from algae to angiosperms. However, there is limited data available on lower plants, making angiosperms the most suitable choice. The production of AgNP has been derived from several plant components, including leaves, bark, roots, and stems. Examples of plants having great medicinal benefits include Boerhaavia diffusa [19], Tinospora cordifolia, Aloe vera, Terminalia chebula, Catharanthus roseus, Ocimum tenuiflorum, Azadirachta indica, Emblica officinalis, Cocos nucifera, as well as common spices Piper nigrum and Cinnamon zeylanicum. The utilization of exotic weeds, such as Parthenium hysterophorus, in the synthesis of AgNP, has been observed. This particular plant species exhibits uncontrolled growth patterns resulting from a shortage of natural predators, hence presenting potential health hazards. The second category comprises botanical specimens synthesizing alkaloids (Papaver somniferum) and essential oils (Mentha piperita). Except for a limited number of cases in which external chemical agents such as sodium-do-decyl sulfate were employed to enhance the stability of the AgNPs, all plant extracts demonstrated potential as agents for decreasing and stabilizing the AgNPs. The presence of metabolites, proteins [20], and chlorophyll in the plant extracts has been found to serve as capping agents for the AgNPs that are generated. Water is commonly preferred as a solvent for removing reducing agents from plants. Nevertheless, organic solvents such as methanol, ethanol, and ethyl acetate have been employed

in a limited number of cases.

Before extraction, several researchers subjected the plant components to pretreatment in either acetone or saline environments. In general, nanoparticle suspensions have predominantly been prepared using aqueous medium despite the utilization of diverse extraction solvents. Nanoparticles synthesized using plant extracts exhibit distinct shapes, structures, and morphology, unlike those made using bark, tissue, or the complete plant. The synthesis of AgNPs by microorganisms is more labor-intensive than using plant extracts and biopolymers as reducing and capping agents. This is primarily due to the challenges associated with growth, culture maintenance, and standardization of inoculum size. The successful synthesis has been achieved using various bacterial and fungal species [21]. AgNPs were primarily produced through two distinct pathways: one utilizing extracellular components released in the growing medium and the other directly utilizing microbial cell biomass. The bacteria produce silver nanoparticles (AgNP) both within their cells and outside of them. Several researchers (17) have documented the intracellular synthesis of silver nanoparticles (AgNPs). Researchers frequently use centrifugation to produce silver nanoparticles as pellets or powders. To generate the product in a powdered state, the suspensions of AgNPs were also subjected to oven drying [22].

Various techniques are commonly employed to characterize AgNPs, including UV-Vis Spectra, SEM, TEM, FTIR, XRD, and EDAX or EDX/EDS. DLS is the primary method used to study AgNPs derived from bio-polymers, as opposed to plant extracts and microorganisms. Zeta potential values indicate the stability of synthesized AgNPs. Thermo-Gravimetric Analysis (TGA) is employed to ascertain the amount of organic material in synthesized AgNPs and predict their thermal stability. TGA is utilized to investigate the impact of AgNO3 and L-cystine on the organic composition of AgNPs. The concentration and conversion of AgNPs were determined using Inductive Coupled Plasma (ICP) analysis [23]. Most studies have assumed that the

emergence of a yellow to slightly brownish-yellow color in the colorless solution is a reliable indicator of the creation of silver nanoparticles (AgNPs). The SPR peak of the generated AgNPs exhibited a significant presence in the wavelength range of 400 to 450 nm, which is crucial for detecting AgNPs [25]. Research has been conducted on the production of AgNPs, examining their relationship with pH, metal ion concentration, extract content, and UV-Vis spectral analysis. These studies have revealed the size stability of the synthesized AgNPs by observing a red shift in the SPR peak as the nanoparticle size increases and a blue shift as the size decreases.

The sources of electrons for the nano-transformation of AgNPs are believed to be the dehydrogenation of acids (ascorbic acid) and alcohols (catechol) in hydrophytes, keto to enol conversions (cyperaquinone, dietchequinone, remirin) in mesophytes, or both mechanisms in xerophytes plants [26, 27]. Microorganisms ' extracellular and cellular oxidoreductase enzymes can perform comparable reduction processes [28]. Murraya koenigii leaf extract was employed in the biological production of silver nanoparticles, focusing on elucidating the impact of broth composition on both the reduction process and particle size. Silver nanoparticle formation was seen within 15 minutes using UV-visible spectrophotometry after the rapid reduction of silver (Ag+) ions [29]. The synthesized silver nanoparticles were examined using atomic force microscopy (AFM) and transmission electron microscopy (TEM). The results indicated that the nanoparticles exhibited a spherical morphology and spanned a size range of 10 to 25 nm. Furthermore, the XRD analysis provides evidence of silver's nanocrystalline phase characterized by an FCC crystal structure. The study's findings indicate that the reduction rate increases with higher broth content and reduces with smaller particle size [30].

## 2. MATERIALS AND METHODS

The primary components required to synthesize AgNps are a reducing biological agent and a solution containing silver metal ions. Cells contain several components, including plant extracts, which function as capping and stabilizing agents. Various silver salts soluble in water can be employed to acquire Ag+ ions, an essential constituent for the synthesis of AgNps. The silver nitrate solution was prepared using two beakers that were appropriately labeled. One experimental procedure involved the addition of 10 ml of sodium citrate as a reducing agent to facilitate the conversion of Ag+ ions into Ag0. The solution was incubated on a magnetic stirrer for one hour. Upon the emergence of silver nanoparticles, the hue transitioned to yellow. A volume of 20 milliliters of Tridax procumbens plant extract was introduced into a separate beaker, followed by continuous agitation and incubation for one hour. The manifestation of silver nanoparticles was seen through the alteration of color to yellow. Utilize plant extracts derived from Tridax procumbens as a reducing agent. The substance functions as both a capping agent and a stabilizing agent.

## 3. RESULTS

Silver nanoparticle characterization research evaluates the dimensions, morphology, and quantity of the particles. Various techniques, such as scanning electron microscopy (SEM), Fourier transmission infrared spectroscopy (FTIR), X-ray diffraction (XRD), and dynamic light scattering (DLS), can be employed to achieve this.

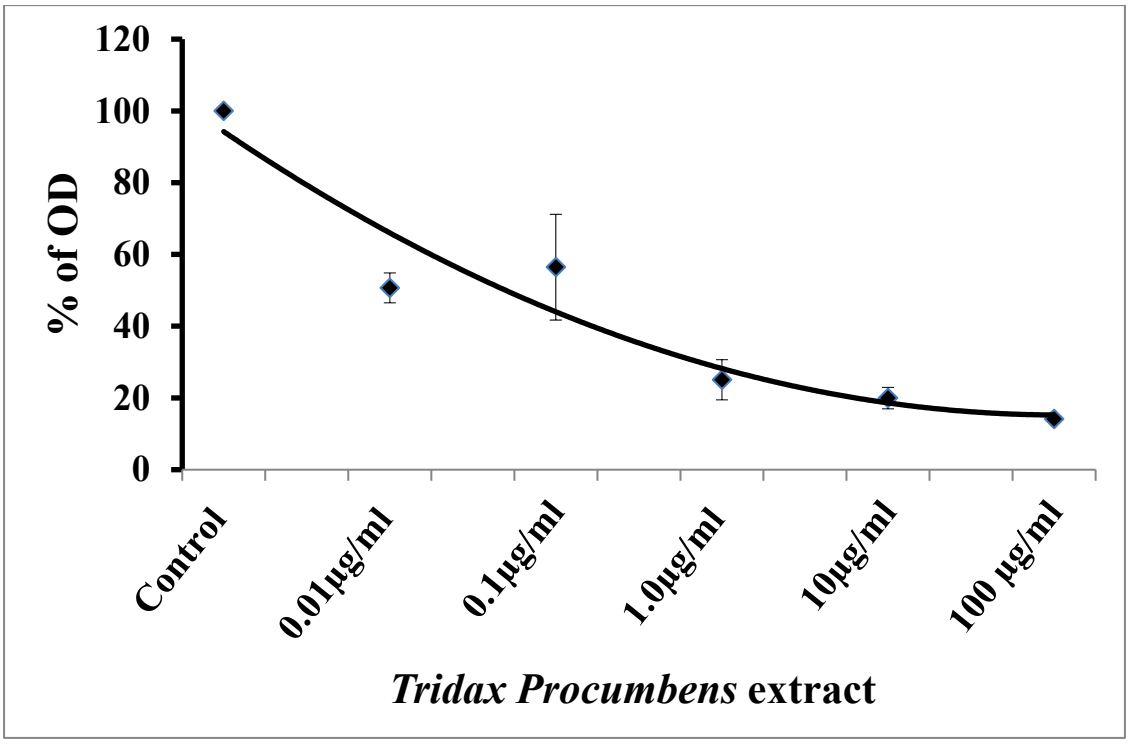


Figure 1. Effect of Tridax procumbens on Osteosarcoma Cell Viability

## 4. CONCLUSION

The utilization of Tridax procumbens extracts has proven to be effective in synthesizing silver nanoparticles, exhibiting cost-effectiveness and environmental advantages. Both scanning electron microscopy (SEM) and ultraviolet-visible (UV-Vis) spectroscopy have confirmed the conversion of silver nitrate into silver nanoparticles. The Ag NPs exhibit significant antimetastatic effects on cancer cell lines. There is currently a considerable amount of research on the possible use of nanoparticles in the field of medicine, driven by the increasing interest in their potential for cancer treatment.

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Nil

## COMPETING INTEREST

The authors declare no conflict of interest.

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