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The Application of Metallic Nanoparticles Derived from Medicinal Plants in Therapeutic Applications

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Abstract

The use of theranostics has piqued the interest of modern scientists. In recent years, researchers have attempted to capitalise on theranostics' potential applications in a variety of fields. Theranostics is a broad field of science that seeks to develop complex diagnostic and therapeutic agents. It is also established that when these cutting-edge systems are combined into a single platform, they are capable of bridging the biodistribution and site specificity gap between imaging molecules and therapeutic agents. At the moment, theranostics uses nanotechnology to deliver active pharmaceutical ingredients (APIs) to absorption sites, resulting in increased bioavailability. In addition to the benefits mentioned above, theranostics have been proposed to be potentially effective in a variety of ailments, particularly cancer, malaria, microbial diseases, and cardiovascular diseases through the use of MNPs. Furthermore, theranostics are important in personalised medicine because they can be developed based on biomarker identification. Because of their versatility, MPNs are among the most promising diagnostic and therapeutic entities in modern medicine. Recently, there has been a significant increase in the biosynthesis of MNPs from medicinal plants, which is critical for the development of theranostics. Medicinal plants are a dependable and necessary source of natural bioactive compounds.

Keywords: Microbial diseases • Cardiovascular diseases • Metallic nanoparticle

Introduction

The use of theranostics has piqued the interest of modern scientists. In recent years, researchers have attempted to capitalise on theranostics' potential applications in a variety of fields. Theranostics is a broad field of science that seeks to develop complex diagnostic and therapeutic agents. It is also established that when these cutting-edge systems are combined into a single platform, they are capable of bridging the biodistribution and site specificity gap between imaging molecules and therapeutic agents. At the moment, theranostics uses nanotechnology to deliver active pharmaceutical ingredients (APIs) to absorption sites, resulting in increased bioavailability. In addition to the benefits mentioned above, theranostics have been proposed to be potentially effective in a variety of ailments, particularly cancer, malaria, microbial diseases, and cardiovascular diseases through the use of MNPs. Furthermore, theranostics are important in personalised medicine because they can be developed based on biomarker identification. Because of their versatility, MPNs are among the most promising diagnostic and therapeutic entities in modern medicine.

Recently, there has been a significant increase in the biosynthesis of MNPs from medicinal plants, which is critical for the development of theranostics. Medicinal plants are a dependable and necessary source of natural bioactive compounds. According to reports, 80% of the world's population still relies on medicinal plants for primary healthcare and the development of a wide range of medicines. Over 40% of pharmaceutical formulations are currently derived from natural ingredients, including commercially available medicines like digoxin, chloroquine quinine, lumefantrine, atovaquone, aspirin, and artemisinin. Nanoparticles (NPs) are materials with the longest dimension of 100 nm, with metal nanoparticles being the primary material. The use of NPs has resulted in significant improvements in nanomedicine, particularly in terms of reducing dosing frequency, improving drug solubility, and increasing the half-life of some drugs; this has resulted in commendable changes in targeted drug delivery.

NPs have also been shown to be more selective and sensitive in disease diagnosis, particularly in cancer. Recent advances in nanomedicine include the use of biosynthesized MNPs as nano-vehicles for optimal drug delivery. As a result, research on the biosynthesis of MNP using medicinal plants is gaining traction as an emerging field of science. Medicinal plants contain phytochemicals that can be used to replace chemical-reducing agents like sodium citrate, sodium borohydride, and ascorbate, which are extremely toxic, expensive, and, in many cases, harmful to the environment. As a result, multiple physicochemical approaches have been used to engineer MNPs, including the cost-effective use of medicinal plant parts such as leaves, fruits, stems, roots, and seeds.

Literature Review

Plant extract phytochemicals such as polysaccharides, flavonoids, phenolic acids, and alkaloids have been shown to effectively reduce metal ions such as Ag^{+}, Cu^{2+}, and Au^{3+}. Furthermore, phytochemicals play an important role in the capping, stabilization, and chelation of NPs during their formation. As a result, phytochemicals are ideal entities for MNP biosynthesis. It is also emphasised that the biosynthesis of MNPs with medicinal plants improves the safety profile of theranostics agents due to a reduction in expected toxicity [1-3]. Traditional physical and chemical procedures for producing MNPs have been reported to be more labor-intensive and toxic. On the other hand, biologically-mediated synthesis, which employs a variety of biological systems such as bacteria, fungi, and medicinal plant extracts, has the potential to produce large quantities of MNPs with specific sizes in a safer and more sustainable manner. This review focuses not only on current medicinal plant-derived MNPs, but also on highlighting the gaps in the field of theranostics.

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Phytochemicals derived from medicinal plants used in the green synthesis of mnps

Green nanotechnology is derived from green chemistry, which aims to create appropriate phytoformulations. Green nanotechnology's versatility has extended to the synthesis of NPs and nanoproducts, which have greatly contributed to environmental sustainability. The use of medicinal plants in nanoparticle formulation is of interest because they are easily accessible and provide a diverse range of metabolites that are required in the formulation of NPs. In this regard, green nanotechnology employs medicinal plants to synthesise nanomaterials such as MNPs that may be useful in the diagnosis and treatment of a variety of diseases. The use of medicinal plant-derived MNPs is less dangerous and less expensive. Furthermore, the literature suggests that the sizes and shapes of plant-derived MNPs can be altered to meet the formulation requirements. Regardless of the advantages of using plant-derived MNPs, their safety profile is still questionable. MNPs have been reported to have low biocompatibility, making formulation in the desired medium difficult. Furthermore, some MNPs are poorly biodegradable and may cause cumulative toxicity.

The role of medicinal plants in modern medicine is critical because they provide a consistent source of diverse and numerous chemical entities required for MNP biosynthesis. MNPs are synthesised using medicinal plant-derived phytochemicals such as alkaloids, flavonoids, saponins, tannins, phenols, and terpenoids [4,5]. These compounds function as reducing, capping, and stabilizing agents that interact with NPs by reducing MNPs. In this regard, researchers are looking into phytochemicals that can be used in conjunction with MNPs to manage diseases. Leaves, flowers, roots, stem bark, and fruits are commonly used in the green synthesis of MNPs and are added to an aqueous solution of metal ions to begin the biosynthesis process.

Discussion

Phytochemicals found in medicinal plant extracts include flavonoids, phenols, terpenoids, and organic acids, which are mostly used as stabilising and reducing agents. Capping agents are known to stabilise NPs by preventing NP agglomeration. Furthermore, capping agents have a significant impact on the morphology of nanostructures. It is also suggested that the molecular weight (MW) of phytochemicals used as capping agents has a significant impact on nanoparticle assembly behaviour, as it influences the van der Waals interaction, capillary interaction, and hydrogen bond effect. During the synthesis of nanoparticles, particularly MNPs, a reducing agent converts metal ions to nanometal. The biosynthesis method necessitates a thorough understanding of raw materials such as plant extracts, especially in relation to their synthesis into nanometals. Finally, the use of biosynthesis methods in the synthesis of MNPs, such as reducing, capping, and stabilising agents, has increased dramatically. The metabolic pathways, phytochemical content, enzyme activity, cell proliferation, and appropriate reaction conditions must all be considered when selecting the best organisms for extract synthesis [6-8].

There is an urgent need for clean, dependable, and environmentally friendly methods to counteract the already known hazardous methods, which primarily use toxic materials. As a result, eco-friendly nanoparticle manufacturing methods based on medicinal plant extracts, microorganisms, and some marine algae have emerged. Biological techniques have recently provided a superior platform for the synthesis of MNPs such as AgNPs. In comparison to the chemical and physical approaches, the green synthesis method has the most advantages because it is cost-effective, environmentally friendly, and simple to scale up for large-scale synthesis without the use of energy, high pressure, high temperature, or hazardous chemicals.

Metallic Nanoparticle Synthesis (MNPS)

The method of preparation for MNPs is critical during nanoparticle synthesis. Physical and chemical synthesis techniques are known to be potentially toxic, and frequently expensive compounds are used in the synthesis and stabilisation of MNPs, resulting in environmentally hazardous by-products. Factors such as the kinetics of metal ion interaction with a reducing agent, the absorption process of a stabilising agent with MNPs, and various experimental techniques all have a significant impact on the NPs' morphology, stability, and physicochemical properties. Many methods are used in the synthesis of MNPs, which can be divided into two broad categories: bottom-up methods and top-down approaches. The top-down approach is the process by which bulk matter is broken down by physical methods, such as pulverization, until it is the size of a small nanoparticle. Small atom-sized matter is built up using chemical methods, i.e., chemical reduction, until NPs are synthesised in the bottom-up approach.

The breakdown technique (top-down) is commonly used in the synthesis of MNPs using physical and chemical techniques. Physical forces such as grinding, pulverization, and other methods are used in the top-down approach, also known as the mechanochemical method, to reduce the size of bulk material as a precursor to the nanosize. Bottom-up strategies include the coalescence or assembly of atoms by atoms, molecules by molecules, and clusters by clusters, resulting in a yield with a wide range of NPs. Plasma or flame spraying, chemical vapour deposition (CVD), sol-gel processing, self-assembly of both monomer and polymer molecules, chemical nanostructural precipitation, laser pyrolysis, and bio-assisted synthesis are all used in the synthesis of NPs.

Conclusion

The diagnostic use of medicinal plant-derived MNPs in general appears to be in its infancy. The majority of studies have used MNPs derived from chemical and physical synthesis, with little information available on the use of plant-derived MNPs as potential diagnostic tools. Olax scandens was studied to demonstrate the self-fluorescence properties of Ag-Cu nanocomposites in microbial cells. Based on the findings, the authors concluded that Ag-Cu nanocomposites exhibited red fluorescence in bacterial cells while exhibiting no fluorescence in untreated cells. MNPs' surface plasma resonance (SPR) properties, for example, have sparked a lot of interest due to their distinct characteristics. The size, shape, composition, optical properties, and internal particle interactions of the particles, as well as the dielectric properties of the surrounding fluids, all play important roles in MNP SPR. Metal nanoparticles' SPR can be adjusted from UV to near-infrared (NIR), and this prosperity can be used in biosensing.

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Conflict of Interest

No potential conflict of interest was reported by the authors.

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