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PLANT EXTRACT MEDIATED GREEN SYNTHESIS OF NANOPARTICLES: A BRIEF REVIEW

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ABSTRACT
Nanoparticles (NPs) are particles with size lesser than 100nm, having a characteristic of high surface to volume ratio which provide unique surface interaction properties to these particles. The routine synthesis of such smaller particles requires harsh physical or chemical treatments to the bulk materials, which utilises either a high energy source (laser, UV, sputtering, electro-explosion etc.) or costly and hazardous chemicals (oxidizing or reducing agents). On the other hand, Green Synthesis provides a path via which nanoparticles may be obtained in an eco-friendly manner at a comparatively lower cost. Green synthesis describes the use of biogenic ways or application of greener regents (eg.Plant extracts, green solvents) for the purpose of reduction, oxidation or capping of nanoparticles which is particularly a crucial step for the nanoparticle synthesis, regulating the shape and size of NPs. In the current article, brief analyses of some green synthesis techniques using various plant parts have been reviewed to establish the concept for the eco-friendly and green methodologies for the nanoparticle synthesis.
KEY WORDS: *Green synthesis, Eco-friendly synthesis, Nanoparticles, Plant extracts, Capping agents, Green reagents.*

INTRODUCTION

During the production of any material with desired properties, working conditions of any system play a key role. Green Chemistry, which operates under the auspices of the Environmental Protection Agency (EPA) of United State (US), has a clear goal of making the living world a better place with giving emphasis on creating a safer environment. In the light of USEPA, use of hazardous chemicals and drastic conditions must be replaced with some safer techniques. One of the principles of green chemistry is- “To use safer chemicals”, pointing out to generate safer conditions during any synthesis. Green methods and technologies use mild conditions and green solvents, likely to be safer for the environment as well as for the workers. Thus green synthesis of nanoparticles is introduced in the field of nanotechnology for the purpose of developing nanoscale substances. Nanoparticles (NPs) are at the forefront of nanotechnology's fast development, because of their great surface vicinity to extent active sight proportions and distinctive properties even in nano levels. Their vast application packages in extensive range of chemical, medical and technological fields make these more important than macro-scale particles. These materials are superior in many areas of human activity due to their unique size-dependent characteristics (Salata, 2004). The routine synthesis of such smaller nanoparticles(NPs) requires harsh physical conditions(eg. laser, UV, sputtering, electro-explosion etc.) or costly and hazardous chemicals (oxidizing or reducing agents).On the other hand, Green Synthesis provides a channel via which nanoparticles may be obtained in an eco-friendly manner at a comparatively lower cost. Green synthesis describes the use of biogenic ways or application of greener regents (eg. plant extracts, enzymes, microbes etc.) for the purpose of reduction or capping of nanoparticles which is particularly a crucial step for the nanoparticle synthesis and regulating the shape and size of NPs (Vyas, 2017). Among various types of nanoparticles metals and metal oxides have found vast applications as one of the best adsorbents deployed for the treatment of liquid wastes. These upturn in their use as a choice of decontaminant, owes to the fact that they provide low solubility and are not responsible for the formation of secondary (usually more toxic) pollutants in treated water, thus they possess minimal environmental impact; therefore, they can be said to have excellent adsorbent properties for safe applications in pollution mitigation (Hamidreza et al., 2017). Bare nanoparticles, prone to oxidation by atmospheric oxygen are easily aggregated in aqueous systems which have necessitated the surface modification of these nanoparticles for their stabilization and subsequent applications as more effective nano-adsorbents. In such surface modified adsorbents, the molecular makeup is significantly different from that of the core of the nanoparticles. Modifications on the surface layer of nanoparticles confer properties which facilitate enhanced adsorption properties with effective removal of pollutants (Gang and Vyas, 2019). For exploring the synthesis techniques, Nanocomposites are introduced; having multiphase solid materials where one of the phases has one, two or three dimensions of less than 100 nanometers (nm) or strucures having nano-scale at repeated distances between the different phases that make up the material unique in contrast to microcomposites (Ioannis et al., 2012). Nanocomposites of metal oxides nanoparticles, carbon, and polymers have been developed as hybrid potential adsorbents for environmental remediation, pollution control and a wide range of other bioprocess based industrial applications (Vinni et al., 2017). Recent advancement in adsorption studies has led to synthesis and availability of a variety of better efficient, eco-friendly and cost-effective nano-adsorbents, whose usefulness could be subjected to decontamination of industrial and domestic liquid wastes (Feka et al., 2021). Notwithstanding, metal/metal-oxide nano particle synthesis is not entirely green; in last decade, much focus has been placed on green synthesis, in which many biological systems had been employed in the synthesis of nanoparticles by researchers due to their numerous benefits over non-biological systems. Fungi, algae and bacteria and terrestrial plants are especially found useful for this purpose because their metabolites can act as reducing agents during nanoparticle synthesis (Murthy and Maria, 2019; Gade et al., 2010). This review briefly emphasises uses of Plant extracts, rich in phyto-chemicals (Kumar et.al.2020) and reported as very suitable green reagent for the synthesis of metal /metal oxide nanoparticles.

PLANT EXTRACT FOR GREEN SYNTHESIS OF NANOPARTICLES

Several research groups have reported different physical and chemical synthesis techniques for the nanoparticle preparations which necessitate hazardous reducing/oxidizing agents, stabilizing reagents, higher energy sources, etc. which may be dangerous to humans and other living organisms (Cao G., 2004).On the other hand, green chemistry research groups have quoted some natural sources as green reagents which have milder conditions like-wide plant varieties have excessively been utilized for the preparation of metal/metal oxide nanoparticles in a single pot synthesis. Plant extracts from *Euphorbia prostrata (*ZahirA.A. et al. 2015),*Red ginseng* (Singh P. et al., 2015) , *Catharanthus roseus (*Kalaiselvi A. et al. 2015),*Nigella sativa* (Amooaghaie R. et al. 2015) and *Aloe vera* leaf broth extract (*Aloe barbadensis miller)* etc. have been used by researchers to make Nanoparticles (Sangeetha et al., 2012). These plant extracts have powerful phytochemicals in various plant parts; mainly in leaves the presence of ketones, flavones, aldehydes, terpenoids, phenols, and ascorbic acids have been reported (Kim etal. 2012) which can act as capping or reducing agents. However, experimental conditions such as solvent type, temperature, pH and many other factors have also exerted some influence on the shape and size of green synthesized nanoparticles (Heim etal. 2002).

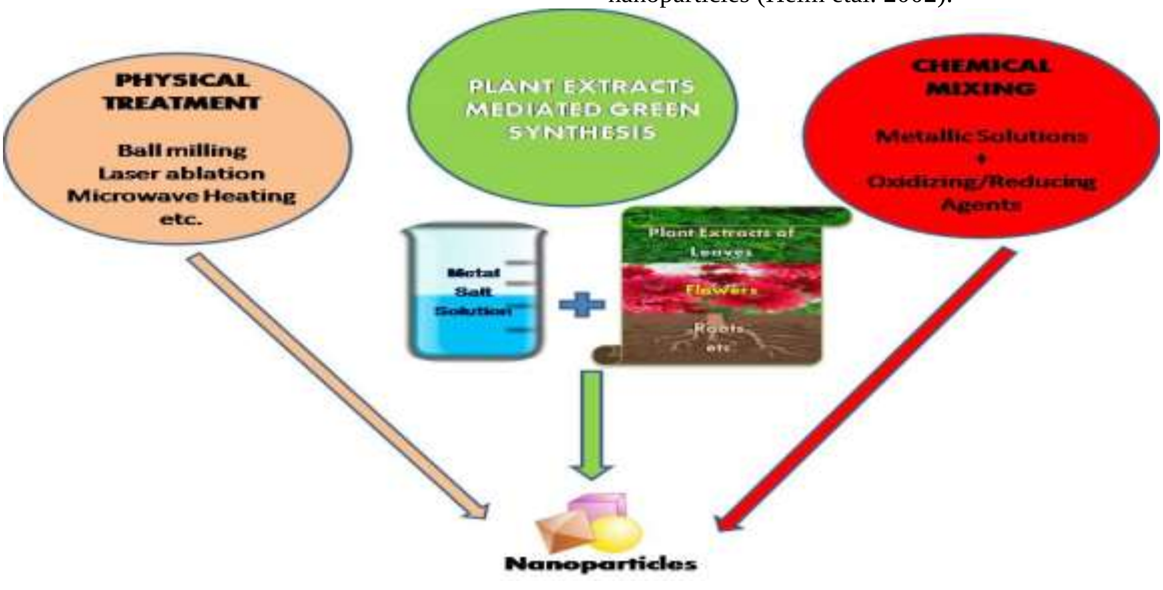

Figure1. Synthesis of Nanoparticles

Among all types of nanoparticles, metal/metal oxides have been extensively studied by researchers like- Zinc oxide nanoparticles(ZnO NPs) have received great concern because of their wide range antibacterial, anti-inflammatory, antifungal, injury recuperation, antioxidant, and optical properties(Agarwal et al., 2017). The usage of bio components of *C. Rose* leaves are utilized for the conversion of Zinc acetate and Sodium hydroxide to get ZnO NPs of varying size of 23-52 nm, then XRD, SEM, EDAX, and Raman spectroscopy had been used to identify the particles. The green synthesis of ZnO NPs is reported to be very easy, effective, and in environmentally pleasant, without any using any harmful reagents (Bhumi and Savithramma, 2014). Zinc oxide Nanoparticles (ZnO NPs) have also been manufactured from Chamomile flower, Olive leaf and Crimson tomato fruit extracts, among these Olive leaf extracts mediated NPs are reported with smallest size of 40.5 nm (Ogyunyemi et al., 2018) UV–visible spectroscopy, Fourier transform infrared spectroscopy, X-ray diffraction, Transmission electron microscopy, and Scanning electron microscopy had been used to characterize these. Similarly, a bio-derived ZnO nanopowder (ZnO-NP) was synthesized using leaf extract of

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Spinaciaoleracea, and Zn $(NO_3)_2$ at 500 ^0C, following a simple and green approach and EDS spectrum was recorded for elemental weight compositions as 67.33% and 32.67% for Zn and O, while the FTIR absorption peaks revealed the presence of Zn-O–H and Zn-O. XRD, SEM, and BET analysis were tools employed to characterize the nano-adsorbent which revealed the mesoporous structure of the ZnO-NPs (Feka et al, 2021).

Silver Nanoparticles (Ag-NPs) have been synthesized using *Neem*(Azarica*indica*) aqueous leaf extract that served as a reducing and capping agent, Ag-NPs were observed to have antibacterial properties against both gram-positive and gram-negative microorganisms with photoluminescence characteristics(Saifullah et al., 2016). The leaf extract of *Hibiscus Rosa Sinens*is is used to biologically synthesize Silver Nanoparticles of different shapes via simple aqueous phase at room temperature (Reveendran A.2016).Silver Nanoparticles of various shapes are generated by varying pH of the reaction medium. UV–Visible, TEM, XRD, and FTIR spectroscopy are used to categorize the Nanoparticles (Phillip, 2010). Nanoparticles were effectively synthesized from Silver Nitrate Solution $(AgNO_3)$ through a simple path from the latex of *Jatropha curcas* as a size reducing and capping agent. XRD and UV–vis absorption spectroscopy is used to categorize Nanoparticles. The Nanoparticles had a face-centered cubic FCC structure, cyclic peptides present in latex stabilized the particles with a radius of 10–20 nm. Naikaet al. (2015) obtained Copper Oxide (CuO) Nanoparticles from *Gloriosasuperba* leaf extract and tested their antibacterial activity. The particles were spherical having size of 05 to 10 nm with robust antibacterial action toward pathogenic bacteria. Vijayakumar et al. (2015) used *Aloe Vera* leaf extract to make Copper Oxide (CuO) Nanoparticles of 20 nm and examined their antibacterial properties for suppressing bacterial fish pathogens viz.- *Aeromonadshydrophilic*, *Pseudomonas fluorescents*, and*flavobacteriumbranchiophilum and* confirmed that CuO NPs has a robust antibacterial action against all 3 fish pathogens, even at low concentrations. Ghidan et al. (2016) used a simple and green procedure to manufacture CuO Nanoparticles from *Punica granatum* peel extract, which were highly crystalline with an average size of 40 nm. Iron(Fe) Nanoparticles were obtained via adding *A. Spinous*aqueous leaf extract to Ferric Chloride solution (Pablo et al., 2015). The extract of *A. Spinous* is rich in amaranthine and phenolic compounds, each of that has excessive antioxidant properties and acted as capping agent also. The results indicated that the *A. Spinous* extract-mediated Fe NPS had greater photocatalytic and antioxidant ability than Sodium Borohydride mediated chemically synthesized Nanoparticles. The green synthesis of Ferric Oxide (Fe_2O_3) Nanoparticles from leaf extract of *Oscimum Sanctum* was documented by Balamurughan et al., 2014. The formation of Fe_2O_3 NPs and their morphological dimensions were identified by SEM evaluation, UV-vis spectrum showed absorbance at 285 and 324 nm, the Fe-o stretching of Fe_2O_3 NPS confirmed by getting a function band at 618 cm^- in FTIR spectrum. Mixed form of Ferric Oxide (Fe_3O_4) NPs were synthesized from *S. muticum* extract using a simple path and fully green biosynthetic process. TEM measurements revealed that the average particle size was 184 nm. The NPs were crystalline, with a cubic structure, according to XRD analysis. Saponins, phenols, phlorotannins, and terpenoids are some of the phytoconstituents contained in *M. Indica* leaf extracts. The reducing properties of those various phytochemical compounds mediated the synthesis of NPs via reducing the precursor Ferrous sulphate $(FeSO_4)$. The existence of phenolic and flavonoid derivatives was found responsible for reduction and capping process required during nanoparticle synthesis (Pierson et al., 2014).

Table 1. Summary of Plant Mediated Green Synthesis of Nanoparticles

Plant Used	Plant Part	Type	Shape	Size	References
C.Rose	Leaves	ZnO	Spherical	23-57 nm	Bhumi and Savithramma,(2014).
Olive	Leaves	ZnO	Crystalline	40.5-124nm	Ogyunyemi et.al.(2018)
Spinacia oleracea	Leaves	ZnO	Mesoporous		Feka et al, 2021
Gloriosa superb	Leaves	CuO	Spherical	5-10 nm	Naika et al. (2015)
Ocimum Sanctum	Leaves	Fe_2O_3	Crystalline	20nm	Balamurughan et.al.(2014)
Catharanthus roseus	Leaves	Pd	Spherical	40nm	Kalaiselvi A. et al. 2015
Tilia	Leaves	Cu	Spherical and Semispherical	4.7 nm-17.4nm	Heliyon 5 (2019)e02339
Jatropha curcas	Latex	Ag	FCC structure	10-20nm	Bar et al., (2009)
Red ginseng	Roots	Ag	Spherical	10–30nm	Singh P. et al., 2015
Nigella sativa	Leaves	Ag	Spherical	15 nm	Amooaghaies R. et al. 2015
Hibiscus Rosa Sinensis	Leaves	Ag	Spherical	Agglomeration	Reveendran A.(2016)
Euphorbia prostrata	Leaves	Ag and TiO_2	Spherical and polydisperse	Ag10–15nm; TiO_2, 81.7–84.7	Zahir A.A. et al. 2015
Aloe vera	Leaves	CuO	Crystalline	20nm	Vijaykumar et.al.(2015)
Punica Granatum	Leaves	CuO	Crystalline	40nm	Ghaidan et.al.(2016)

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CONCLUSION

The routine chemical methods for the preparing nanoparticles involve expensive chemicals and harmful substances/conditions that are accountable for several risks. In present review, we have our focus on greener techniques to produce nanoparticles in eco-friendly manner at comparatively lower cost and Nanoparticles prepared from green methods using different plant extracts have been briefly reviewed herein. In countries like India and Nigeria, large quantities of solid biomass based waste viz. plant stalks, peels, fruit-wastes, seeds, leaves etc. are often thrown out as garbage or otherwise converted to domestic cooking fuels which causes land and air pollution respectively. Therefore usage of plant based waste materials is especially significant in ensuring the safe way for preparation as well as decaying pollution in our environment. The syntheses of nanoparticles from such greener reagents using plant-extracts provide an eco-friendly method, which is cheap, easy to achieve and free from toxic chemicals.

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