ANTIMIRCOBIAL PROPERTIES OF GREEN SYNTHESISED METAL NANOPARTICLES

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ABSTRACT

Metallic nanoparticles are gaining popularity due to their application potential in various industries. The emphasis on potential antibacterial applications of nanoparticles originates from the emergence of resistance in many deadly infections to conventional antiseptics and drugs. While many processes exist to generate metallic nanoparticles, the biological synthesis using plant sources are sustainable, cost-effective, and environmentally friendly. This paper summarises the use of various plant-based materials for nanoparticle production, the antibacterial properties of metal nanoparticles, and their prospective applications. The production of metal nanoparticles using extracts and solutions derived from various plant species is described. Additionally, this paper examines the factors affecting the synthesis of nanometal oxides from a diversity of green resources, and also their uses. Since biosynthesized nanoparticles have been shown to have antimicrobial, antifungal, and even antiviral capabilities, they are extensively studied, with silver, zinc and copper nanoparticles being the most investigated and having the greatest promise for therapeutic applications. Other sectors in which biosynthesized nanoparticles can be used are also mentioned, such as wastewater treatment and UV protection. This review sheds lights on the current trends in metallic nanoparticle synthesis and applications for the growing research community.

Keywords: *leaf extracts, fruits, metal oxide nanoparticles, antimicrobial agent*

INTRODUCTION

Nanotechnology is a field of science and engineering concerned with materials that are between 1 and 100nm in size. Nanoparticles (NPs) have gained a lot of interest in recent decades because of their special physicochemical features due to their small size, and high surface-area-to-volume ratios (Akter et al., 2018). Carbon nanoparticles, ceramic nanoparticles, metal nanoparticles, semiconductor nanoparticles, polymeric nanoparticles, and lipid-based nanoparticles are some of the nanomaterials being synthesized and applied. Over the last few years, NPs have become more widely used in industries, with applications ranging from food enhancers to drug delivery and nanomedicine (Yao et al., 2020; Yang et al., 2022). Additionally, antibacterial capabilities of some metallic NPs such as silver, copper, nickel, titanium dioxide and zinc are well recognised, with several, particularly silver, currently being employed in medical equipment to help disinfect equipment and reduce the transmission of contagious diseases (Mirel et al., 2022).

METAL BASED NANOPARTICLES

Metallic nanomaterials made up of a single element, a combination of two or more elements and/or their metal oxides have been widely studied due to their high electrical properties, high optical and magnetic properties. Among the various metals, silver, gold, copper, iron, titanium, zinc and their oxides are the most commonly researched and applied. These metallic nanomaterials have been shown to have good anti-oxidant, anti-inflammatory and antimicrobial actions, as well as tumor targeting and effective drug delivery capability. Thus, metal have been explored as potential alternatives for use in a variety of biological applications (Yaqoob et al., 2020).

GREEN SYNTHESIS OF METALLIC NANOPARTICLES

Due to their usage in biomedical and manufacturing purposes, the procedure for the synthesis of metal nanoparticles have been well researched in recent years. Nanoparticle synthesis approaches can be divided into three categories: physical, chemical, and biological (also referred to as green technique). The physical synthesis processes take a top-down approach, beginning with bulk metal that is fractionated into tiny bits by mechanical action and then further fragmented (Sánchez-López et al., 2020). This approach, despite its simplicity, however, involve high cost, as well as drawbacks such as the necessity to employ a huge amount of energy, high temperature and high pressure (Singh et al., 2015). On the other hand, the sol-gel approach, micro-emulsion method, hydrothermal synthesis, polyol fabrication, and chemical vapour synthesis are the common chemical procedures (Pal et al., 2019). Although the approach can produce a huge number of nanoparticles, but the chemicals used are hazardous, and the by-products produced can harm the environment as well as being cytotoxic and carcinogenic (Agarwal et al., 2017; Pal et al., 2019).

Presently, there is a rising demand to design environmentally friendly synthesis techniques which does not involve harmful compounds (Iravani et al., 2014). The utilisation of various plants or plant components for the bioreduction of metal ions into their elemental state in the range of sizes of 1–100 nm has been reported. Green synthesis is much more productive, easier, and cost-effective, and it can be easily scaled up to handle greater workloads (Iravani et al., 2014).

Plants have some benefits over other sources of biosynthesis because phytochemicals can serve as protective and stabilising agents, removing the need for a second process to avoid particle aggregation. Furthermore, cell culture methods are not required in this scenario, allowing for large-scale nanoparticle production in a non-aseptic situation. Besides that, plant-based techniques are both cost-effective and environmentally friendly (Zhang et al., 2016). In the green synthesis of NPs, numerous plant species and parts of plants have been employed. Earlier studies have shown that many plant components, such as leaf, root, stem, bark, bud, fruit, and latex, can be used to synthesise silver nanoparticles (Yarrappagaari et al., 2020). Table 1 lists a few examples of metal / metal oxide particles synthesized using the green approach.

Table 1: Examples of Metal Nanoparticles Synthesised from Plant Extracts

PLANT	PLANT PART	METAL NPS	EXTRACTION METHODS	REFERENCES
Vitis vinifera	Fruit	Silver Nickel oxide	Aqueous extraction	Hashim et al. (2020) Hussein et al. (2021)
Murraya koneigii	Leaves	Silver Copper oxide	Decoction extraction	Chahande et al. (2020) Pantawane et al. (2020)
Salvia officinalis *Thymus vulgaris*	Dried leaves	Silver	Decoction extraction	Odemis et al. (2022)
Artemisia aucheri	Aerial parts	Zinc oxide	Methanol extraction	Nezamabadi et al. (2020)
Liliaceae	Leaves gel	Zinc oxide	Decoction extraction	Agarwal et al. (2017)

Odemis et al. (2022) reported that siver NPs synthesized from dried leaves of sage (*Salvia officinalis*) and thyme (*Thymus vulgaris*) hot water extracts had crystalline and spherical structures with particle size of 42.3 and 50.4 nm respectively, based on X-ray diffraction analysis. On the other hand, ZnNP formation from leaf extract of aloe vera (*Liliaceae*) had the size range of 8-20 nm and spherical, oval and hexagonal shapes (Agarwal et al. 2017).

ANTI-MICROBIAL PROPERTIES OF GREEN SYNTHESISED NANOPARTICLES

Antimicrobial resistant microbes are one of the most significant causes of antimicrobial agent inefficacy. The ongoing evolution of bacterial resistance has presented a challenge and prompted the scientific community to search for and develop new antimicrobial agents. Metal NPs, that have demonstrated excellent antibiotic activities in a large number of trials, are one of the most potential of these emerging antimicrobial agents (Sánchez-López et al., 2020). As shown in Table 2, silver, zinc oxide, nickel oxide and copper oxide showed promising activities against a variety of Gram-negative and Gram-positive bacterial pathogens.

Table 2: Antimicrobial investigations of green synthesized nanoparticles

Metal Nanoparticles	Plant Extract	Microorganisms	Key Findings	References
Silver	*Vitis vinifera fruit*	*S.aureus, S.epidermidis and Listeria monocytogenes*	Strongest action against *S. aureus*	Hashim et al. (2020)
Silver	*Murraya koneigii leaves*	*E. coli, E. faecalis and P. aeruginosa*	More effective against Gram negative bacteria	Chahande et al. (2020)

Silver	*Sumac leaves*	*E. coli and S. aureus*	Exhibited good biocidal activities on both bacteria	Stular et al. (2021)
Silver	*Chara algae*	*S.aureus, E.coli, K.pneumonia, and P.aeruginosa*	Greater action against Gram-negative bacteria	Hassan et al. (2021)
Silver	*Salacia chinensis* L.	*S. aureus, S. pyogenes, E. coli, P. vulgaris, Aspergillus niger, Candida albicans*	Activities against S. aureus, P. vulgaris and C. albicans	Nagesh et al. (2022)
Zinc oxide	*Artemisia aucheri*	*E.coli and S.aureus*	More effective against *E.coli*	Nezamabadi et al. (2020)
Zinc oxide	*Nilgiriantusciliantus leaf*	*P.aeruginosa, E.coli, S.aureus and S.mutans*	Largest zone of inhibition was shown against *P.aeruginosa*	Resmi et al. (2021)
Nickel oxide	*Vitis vinifera* fruit	*K. pneumoniae and S.aureus*	More effective against Gram-positive bacteria	Hussein et al. (2021)
Copper oxide	*Murraya koenigii* leaves	*E.coli, K.pneumonia, E. faecalis and S.aureus*	More effective against *K.pneumonia* and *E. faecalis*	Pantawane et al. (2020)

NPs act by altering the permeability of cell membranes and also interfere with the functions of sulfur-containing proteins and phosphorus-containing compounds (such as DNA), making it difficult for bacteria to develop resistance to them. Further, due to the fact that they target multiple biomolecules at once, antimicrobial NPs are able to delay or even prevent the emergence of more resistant strains (Furno et al., 2004). Among all the metal NPs, silver NPs is the most investigated and commonly employed (Sánchez-López et al., 2020).

The antimicrobial property of NPs makes them advantageous in a range of aspects such as biological sciences, cosmetics, healthcare and environmental pollution (Jagwani et al., 2021). Amina et al. (2021) reported that the bionanocomposite of Ag-MgO synthesised from *L. sativum* seed oil showed antibacterial activities against *S. aureus* and had the potential to be developed as an anti-microbial agent. Besides, nanomaterials have demonstrated a significant role in environmental pollution remediation, mainly in the remediation of wastewater and groundwater. According to new research from Swathi et al. (2021), iron oxide NPs exhibit significant antibacterial efficacy against microorganisms that cause waterborne illnesses. In addition, titanium oxide was used in the creation of antimicrobial textiles for developing fabric-protective face mask due to their potential antibacterial action (Jung et al., 2022)

CONCLUSION

This paper summarized some novel strategies for the synthesis of metal NPs utilizing the "green approach" for employment in various biological and biotechnological applications. Extracts from various plants and plant parts are promising in facilitating the green synthesis of metallic nanoparticles. Their anti-microbial activities against Gram-positive and Gram-negative pathogens have been demonstrated in numerous studies. Thus, nanoparticles based on plant sources have the potential to be widely employed in healthcare and medicine as antimicrobial therapeutic agent, in wastewater remediation as well as in the industry to develop equipment, fabrics or other materials with anti-microbial functions. This review sheds lights on the current trends in metallic nanoparticle synthesis and applications for the growing research community.

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