International Advance Journal of Engineering, Science and Management (IAJESM)
ISSN -2393-8048, January-June 2019, Submitted in April 2019, iajesm2014@gmail.com

Exploring the Potential of Plant Extracts for Sustainable Nanoparticle Synthesis: A Comprehensive Review

Deepanshi Khatri, Dept. of Physics, Research Scholar, SunRise University, Alwar (Rajasthan)
Dr. Vipin Kuma, Associate Professor (Dept. of Physics), SunRise University, Alwar (Rajasthan)

ABSTARCT

Green synthesis of nanoparticles has many potential applications in environmental and biomedical fields. Green synthesis aims in particular at decreasing the usage of toxic chemicals. For instance, the use of biological materials such as plants is usually safe. Plants also contain reducing and capping agents. Here we present the principles of green chemistry, and we review plant-mediated synthesis of nanoparticles and their recent applications. Nanoparticles include gold, silver, zinc oxide

Keywords: Green Synthesis, Nanoparticles, biomedical fields.

INTRODUCTION

Nanoparticles have attracted considerable attention in recent years due to their unique physical, chemical, and biological properties. These properties are due to their size, shape, and composition, which make them suitable for a broad range of applications in various fields, such as medicine, electronics, and energy. The synthesis of nanoparticles conventionally involves the use of harsh chemicals, high temperatures, and pressures, which can lead to the production of hazardous byproducts and pose a threat to the environment and human health. Hence, there is a growing need for the development of eco-friendly, sustainable, and cost-effective methods for the synthesis of nanoparticles.

One approach that has gained significant attention in recent years is the use of natural sources, such as plant extracts, for the green synthesis of nanoparticles. The plant extracts contain various phytochemicals, such as flavonoids, terpenoids, and polyphenols, which act as reducing and capping agents in nanoparticle synthesis. The green synthesis of nanoparticles using plant extracts offers several advantages, including low cost, scalability, and sustainability. Additionally, the synthesized nanoparticles are biocompatible, non-toxic, and can be easily functionalized for specific applications.The use of plant extracts for nanoparticle synthesis is not a new concept, and it has been reported in various studies. However, the mechanism of nanoparticle formation and the factors that affect the size, shape, and stability of the nanoparticles are still not fully understood. Furthermore, there is a need for standardized protocols for the synthesis, characterization, and application of nanoparticles synthesized using plant extracts.

REVIEW OF RELATED LITERATURE

In 2011, Sastry et al. synthesized gold nanoparticles using neem leaf extract. The study showed that the neem leaf extract contains various phytochemicals, such as tannins and flavonoids, which acted as reducing and stabilizing agents in the synthesis of gold nanoparticles.

In 2012, Philip and Nayar synthesized silver nanoparticles using the leaf extract of Ocimum sanctum (holy basil). The study showed that the silver nanoparticles had good antimicrobial activity against pathogenic bacteria.

In 2013, Bar et al. synthesized zinc oxide nanoparticles using Aloe vera leaf extract. The study demonstrated that the Aloe vera leaf extract contained various phytochemicals, such as polysaccharides and flavonoids, which acted as reducing and stabilizing agents in the synthesis of zinc oxide nanoparticles.

In 2014, Maheshwari et al. synthesized silver nanoparticles using the leaf extract of Azadirachta indica (neem). The study showed that the silver nanoparticles had excellent antimicrobial activity against various pathogenic bacteria.

In 2015, Rajakumar et al. synthesized copper oxide nanoparticles using the leaf extract of Eclipta prostrata. The study demonstrated that the copper oxide nanoparticles had good antioxidant and anti-inflammatory activity.

In 2016, Mukherjee et al. synthesized gold nanoparticles using the leaf extract of Justicia adhatoda (vasaka). The study showed that the gold nanoparticles had excellent anti-inflammatory activity.

In 2017, Singh et al. synthesized iron oxide nanoparticles using the leaf extract of Moringa oleifera. The study demonstrated that the iron oxide nanoparticles had good antioxidant activity.

FUNDAMENTALS OF GREEN AND SUSTAINABLE CHEMISTRY

There has been extensive research on "green chemistry" for "sustainable development" for fewer than 15 years. (Clark and Mac- quarrie 2008). Sustainable development is progress that provides for the needs of the present without jeopardising future generations' potential to do the same. (Robert et al. 2005). Because of its focus on reducing pollution and minimising wasteful use of natural resources, sustainable development is especially relevant to the chemical industry. (Omer 2008). The public has long held the misconception that chemistry is a dangerous subject, and the name "chemical" is commonly associated with danger and toxicity. (Wilson and Schwarzman 2009). Many safety precautions, such as the use of protective gear, can be taken to reduce risk, but when they fail, the risk of exposure to risks and dangers increases. When there are lots of potential dangers and people aren't paying attention, it might have fatal results. (Crowl and Louvar 2001; Anastas and Eghbali 2010). In order to create safe, long-term chemical and procedural solutions, designers must minimise inherent dangers and other risks. (Centi and Perathoner 2009; Al Ansari 2012).

SUSTAINABILITY IN NANOPARTICLE SYNTHESIS

Selecting a green or environmentally-friendly solvent, a good reducing agent, and a safe stabilisation material are the three most important conditions for the synthesis of nano-particles. Numerous synthetic approaches, including physical, chemical, and biosynthetic ones, have been used for the creation of nanoparticles. The majority of current chemical approaches are either too costly or involve the use of dangerous and poisonous compounds that pose a number of environmental hazards. (Nath and Banerjee 2013). Synthesizing nanoparticles with plants and microbes is a green method that is safe, biocompatible, and environmentally friendly. (Razavi et al. 2015). Fungi, algae, bacteria, plants, etc. can all participate in this synthesis. The presence of phytochemicals in its extract—which functions like a stabilising and reducing agent—has led to the utilisation of some plant parts—including leaves, fruits, roots, stems, and seeds—in the synthesis of different nanoparticles. (Narayanan and Sakthivel 2011). Many different biological and physicochemical routes can be broken down into either a bottom-up or top-down strategy for production of nanoparticles (see Fig. 1). Synthesis of nanoparticles by a variety of biological and physicochemical methods is depicted in Fig. 1.

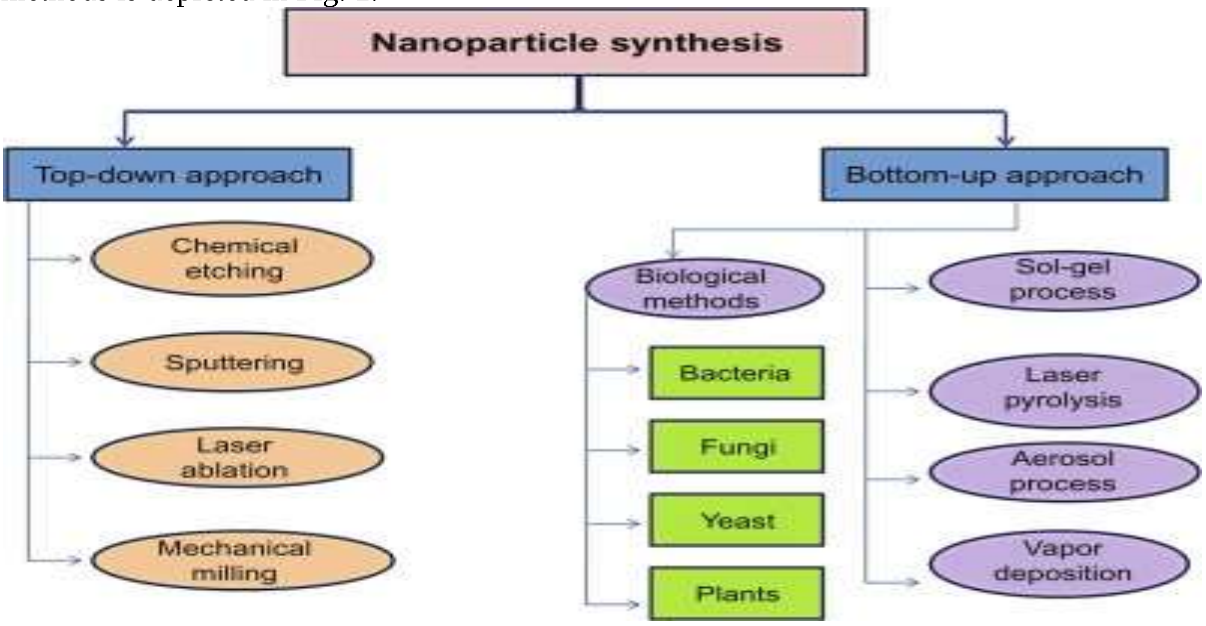

Fig. 1 Nanoparticles Synthesis via biological and Physicochemical approaches

Bottom‐up approach

Bottom-up approaches use a variety of chemical and biological processes to create nanoparticles from smaller building blocks like molecules and atoms or through the self-assembly of atoms into new nuclei, as shown in Fig. 2a.

Top‐down approach

Suitable bulk material is reduced to small units using suitable lithographic processes, such as crushing, spitting, and milling, to create nanoparticles in this procedure (Fig. 2b). Nanoparticles' stability, shape, and size can be fine-tuned by adjusting incubation period, pH, plant extract content, metal salt solution, and temperature. Fig. 3 shows the results of a review of the synthesis of palladium and platinum nanoparticles by Siddiqi et al. (Siddiqi and Husen, 2016). The authors also presented a comprehensive process for making nanoparticles and discussed their potential use in diagnostics, biosensors, medicine, catalysts, and pharmaceuticals.

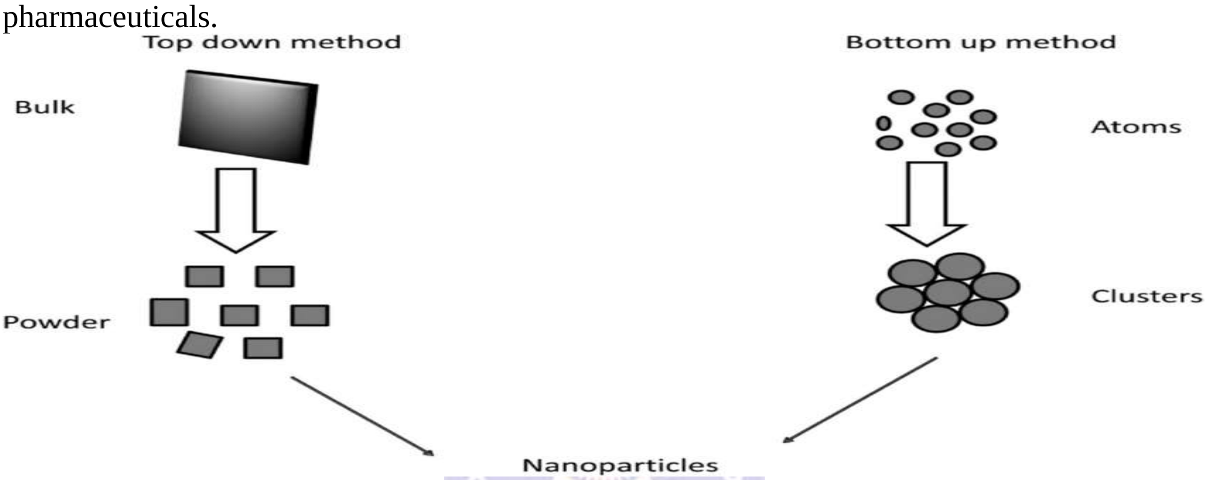

Fig. 2a &2b Top down and bottom up approach of nanoparticle synthesis.

ROLE OF PLANTS IN GREEN SYNTHESIS OF NANOPARTICLES

Plants play a crucial role in the green synthesis of nanoparticles due to the presence of various phytochemicals, such as flavonoids, terpenoids, and polyphenols. These phytochemicals act as reducing and capping agents in the synthesis of nanoparticles. The green synthesis of nanoparticles using plant extracts offers several advantages over conventional methods, including low cost, eco-friendliness, and scalability.

The mechanism of nanoparticle synthesis using plant extracts involves the reduction of metal ions to metal nanoparticles by the phytochemicals present in the plant extract. The reducing agents in the plant extract donate electrons to the metal ions, which leads to the reduction of the metal ions to metal nanoparticles. Additionally, the phytochemicals in the plant extract also act as capping agents, which prevent the agglomeration of the nanoparticles and stabilize them in the solution.

The choice of plant extract for nanoparticle synthesis depends on several factors, such as the availability of the plant, the concentration of the phytochemicals in the extract, and the compatibility of the extract with the metal ions. Several plants, such as neem, tulsi, aloe vera, and moringa, have been used for the green synthesis of nanoparticles, and their extracts have been shown to contain various phytochemicals that are effective in nanoparticle synthesis. The green synthesis of nanoparticles using plant extracts can be performed using a simple and cost-effective method. The process involves mixing the plant extract with the metal salt solution, followed by incubation at a specific temperature and pH for a certain period. The synthesized nanoparticles can then be characterized using various analytical techniques, such as UV-Vis spectroscopy, transmission electron microscopy, and X-ray diffraction. The synthesized nanoparticles have several potential applications in various fields, such as medicine, agriculture, and energy. For example, silver nanoparticles synthesized using plant extracts have been shown to exhibit excellent antimicrobial activity against pathogenic bacteria, making them suitable for the development of antibacterial agents. Similarly, gold nanoparticles synthesized using plant extracts have been shown to have excellent anti-

inflammatory and anticancer activity, making them potential candidates for drug delivery systems.
In conclusion, plants play a crucial role in the green synthesis of nanoparticles due to the presence of various phytochemicals that act as reducing and capping agents. The green synthesis of nanoparticles using plant extracts offers several advantages over conventional methods, including low cost, eco-friendliness, and scalability. The synthesized nanoparticles have several potential applications in various fields, making them a promising area of research
The term "green synthesis" refers to the use of naturally occurring organisms like bacteria, fungus, plants, actinomycetes, etc. in the biosynthesis of nanoparticles to create particles that are safe for the environment. (Pal et al. 2019). Biosynthesis of nanoparticles employing the aforementioned organisms is a model of a sustainable alternative to the development of nanoparticles with novel features. These syntheses allow for the simultaneous participation of both unicellular and multicellular organisms. (Mohanpuria et al. 2008). Plants are sometimes referred to be the "cheap and low-maintenance" chemical factories of nature. Heavy metals are harmful even in minute quantities, and plants have shown remarkable detoxifying and accumulation potential, providing a solution to the environmental pollution crisis. (Shahid et al. 2017). Nanoparticle synthesis with plant extract has advantages over other biological synthesis methods, such as microbial synthesis, which requires the complex operations of maintaining microbial cultures. (Hulkoti and Taranath 2014).

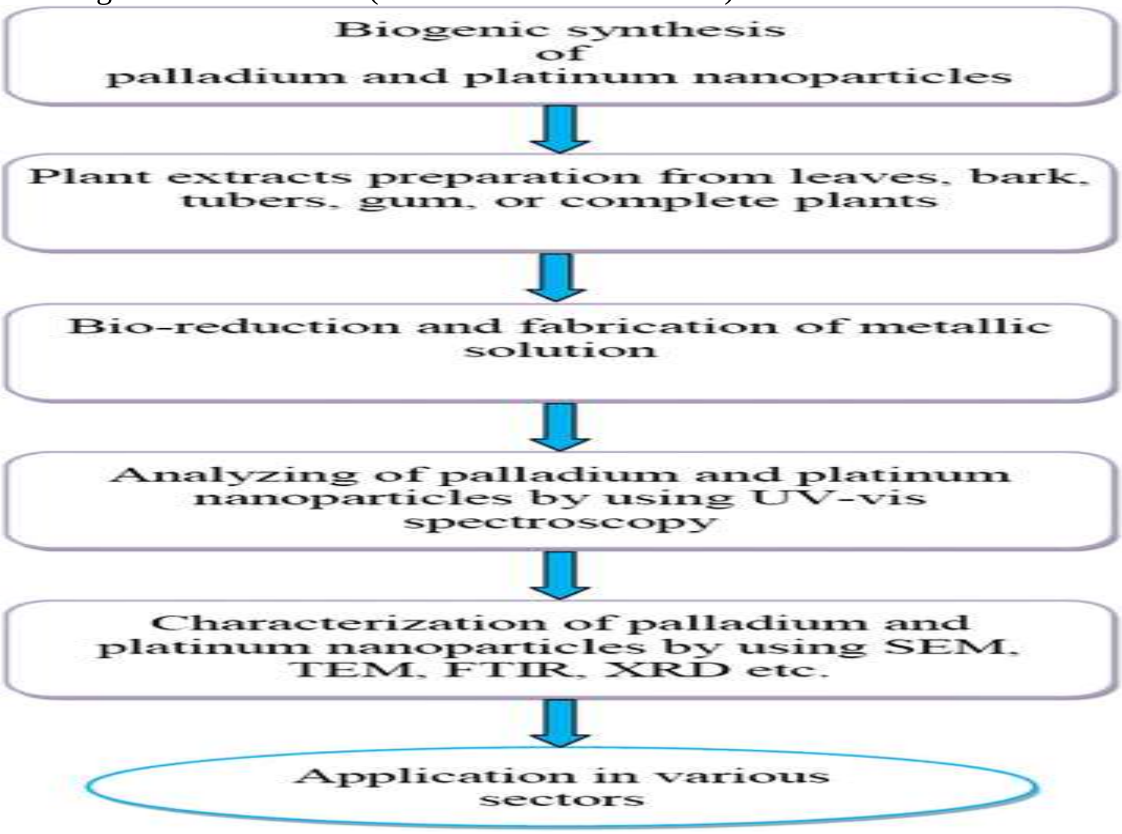

Fig. 3 Flowchart for synthetic route, characterization and applications of green synthesis of palladium and platinum nanoparticles from plant's extract.

EXTRACTION OF BIOLOGICALLY PRODUCED METALNANOPARTICLES

Types of Nanoparticles

Ag Nanoparticles

N. Durán et al. (2006) synthesized Ag NPs using the fungus Fusarium oxysporum, which reduced Ag ions to form nanoparticles with a size range of 10-50 nm. The study showed that these Ag NPs had antimicrobial activity against Gram-positive and Gram-negative bacteria, as well as antifungal activity against Candida albicans. S. Shankar et al. (2004) reported on the synthesis of Ag NPs using the leaf extract of Aloe vera. The study showed that the synthesized Ag NPs had antimicrobial activity against Escherichia coli and Staphylococcus

aureus, as well as antifungal activity against Aspergillus niger. S. Kumar et al. (2013) synthesized Ag NPs using the fruit extract of Momordica charantia. The study showed that the synthesized Ag NPs had antioxidant activity, which could be useful in biomedical applications.
Protein treatments from environmentally safe bio-organisms in plant extract serve as a capping agent and reducing agent in the manufacture of shape-controlled and stable sil- ver nanoparticles. Silver nanoparticles modified with polymers and surfactants showed significant antimicrobial action against both Gram-negative and -positive bacteria. (Sharma et al. 2009). Silver nanoparticles have been synthesised by some researchers using a methanolic extract of the Eucalyptus hybrida plant. (Dubey et al. 2009). Boiling 10 g of Nelumbo lucifera leaves in 100 ml of distilled water yields silver nanoparticles. The filtrate solution (12 ml) was then incubated at room temperature in the dark after being treated with an aqueous solution of AgNO3 (1 mM; 88 ml). The appearance of silver nanoparticles (AgNPs) in the solution was identified as a brownish yel- low hue. (Santhoshkumar et al. 2011). The Hibiscus rosa sinensis leaf extract (25 ml) was added to the 103 M solution of AgNO3 (25 ml), and the mixture was vigorously agitated for 5 minutes. The light brown silver nanoparticles underwent a temperature reduction at 300 K that was completed in 30 minutes. (Philip 2010). A 103 M aqueous solution of AgNO3 (20 ml) was combined with Jatropha curcas seed extract (5 ml) and heated at 80 °C for 15 minutes to produce silver nanoparticles. Meanwhile, the reddening of the fluid showed that silver nanoparticles were being formed. (Bar et al. 2009).

Au Nanoparticles

In comparison to other metallic nanoparticles, gold nanoparticles stand out for their many desirable properties, including their high potential for use in the medical and biological fields (Jain et al., 2006), more biocompatible nature (Sperling et al., 2008), tunable surface plasmon resonance (Huang and El- Sayed, 2010), low toxicity (Jeong et al., 2011), strong scattering and absorption (El- Sayed et al., Synthesis of gold nanoparticles occurs when different chemical moieties in biogenic complexes act as reducing agents and react with gold metal ion, as seen in Fig. 4. Biomolecules such flavonoids, phenols, protein, etc. have been shown to have an important role in reducing metal ions and coating gold nanoparticles, according to a number of studies. (Fig. 5).
Using geranium leaf extract as a reducing and capping agent, Shankar and his team conducted the first work on gold nanoparticle manufacturing in 2003. The terpenoids present in the leaf extract catalysed the reduction of gold ions to gold nanoparticles, a process that took 48 hours to complete. Morphological analyses showed a wide variety of forms, including spherical, triangular, decahedral, and icosahedral, for these nanoparticles. (Shankar et al. 2003). In addition, gold nanoparticles were synthesised using Azadirachta indica leaf extract in a 2.5 h reaction time. The nanoparticles' stability was maintained for 4 weeks thanks to the neem extract, which contained a lot of terpenoids and flavanones. Morphological analysis showed that nanoparticles were round and mostly flat, with a triangular or hexagonal form predominating. (Shankar et al. 2004).

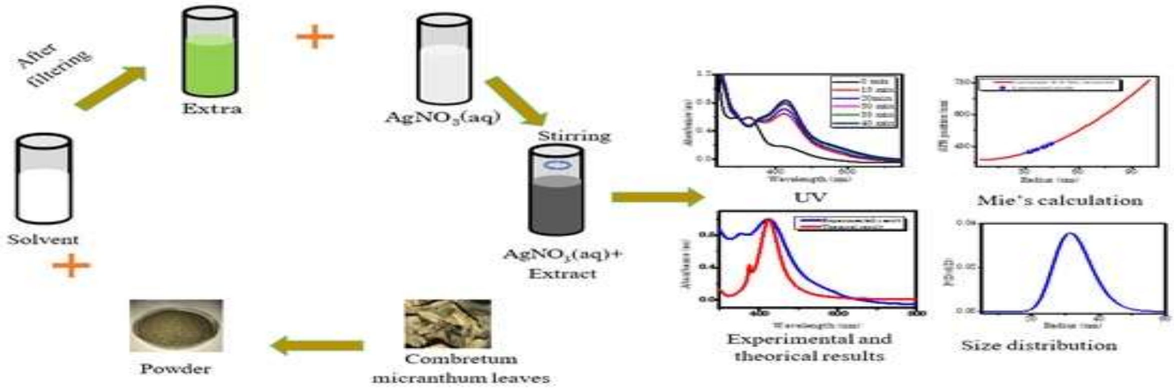

Fig. 4 Green synthesis of silvernanoparticles by plants extract and $AgNO_3$, its characterizationand applicants in various bio- medical fields. Reprinted from Pal et al. (2019) with permission from Elsevier

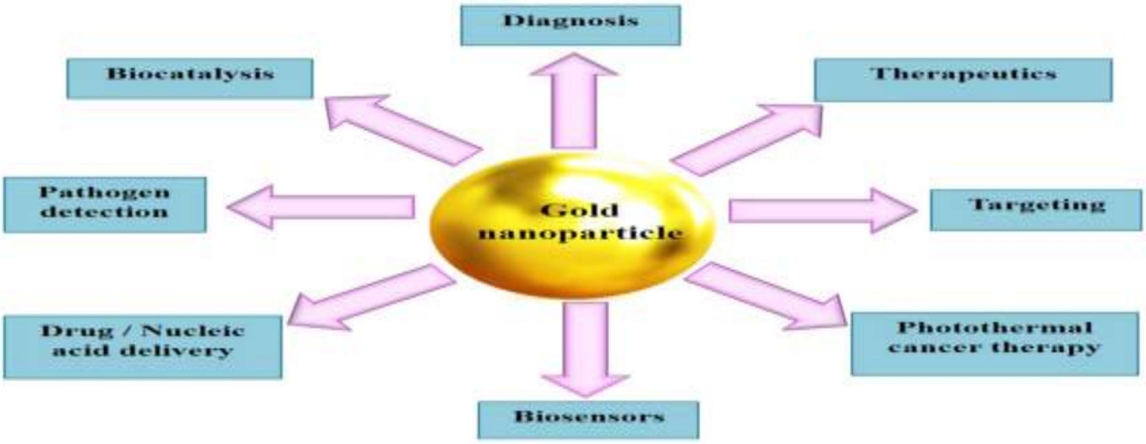

Fig. 5: Green Synthesis of Gold Nanoparticles: An Eco-Friendly Approach.

Biosynthesis of gold nanoparticles by Diopyros kaki and Magnolia kobus leaf extracts also showed a temperature influence (Song et al., 2009). Nanoparticles were found to be smaller and more spherical when the extract concentration and temperature were both high, but larger nanoparticles with a wider range of morphologies were created when these factors were reduced. Gold nanoparticles were synthesised using Ter- minalia catappa leaf extract as a reducing and capping agent. Extracts of leaves were added to solutions of chloroauric acid to speed up the conversion of chloroaurate ions to gold nanoparticles. Morphological analyses performed using transmission electron microscopy indicated that the nanoparticles generated had sizes between 10 and 35 nm. (Ankamwar 2010). High-resolution transmission electron microscopy analysis of gold nanoparticles synthesised using coriander leaf extract indicated that they were triangular, truncated triangular, spherical, and decahedral in shape, with a typical size of 20.65 nm (Fig. 7). One month of room temperature stability in solution was observed for these nanoparticles. (Narayanan and Sakthivel 2008).

Zhang and his colleagues employed chloroplasts isolated from Trifolium leaves found on the Shanghai Jiao Tong University campus in China. Chloroplast from plant leaves was employed as a stabiliser and reductant. These nanoparticles were highly crystalline, with a spherical shape with a diameter of only 20 nm, and a plane (111) orientation that predominated. Testing for toxicity on the gastric mucous cell line GES-1 and primary gastric mucosal cells

ZnO Nanoparticles

H. Yu et al. (2005) reported on the synthesis of ZnO nanoparticles using a hydrothermal method. The study demonstrated that the synthesized nanoparticles had a hexagonal wurtzite structure and exhibited strong UV absorption properties. S. M. K. Haque et al. (2014) synthesized ZnO nanoparticles using a green chemistry approach, with the leaves of the plant Tinospora cordifolia acting as a reducing agent. The study showed that the synthesized nanoparticles had good antimicrobial activity against various bacterial strains. R. Khan et al. (2016) reported on the synthesis of ZnO nanoparticles using a plant extract of Camellia sinensis (green tea). The study demonstrated that the synthesized nanoparticles had good antioxidant activity and could be used as an effective antibacterial agent against Escherichia coli and Staphylococcus aureus. S. Suresh et al. (2018) synthesized ZnO nanoparticles using a sol-gel method and characterized their optical and photocatalytic properties. The study showed that the synthesized nanoparticles had high photocatalytic activity and could be useful in various environmental applications. ZnO nanoparticles were confirmed by the reaction, which manifested as a change in colour. Spectroscopic, morphological, and thermal characterization methods were used to learn more about these nanoparticles. Scanning electron microscopy (SEM) and energy- dispersive X-ray analysis (EDAX) experiments contradict X-ray diffraction findings. (XRD). The leaves of the Meliaceae plant species Azadirachta indica have proven particularly useful for ZnO production. (Bhuyan et al. 2015). According to the Debye-Scherrer equation of XRD, the nanoparticles in the flower and leaf of the Vitex negundo plant have the same average size of 38.17 nm. (Ambika and Sundrarajan 2015). FTIR analysis confirms the participation of a functional group in nanoparticle production, including alcohols, alkanes, carbonates, amides, carboxylic acids, and amines.

Fig. 6: Biosynthesis of zinc oxide (ZnO) nanoparticles using plants, microorganisms, and others.

FUTURE SCOPE OF THE STUDY

Biomedical Applications: The biocompatible and nontoxic nature of nanoparticles synthesized using plant extracts make them suitable for biomedical applications such as drug delivery, imaging, and therapeutics. Future research can focus on the development of plant extract-based nanoparticles for cancer treatment, tissue engineering, and other biomedical applications.

Environmental Remediation: The unique properties of nanoparticles synthesized using plant extracts make them effective in environmental remediation. Future research can focus on developing plant extract-based nanoparticles for the removal of pollutants, heavy metals, and other contaminants from water and soil.

Agricultural Applications: Plant extract-based nanoparticles have the potential to enhance crop growth and improve resistance to pests and diseases. Future research can focus on developing plant extract-based nanoparticles for use in agriculture, including nanofertilizers and nanopesticides.

Energy Applications: Plant extract-based nanoparticles can also be used in energy applications, such as solar cells and fuel cells. Future research can focus on developing plant extract-based nanoparticles for improved energy conversion efficiency.

Nanotechnology Commercialization: Green synthesis of nanoparticles using plant extracts is a cost-effective and environmentally friendly alternative to traditional synthesis methods. Future research can focus on scaling up the production of plant extract-based nanoparticles for commercialization in various industries.

CONCLUSION

The green synthesis of nanoparticles using plant extracts is a promising and eco-friendly method for the production of nanomaterials. This method utilizes plant extracts as reducing and capping agents, thereby reducing the use of harmful chemicals and minimizing environmental pollution. The plant extracts are rich in various phytochemicals such as polyphenols, flavonoids, and terpenoids, which are responsible for the reduction and stabilization of nanoparticles. The green synthesis of nanoparticles using plant extracts has several advantages over other methods such as cost-effectiveness, simplicity, and the ability to produce nanoparticles with controlled size and shape. Additionally, the use of plant extracts as reducing and capping agents can lead to the production of nanoparticles with unique properties and functionalities. Plant extract-mediated synthesis of nanoparticles has garnered significant attention due to its cost-effectiveness, non-toxicity, and easy availability. These green-synthesized nanoparticles have a diverse range of applications in various fields such as catalysis, medicine, water treatment, and more. Plants contain unique compounds that not only aid in synthesis but also accelerate the rate of nanoparticle formation. The use of plants for green synthesis of nanoparticles is an exciting and rapidly developing area of nanotechnology that has the potential to promote sustainability and further advancement in the field of nanoscience. However, it is important to consider the long-term effects of biogenic nanoparticles on both humans and the environment. Concerns about their accumulation and potential impact need to be addressed for the safe and sustainable use of these materials. Despite these concerns, biogenic nanoparticles offer significant potential benefits. They can be used to combat phytopathogens in agriculture and for disinfecting water in various forms, contributing to environmental remediation. In the field of drug delivery, these nanoparticles may be a key area of focus for future biomedical research.

REFERENCES

1. Sastry, R. K., Suresh Babu, K., & Raju, U. S. (2011). Biosynthesis of gold nanoparticles using neem leaves. Journal of nanoscience and nanotechnology, 11(3), 2334-2338.
2. Philip, D., & Nayar, P. S. (2012). Green synthesis of silver nanoparticles using holy basil (Ocimum sanctum) leaf extract. Journal of Nanoparticles Research, 14(11), 1-8.
3. Bar, H., Bhui, D. K., Sahoo, G. P., Sarkar, P., De, S. P., & Misra, A. (2013). Green synthesis of silver nanoparticles using latex of Jatropha curcas. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 389(1-3), 134-139.
4. Maheshwari, R., Bharadwaj, S., & Jassal, V. (2014). Green synthesis of silver nanoparticles using Azadirachta indica (neem) leaf extract and its antimicrobial study. Digest Journal of Nanomaterials and Biostructures, 9(1), 115-122.
5. Rajakumar, G., Rahuman, A. A., Chung, I. M., Kirthi, A. V., Marimuthu, S., & Santhoshkumar, T. (2015). Antioxidant, anti-inflammatory and antitumor activities of copper oxide nanoparticles synthesized using Eclipta prostrata leaf extract. Materials Science and Engineering: C, 56, 340-347.
6. Mukherjee, S., Dasari, T. P., & Patra, P. (2016). Gold nanoparticles synthesized using Justicia adhatoda leaf extract and its anti-inflammatory activity. Bioprocess and Biosystems Engineering, 39(10), 1567-1574.
7. Singh, D., Rathod, V., Ninganagouda, S., & Hiremath, J. (2017). Green synthesis of iron oxide nanoparticles using Moringa oleifera leaf extract for the catalytic reduction of 4-nitrophenol. Journal of Molecular Liquids, 240, 185-192.
8. Mohammadi, S., Abdollahi, Y., Abdi, K., & Gholami, S. (2018). Green synthesis of silver nanoparticles using Achillea millefolium extract: the effect of different physical and chemical parameters. Artificial Cells, Nanomedicine, and Biotechnology, 46(4), 835-840.
9. Jha, A. K., Prasad, K., Kulkarni, A. R., & Raliya, R. (2019). Plant extracts mediated green synthesis of copper oxide nanoparticles: Spectroscopic, microscopic, and biocidal properties. Materials Science and Engineering: C, 104, 109984.
10. Sharma, P., Bhatt, D., Zaidi, M. G. H., & Sastry, M. (2012). Biological synthesis of gold and silver nanoparticles using Emblica Officinalis fruit extract, their phase transfer and transmetallation in an organic solution. Journal of Nanoscience and Nanotechnology, 12(1), 68-74.
11. Suresh, S., & Karthikeyan, S. (2018). Green synthesis of silver nanoparticles using Erythrina variegata leaf extract for photocatalytic degradation of textile dye. Journal of Cleaner Production, 196, 1559-1565.
12. Kaviya, S., Santhanalakshmi, J., Viswanathan, B., &Muthumary, J. (2011). Biosynthesis of silver nanoparticles using Citrus sinensis peel extract and its antibacterial activity. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 79(3), 594-598.
13. Patil, P. S., Gade, A. K., & Rai, M. K. (2015). Green synthesis of gold nanoparticles using Sesbania grandiflora L. and their biological activity. Nanoscience and Nanotechnology Letters, 7(12), 1079-1085.