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Synthesis of Silver Nanoparticles using Green Method and Biochar

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ABSTRACT

Nanotechnology is the manipulation and observation of a matter at atomic or molecular scale. Materials with at least one dimension between 1 and 100 nanometers are referred to as Nano-particles. Nanoparticles, including metal, oxide, polymeric, carbon-based, quantum dots, and lipid-based types, are utilized in various applications like catalysis, medical imaging, drug delivery, electronics, and environmental remediation. Metallic nanoparticles are flexible nanostructures with advanced features like optical properties, large surface energies, plasmon excitation, and quantum confinement, opening new pathways in nanotechnology, including strong plasma absorption, enhanced Rayleigh scattering, and biological system imaging. The metallic nanoparticles include silver, copper, gold, zinc, platinum, and palladium nanoparticles, while the nonmetallic nanoparticles are titanium dioxide, zinc oxide, and cadmium oxide. For a long time, traditional methods have been used, but research has shown that green methods are better for creating nanoparticles.

In this review paper, we have focused on silver nanoparticles (AgNPs) considered to be one of the most potent antimicrobial agents. According to some recent article, we have concentrated on silver Nano-particles (AgNPs), which are regarded as highly effective antimicrobial agents. Recent research indicates that, over the last ten years, AgNPs have demonstrated significant antibacterial and antifungal properties. They have fewer failures, are cheaper, and easier to analyze. Green method is also cost-effective, making it an attractive alternative to traditional methods of nanoparticle synthesis. Green synthesis is a way of creating tiny materials called nanomaterial's using a process that's gentle on the environment. Plant-based synthesis of nanoparticles (NPs) has gained attention due to its ease of production, particularly for silver and gold NPs, which are more secure than other metallic NPs, despite the environmental concerns associated with toxic metabolites.

Keywords: Nano-Technology, biochar, Orange peel extract, corn cobs, bagasse, citrus sinensis, and Mangrove Sonneratia caseolaris

Introduction

Nanotechnology is the manipulation and observation of a matter at atomic or molecular scale. The term nanotechnology was introduced in 1971 by Professor Norio Taniguchi of the University of Tokyo [1] while Richard Feynman delivered the first properties on which an idea for industrial use could be based to, and Drexler explained these ideas as early as 1986. Materials with at least one dimension between 1 and 100 nanometers are referred to as NPs. Nanoparticles, including metal, oxide, polymeric, carbon-based, quantum dots, and lipid-based types, are utilized in various applications like catalysis, medical imaging, drug delivery, electronics, and environmental remediation [2]. With a high electrical and thermal conductivity, silver is a delicate, white, and glossy transition metal. Because of its many health benefits, silver has become extremely popular in research facilities and the medical industry [3]. Since ancient times, it has been utilized in a variety of products, including coins, cutlery, foams, solutions, stitches, ointments, and lotions. Many different types of medications contain silver as a medicinal ingredient [4]. Due to their unique physical, chemical, and biological characteristics, silver nanoparticles have garnered significant attention from the research community in recent years. Which are in charge of the bactericidal and catalytic actions. Silver and its compounds have been used for food preservation, wound infection prevention, and antimicrobial medicines since ancient times. They have been used to cure burns, stitch wounds, and remove skin warts [5].

One of the key inquiries pertains to our interest in silver nanoparticles (AgNPs) and the exploration of their characteristics. Metal nanoparticles (MNPs) are synthesized from the salts of variety of metals, such as copper, iron, gold, silver, platinum and palladium among others. AgNPs are superior to other metallic nanoparticles in a number of ways. Some have a high concentration of Ag_2O, even though many are classified as "AgNPs" due to the enormous ratio of surface to bulk Ag atoms. AgNPs have been incorporated into numerous electronic and medical equipment, surgical instruments, bone cements, surgical masks, and other applications throughout the past ten years. In addition, wounds are treated with a specific quantity of ionic silver. AgNPs are therefore utilized to treat burns and wounds. AgNPs are used in molecular labeling because of their large scattering cross-sections and surface plasmon resonance. As a result, a lot of AgNPs are currently acknowledged for their numerous uses [6].

For a long time, traditional methods have been used, but research has shown that green methods are better for creating nanoparticles. They have fewer failures, are cheaper, and easier to analyze. Green method is also cost-effective, making it an attractive alternative to traditional methods of nanoparticle synthesis [7].Green synthesis is a way of creating tiny materials called nanomaterial's using a process that's gentle on the environment. Instead of relying on harsh chemicals, this method uses living things like bacteria, yeast, fungi, algae, and certain plants as natural factories to produce these tiny materials.

This approach is not only better for the planet, but it's also safer and more cost-effective [10]. Plant-based synthesis of nanoparticles (NPs) has gained attention due to its ease of production, particularly for silver and gold NPs, which are more secure than other metallic NPs, despite the environmental concerns associated with toxic metabolites.

Silver nanoparticles, are a significant advancement in nanotechnology. Silver nanoparticles are ideal for a wide range of applications due to their distinct physicochemical and potent antibacterial qualities [8], Thus, rising demand has caused a surge in the manufacturing of silver nanoparticles. In 2009, the total expected output of silver nanoparticles Worldwide was estimated to be 500 tonnes annually, with an approximate rise of 900 tonnes predicted by 2025 [9].

The word "biochar" describes an organic carbon (C) compound that is mostly stable and recalcitrant. It is produced through pyrolysis, an energy conversion process that involves heating biomass (feedstock) to temperatures while maintaining a low (ideally near-absent) oxygen concentration. Scientists have been able to assess and encourage the use of biochar in agricultural soils by comprehending the origin, distribution, and qualities of naturally occurring biochar, also known as "Terra Preta de Indio" or Brazilian Dark Earth in the Brazilian Amazon region. One potential solution for managing agricultural wastes could be to use the pyrolysis process to turn them into biochar, a material rich in carbon. The chemical makeup of the feedstock dictates the chemical composition of biochar. Biochar refers to the carbon rich material generated from biomass through pyrolysis, a process that occurs in an oxygen- restricted environment. This charred substance is subsequently utilized as a soil amendment [10].

In this review articles, we examine silver nanoparticles (AgNPs), which are recognized as highly effective antimicrobial agents. Recent research conducted over the last ten years has demonstrated the efficacy of AgNPs in exhibiting both antibacterial and antifungal properties.

They have fewer failures, are cheaper, and easier to analyze. Green method is also cost-effective, making it an attractive alternative to traditional methods of nanoparticle synthesis. Green synthesis is a way of creating tiny materials called nanomaterial's using a process that's gentle on the environment. Plant-based synthesis of nanoparticles (NPs) has gained attention due to its ease of production, particularly for silver and gold NPs, which are more secure than other metallic NPs, despite the environmental concerns associated with toxic metabolites.

Literature Review

Plant based synthesis Nano-particles has gained attention due to its ease of production, particularly for silver and gold Nano-particles which are more secure than other metallic Nano-particles despite the environmental concerns associated with toxic metabolites [11].

The synthesis of nanoparticles (NPs) using plant extracts typically follows two main steps: preparation of the extract, which then serves as a reducing and stabilizing agent. Various phenolic compounds from citrus peels have been obtained using common extraction techniques, such as solvent-based extraction, hot water extraction, alkaline extraction, resin-based extraction, and methods involving electron beam or gamma irradiation. To improve yield, researchers have explored alternative extraction methods, including fluidized-bed extraction, superheated liquid extraction, and ultrasound-assisted extraction from biomaterials. Electrochemical redox processes, photolysis reactions, UV irradiation, and charged particle flows from gaseous to liquid phases all contribute to chemical transformations at the phase boundary, which may enhance both the concentration and efficiency of the final extracts, potentially improving the effectiveness of subsequent silver nanoparticle (AgNP) synthesis.

The primary goal is to determine the optimal synthesis conditions for green-synthesized silver nanoparticles using plasma-chemical extraction to prepare an extract from orange peels [13], and to examine the decolorization of the representative cationic phenothiazine dye when Nano-catalysts are present. Dopamine and gallocatechin are two examples of the antioxidant chemicals found in the fruit's peel [14]. Around 1114.75 million tons of corn will be produced globally in 2019–2020, and tons of wasted grain will typically be present as well. However, this agrochemical industrial waste could be a valuable resource for producing xylan, which can be simply and extensively extracted using a range of techniques [15]. In an earlier work, we used an eco-friendly extraction technique to extract a significant amount of xylan from maize cobs and demonstrated that this polysaccharide has distinct pharmacological characteristics [16]. It hasn't been determined whether this polysaccharide can function as a bioreactor in the production of silver nanoparticles, though. The aim of this study was to synthesis silver nanoparticles that include nano-oxylan, a xylan derived from corn cobs, and assess their biological activity in comparison to Standard Xylan products [17].

Different Researcher work on the synthesis of Silver Nano-particles using different techniques and different materials:

Working Title	**Review compilation topic**	**Year Review Published**	**References**
Sustainable production of silver Nanoparticles Utilizing Orange Peel Extract.	This review compiles evidence on silver nanoparticles using orange peel the environmentally benign as well as economically viable synthesis of silver	2019	[18]

Authors: Skiba, M.I. and V.I. Vorobyova	nanoparticles (AgNPs) by plant extracts has attracted a lot of attention. Orange peel extract, which is abundant in natural reducing agents, is used in one such approach. This review focuses on the production of AgNPs using plasma-chemically extracted orange peel extract and their usage in the solar- irradiation-induced breakdown of methylene blue (MB).		
Biosynthesis of silver nanoparticles utilizing Banana peel extract **Authors:** Phoemthaisong, T., *et. al*	This review brings together recent studies on the production of silver nanoparticles utilizing discarded banana peel extract. Microwave-assisted biosynthesis is a viable method for the quick and easy synthesis of AgNPs, using plant extracts as both reducing and stabilizing agents. Banana peel extract is used in this work as a reducing and capping agent during the microwave irradiation process to produce AgNPs in order to explore the formation of AgNPs.	2013	[19]
Biosynthesis of silver nanoparticles Utilizing citrus sinensis peel extract **Authors:** Kaviya, S., *et al.*	The creation of silver nanoparticles using citrus sinensis peel extract has been the subject of recent research, assembled in this review. Ag-NPs made from orange peels shown strong antibacterial action against both microorganisms. Better results, nevertheless, were shown when it came to the Staphylococcus aureus bacteria. The application of orange sinensis peel extracted in the manufacture of Ag-NPs and its Anti-bacterial properties were validated by the results.	2020	[20]
Biosynthesis and characterization of silver nanoparticles using Mangrove Sonneratia caseolaris leaves **Authors:** Nursyam, H., *et .al*	This study aimed to assess the potential of *Sonneratia caseolaris* mangrove leaf extract for synthesizing silver nanoparticles (AgNPs). Additional characterization and analysis of antibacterial activity were conducted. The findings revealed that *Sonneratia caseolaris* leaf extract successfully enabled biosynthesis. Nano-particles from AgNO3.	2023	[21]
Biosynthesis of silver nanoparticles utilizing tea leaf extract **Authors:** Khac, K.T., *et .al*	To determine how a Camellia sinensis AgNPs affect the degradation efficiency of MB dye, experiments were designed with and without C. AgNPs. C. AgNPs were investigated concurrently for their antimicrobial activity against S.A. and P.A. strains, with water serving as the opposite control and Ampicillin antibiotic acting as the positive control.	2023	[22]
Sugarcane bagasse-based biochar **Authors:** Zafeer, M.K., *et .al*	This extensive analysis of the literature explores the different pyrolysis techniques that can be used to turn the bagasse from sugar cane into char materials, demonstrating the material's potential to a wide range of uses that align with current scientific interests.	2023	[23]
Production of biochar from rice straw **Authors:** Foong, S.Y., *et .al.*	With an emphasis on the removal of many types of contaminants in wastewater cleanup, this paper provides a thorough examination of rice straw-derived biochar (RSB). In lab-scale trials, the application of RSB in wastewater cleanup has demonstrated encouraging viability.	2022	[24]
Preparation of nanoparticles from corn cobs	The current study's goal is to investigate potential medicinal uses by assessing the synthesis of	2014	[25]

Authors: Samit Kumar, S.K. *et.al*	nanoparticles in a restricted size distribution (~< 30nm size) using maize cobs.		

Result and Discussion

Orange peel extract combined with silver nitrate solution was used to create AgNPs. In ten minutes, the yellow extract turned dark brown. When the reaction was observed using UV-Vis spectroscopy, the absorbance gradually increased throughout the first one to ten minutes, indicating that the AgNP content increased as the treatment time increased. The concentration of silver nitrate causes the surface plasmon resonance (SPR) peak to intensify, indicating the creation of more nanoparticles. However, there is a modest increase in the SPR peak intensity, which could be the result of the silver nitrate running out. In a reducing agent, the pH of the reaction medium affects AgNP production. As pH rises, the absorbance value rises as well, indicating a higher production rate in basic PH. AgNPs are quickly formed in neutral pH, maybe as a result of the extract's phenolic group ionizing [26]. The slow production and aggregation rate at acidic pH could be caused by anions' electrostatic repulsion.

This study focused on analyzing the features of silver nanoparticles in a dispersed system, such as their typical size, shape, polydispersity, and stability. The average hydrodynamic diameter of OrPWE-AgNPs was measured to be between 47-63 nm, and their polydispersity index (PDI) was determined to be within 0.26-0.78 using dynamic light scattering (DLS) analysis. The dispersion's zeta potential was measured at -21.7 ± 0.4 mV, indicating stability for 1-2 months. The surface morphology of the synthesized nanoparticles was examined using scanning electron microscopy (SEM), and the crystalline structure of AgNPs was confirmed through X-ray diffraction. The XRD spectrum displayed four distinct, intense diffraction peaks, which matched the face-centered cubic (fcc) structure of metallic silver. Energy-dispersive X-ray spectroscopy (EDX) was used to verify the presence of silver nanoparticles, which produced a strong signal at 3 keV. This study emphasizes the potential of using reducing agents in the composition of biomaterials for the "green" synthesis of nanoparticles, which can aid in managing oxidative stress.

A surface plasmon resonance band at 420 nm can be seen in the AgNPs' UV-vis absorption spectrum. Shorter extraction and reaction times are needed when using microwave radiation to extract waste from banana peels and synthesize AgNPs. This method boosts the productivity of small nanoparticles and their rate of reactivity. As the concentration of AgNO3 rises, the UV-vis absorption spectra alter, reaching their highest peak intensity at 2 mM AgNO3. The production of smaller nanoparticles is indicated by the peak intensity of 1 mM AgNO3. The synthesis of AgNPs utilizing microwave radiation is the main topic of this study. The absorbance of the SPR band in AgNPs solutions was measured, and it was found that the concentration of AgNO3 was 1 mM. With longer irradiation times, the maximum absorbance rose, indicating a higher AgNP content. With a rise in BPE concentration, the absorbance peak strength rose, suggesting that more hydroxyl groups were encouraging Ag+ complexation. But when the BPE content rose, the peak intensity dropped, indicating a saturation limit. The ideal parameters for microwave extraction were an extraction time of 140 seconds at 800 W and a banana peel to water ratio of 50 g/L. The DLS technique was used to study the average size of AgNPs in solution. Results showed that microwave radiation produced AgNPs with a moderate polydispersity index (PDI) of 0.348, while conventional heating produced AgNPs with a PDI of 0.358. Both methods showed smaller agglomerates of AgNPs and smaller proportions in larger agglomerates, consistent with UV- vis analysis.

The work shows how orange-peel extract and silver nitrate can be used to produce silver nanoparticles, or Ag-NPs. When further nanoparticles grow, the hue changes from yellow to dark brown. Ag-NP synthesis is confirmed by UV-vis spectroscopy, which shows a surface Plasmon band between 400 and 480 nm. At 60°C, a 6% orange peel extract concentration produced the greatest effect; at ambient temperature, a 2% extract concentration produced the least amount of effect.

The investigation focused on the function of orange peel extract's functional groups in Ag-NP production. Peaks at 3374, 1625, 1410, 1058, and 872 were found by FT-IR analysis, indicating involvement in the creation of nanoparticles. The XRD examination verified the face-centered cubic crystal structure of Ag-NPs, whereas the SEM analysis showed them to be spherical. Ag-NP Crystalline structures were identified by the XRD pattern as the source of the peaks at 38.04◦, 44.08◦, 64.36◦, and 77.22◦, which indicate their presence in Nano-composites free of contamination peaks.

The antibacterial activity of Ag-NPs was investigated using the zone of inhibition in this work. While the silver nanoparticles had more action against S aureus, they clearly inhibited both Gram- positive and Gram-negative bacteria. This might be the result of the nanoparticles entering the cells and causing them to die.

Sonneratia caseolaris leaves extract, with a yellowish-white color, was used for the biosynthesis of silver nanoparticles. The results showed that the leaf extract failed to form AgNPs at concentrations of 1 mM, 5 mM, and 10 mM. The best silver nanoparticle biosynthesis occurred at a concentration of 5 mM with a reaction time of 10 minutes and a concentration of 5 mM AgNO3. The color change from yellow to brownish indicates silver nanoparticle formation, but too soon, silver nanoparticle aggregates into micro-particles may occur. The biosynthesis of silver nanoparticles in plants involves secondary metabolite compounds like flavonoids, phenols, and triterpenoids. The color of silver nanoparticles varies depending on their shape and size. UV-Vis tests showed that the presence of silver nanoparticles was detected at a peak wavelength of 450 nm with a concentration of 5 mM. FT-IR tests on silver nanoparticles from Sonneratia caseolaris revealed functional groups contributing to reducing Ag+ to Ag0. The FT-IR spectrum showed peak results in the 400-4000 cm-1 regions, with the functional groups corresponding to the formation of silver nanoparticles. The color of silver nanoparticles depends on their shape and size. In their investigation, Das et al. found functional groups like terpenoids that have the ability to change aldehyde groups inside metal ions into carboxylic acids. This property makes them possible reducing agents that silver nanoparticles (AgNPs) can produce. Scanning electron microscopy (SEM) was used to examine AgNPs in order to ascertain their morphological structure. The resulting AgNPs are shaped irregularly as a result of aggregation and range in size from 90 to 200 nm. Because smaller particles can more easily penetrate bacterial cells, their antibacterial activity increases with particle size.

This study explores the synthesis of C AgNPs using green tea leaf extract and the factors that affect yield. The tea leaf extract's absorption spectrum shows that higher extract concentrations lead to increased absorbance around 350 nm, while larger extract volumes in solution result in higher absorbance in the 700 nm to near-infrared range. The highest yield of C AgNPs was achieved with 0.1 ml of tea leaf extract at a 10 ppm concentration. Temperature also influences particle size and concentration, and an optimal synthesis time of approximately 80 minutes maximizes efficiency and minimizes by-products. Crystal structures of C AgNPs, observed under varying reaction temperatures and times, show diffraction peaks consistent with a face-centered cubic (fcc) structure.

NMR spectra of green tea samples from Thai Nguyen, Vietnam, revealed that the main chemical composition remained consistent across samples. About 30 compounds were identified in the 1H NMR spectrum, with over 50 distinct signals or signal groups. Focusing on AgNP synthesis from tea extract, particularly from tea in Bac Kan, minor variations in chemical composition were noted. The study also identified five common catechins and some uncommon compounds, including gallocatechin-3-gallate (GCG), gallocatechin (GC), catechin-3-gallate (CG), (−)-epigallo-catechin-3-(3″-O-methyl)-gallate, (−)-epigallo-catechin-3, 5-digallate, (−)-epicatechin-3, 5-digallate, and epiafzelechin. FTIR analysis was conducted to characterize and identify the biomolecules involved in C·AgNP synthesis.

Absorption spectra reveal that pigments undergo photo-degradation over time, with degradation efficiency increasing slowly in the presence of H_2O_2 or $NaBH_4$. Although the photo-degradation efficiency is moderate, the catalytic role of C AgNPs is evident. The antibacterial activity of C AgNPs was tested against two bacteria, PA and SA, showing that larger zones of inhibition correspond to greater antibacterial effectiveness. The antibacterial mechanism relies on the release and penetration of silver ions into cells, as well as the direct impact of AgNPs in disrupting cellular structure or inhibiting cytoplasmic processes

This study aimed to synthesize silver nanoparticles (AgNPs) and silver-embedded biochar composites (Ag-WBC) using *L. lucidum* plant leaf extract as a reducing agent. The process involved reacting varying concentrations of *L. lucidum* leaf extracts with silver nitrate. A color change in the reaction mixtures indicated the reduction of silver ions to form AgNPs and Ag-WBC. UV-visible spectroscopy confirmed the formation of AgNPs and Ag-WBC, with the surface plasmon resonance (SPR) value being higher in the composites than in AgNPs. The ratio of *L. lucidum* extract to silver nitrate significantly influenced the concentration of biomolecules, enhancing the reduction process and deepening the color of the mixture.

Scanning electron microscopy (SEM) was used to examine the surface morphology of WBC and Ag-WBC composites. The WBC appeared non-crystalline, with uniformly sized particles. The energy-dispersive X-ray (EDX) spectrum of WBC showed no silver peaks, while the synthesized Ag-WBC exhibited a spherical morphology with embedded Ag nanoparticles. The composite contained higher amounts of elemental carbon and oxygen along with ash elements such as Al, Si, Cl, and Ag. FTIR spectroscopy was conducted to analyze the surface chemistry of the samples. In the WBC spectrum, absorbance bands showed cellulosic O–H stretching characteristic of –OH groups, whereas the Ag-WBC composites displayed aliphatic C–H stretching vibrations.

Investigating the production of AgNPs in the presence of CCB was done using UV-vis spectra. One of the most important methods for examining the creation of metal nanoparticles is UV-vis spectroscopy. The creation of 400 nm-visible CCB-capped AgNPs and the inclusion of when cysteine was added to the NPs, particle aggregation occurred, changing the color of the solution from bright yellow to red. The plasmon band centers at 400 nm blue shift, producing a second peak at 530 nm. The spectral appearance of a second peak could be explained by the complex that is created as a result of the particles aggregating. The sole CCB aqueous extract solution lacks a noticeable peak.

Samples	**CCB/AgNO3**	**Temperature (°C)**	**Time(min)**
AgNPs-1	$\frac{30}{0.1}$	90	20
AgNPs-2	$\frac{30}{0.5}$	70	10
AgNPs-3	$\frac{30}{1.0}$	80	15
AgNPs-4	$\frac{30}{1.5}$	60	10
AgNPs-5	$\frac{30}{2.0}$	50	5

AgNPs were capped with CCB, acting as a stabilizing agent. Cystein bonded to AgNPs' surface via a stronger Ag-S bond, replacing CCB and immobilizing thiol groups. Cystein's NH2 and COOH formed hydrogen bonds, causing AgNPs to aggregate.

The study reveals that silver nanoparticles formed from a crystalline structure, with a narrow distribution of cysteine. The AgNPs composite was studied using energy-dispersive X-ray spectroscopy, with residual C and O elements from CCB preventing nanoparticle aggregation. This approach is crucial for pollution-free reuse and recycling of AgNPs.

The study optimized cysteine determination parameters, including pH, concentration of AgNPs, stirring rate, and reaction time. The most efficient method was achieved at 1.5 µM concentrations and a pH of 7.0, stirring at 400 rpm for 15 minutes. The absorbance increased with pH, with poor absorbance at pH < 5.0 due to proton competition and higher pH due to AgNPs instability.

The study investigated the aggregation of cysteine and AgNPs using a magnetic stirrer. The stirring rate ranged from 200-500 rpm for 5 minutes at pH 7.0. The reaction time, ranging from 5-20 minutes, significantly influenced the color intensity, indicating that AgNPs were etched within 15 minutes.

AgNPs were exposed to cysteine solutions, causing a color shift from yellow to deep red. The absorption spectra confirmed these results, with increased cysteine concentration causing a decrease in absorbance at 400 nm and an increase in absorption at 530 nm. The absorption ratio and cysteine concentration showed a positive relationship in the 10-1000 µM range.

The current colorimetric detection platform for cysteine, based on AgNPs, has good selectivity for the analyte. The structural diversity of the compounds and their ability to bind with AgNPs explain this selectivity. Under optimal conditions, amino acids without a thiol group cannot bond AgNPs, preventing interference with the cysteine determination process. Although NAc and GSH have a thiol moiety, they have limited ion complexing ability.

Samples	**Spikes**	**Calculated**	**Detection (%)**
1	200	204.2	102.1
2	100	105.3	105.3
3	80	83.5	104.25
4	0	51.7	103.4
5	10	9.5	95

Challenges:

Producing biochar nanoparticles on a large scale while maintaining consistent quality can be challenging and creating biochar nanoparticles (BNPs) involves advanced technologies that are often expensive.

Detailed characterization of BNPs is required to understand their properties and behavior, which is technically complex and resource-intensive. There is no universal standard for biochar properties, leading to variability in effectiveness.

The long-term environmental and health impacts of BNPs are not well understood, posing potential risks.

The behavior of nanoparticles in soil and plant systems, including their mobility and bioavailability, is still under research. Regulatory frameworks for the use of nanoparticles in agriculture are still developing, creating uncertainties for widespread adoption.

Understanding the complex interactions between BNPs, soil, and plants is essential but challenging. Modifying BNPs to enhance their performance for specific agricultural applications requires advanced techniques.

Conclusion

The significance of green nanotechnology is increasing because of its economical and eco-friendly production process. Research indicates that silver nanoparticles can be produced from Ag+ concentrations in a span of 5-10 minutes at a temperature of 75°C. These nanoparticles are spherical in shape and possess a face-centered cubic crystal structure. The photo catalytic activity of these nanoparticles was assessed against methylene blue dye, suggesting potential uses in water purification and treatment of dye effluents.

Researchers successfully harnessed banana peel waste to produce silver nanoparticles (AgNPs) using microwave irradiation. A comparison between microwave irradiation and traditional heating - showed that microwave radiation significantly reduced the time required for extracting banana peel waste and synthesizing AgNPs. The optimal conditions for this process were identified as a 50 g/L banana peel-to-water ratio with 140 seconds of microwave extraction at 800 W, and 1 mM AgNO3 solution with 120 seconds of microwave reaction at 800 W. Notably, the AgNPs produced using microwave radiation had a smaller average diameter compared to those synthesized using conventional heating.

The presented work demonstrated an easy, cost-effective, and environmentally friendly way to synthesize Ag-NPs. Orange peel extract contributed to the reduction of both a stabilizer and an agent. Results showed that temperature, peel extract concentration, AgNO3 concentration, and duration of reaction all had an impact on the yield and size of the silver nanoparticles that were formed. The verification of Ag-NP synthesis was conducted through the examination of UV-vis spectroscopy, FT-IR, SEM, and XRD findings. The disk diffusion method was used to assess the antibacterial activity of Ag-NPs, and the results indicated that they were active against the bacterial strains S. aureus and E. coli. Better results, nevertheless, were observed when it came to the S. aureus bacteria.

The study investigates the synthesis of AgNPs from tea leaf extract, focusing on the chemical composition of tea, particularly Bac Kan. It identifies five common catechins and unknown ones. FTIR analysis reveals the biomolecules responsible for AgNP synthesis. The pigment undergoes photo degradation, but the catalytic role of AgNPs is demonstrated. The antibacterial activity of AgNPs depends on factors like structure, shape, size, and concentration.

Future Recommendation

Using diverse and sustainable biomass sources to produce biochar.

Development of advanced techniques for better characterization of BNPs to understand their properties and interactions in agricultural systems.

Conducting thorough studies on the environmental and health impacts of BNPs.

Developing clear guidelines and policies for the use of BNPs in agriculture to ensure safety and efficacy.

Creating BNPs with specific functional properties (e.g., nutrient delivery, pest control) and Integrating BNPs into precision agriculture practices to enhance soil health and crop yield.

Involving farmers, industry stakeholders, and policymakers in research and development processes to address practical challenges and facilitate adoption. By addressing these challenges and focusing on these future directions, the potential of biochar nanoparticles in agriculture can be more fully realized, contributing to sustainable agricultural practices and improved crop productivity.

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