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Research article

Insights Into Green Synthesized and Chemical Synthesized Nanoparticles for Biomedical Applications

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Abstract

Nanotechnology currently garners substantial attention due to its capacity to alter metals' chemical, physical, and optical attributes through nanosizing. Consequently, a significant emphasis exists on devising novel approaches that utilize biological sources to synthesize diverse nanoparticles with specific sizes and compositions. Most current approaches are costly, environmentally harmful, and inefficient in using materials and energy. The properties of nanoparticles are affected by a range of factors such as time, temperature, pH, and ambient conditions. The potential of eco-friendly nanoparticles is also evident in agriculture, which can safeguard the environment and enhance agricultural productivity. Moreover, the thorough characterization of synthesized nanoparticles is paramount, especially in their potential applications in drug delivery and biomedicine. Green-synthesized nanoparticles excel in biocompatibility and sustainability, while chemically-synthesized nanoparticles provide precise control and functional versatility. The choice between these approaches depends on specific biomedical demands, cost factors, and the desire for sustainable healthcare solutions. Harnessing the strengths of both synthesis methods holds the potential to revolutionize biomedical applications, advancing healthcare accessibility and efficacy. This review paper mainly focuses on green synthesis, chemical synthesis, economic impact and biomedical application.

Keywords: Green synthesis, chemical synthesis, economic impact, biomedical applications

1. Introduction

Nanotechnology is a branch of science concerned with nanometer-sized particles, also known as nanoparticles (NPs). Nanomaterials are solid entities with dimensions between 1 and 100 nanometers. Nanomaterials show promise in antibacterial therapy as a result of their enhanced and distinct physicochemical properties, such as their extremely small dimensions, large surface area relative to their mass, and increased reactivity [1, 2]. El-Belely et al. [3] say that nanoparticles are parts of nanometers widely used in medicine, environmental defense, sunscreen, and cosmetics. Researchers in material science fields face problems when they try to study biomaterials. Researchers waste a lot of time developing new ideas, especially regarding plastics used in medicine and microorganisms resistant to antibiotics [1]. Physical and chemical differences can be seen in nanocomposite materials' mechanical and biological characteristics (Figure 1)[4]. A nanoparticle has better qualities than bulk materials and could be used in many ways in the real world. It has a smaller ratio of surface area to volume and important properties like being flexible, strong, and able to carry electricity. This material is stronger and sticks together better than bulk materials that are made of the same chemicals [5].

Nanoparticles made using biological means or green technology have different properties and are more stable and the right size because they are made in a single step. Many bad processing conditions are handled by letting the synthesis happen at average temperatures, pH, and pressure at a negligible cost [5, 6]. Specific characterization methods can determine how synthesized nanoparticles might be used in the drug delivery and biomedical fields. NPs are used as supercapacitors because they have a high energy density, are electrochemically active, are suitable for the environment, are easy to find, and are cheap. ZnO nanoparticles have been used to remove arsenic and sulfur from water because they have a lot of surface area. Compared to green synthetic ways, these have problems, like being hard to use, expensive, giving off radiation, needing very high pressure, and being toxic [7]. The buildup of dangerous chemicals on the surface of some technologies makes it harder for them to be used in medicine. This review paper looks at how green and chemical syntheses compare their economic effects and medical uses.

2. Green Synthesis/Methods of Extractions

Green-synthesized nanoparticles, which are made using eco-friendly processes, have several benefits. They are ideally suited for biomedical functions because of their innate biocompatibility, which lowers the possibility of negative reactions when interacting with biological systems [7]. These nanoparticles are a perfect fit for the expanding need in healthcare for environmentally friendly and sustainable solutions. When natural or renewable materials are used in their synthesis, the environmental impact is reduced and a more conscientious approach to nanoparticle synthesis is encouraged. Additionally, some green synthesis techniques can be economical, which could result in more reasonably priced medical diagnoses and therapies. Furthermore, biomolecules can be easily functionalized onto these nanoparticles to enable targeted drug administration, molecular imaging, and the development of customized medicine strategies [1,7,8].

Green synthesis is the process of making materials, chemicals, or nanoparticles in a way that is good for the environment and has a small amount of environmental damage. This method often involves using resources that can be replenished, things that break down, and reaction conditions that do not harm the environment. Upadhyay et al. [8] say that the sizes of avocado fruits were cut and washed six times by double distillation and three times by ethanol to make them smaller. A magnetic mixer was used to keep heating 16 g of avocado and 170 mL of double-distilled water for 30 minutes. The watery solution made from avocado extracts was filtered with Whatman paper and kept at room temperature until needed. Using a triple bean balance, 10 g of $Zn(NO_3)$, $2.6H_2O$ was weighed and dissolved in 30 mL of double-distilled water for 30 minutes using a high-speed magnetic stirrer at a constant temperature. Then, 1.75 M of avocado extract was added to the $Zn(NO_3)_2.6H_2O$ mixture, which was mixed all the time for 1 hour. Now, the solutions had sat for 24 hours at room temperature. Papaya and mango were handled in the same way.

3. Chemical Synthesis Methods of Nanoparticles

Nanoparticles that are chemically manufactured offer exact control over their dimensions, form, and surface characteristics. Because of their accuracy, nanoparticles may be customized to fit certain biological needs, which makes them useful for applications like cancer treatment, drug administration, and imaging [9]. Chemical synthesis's consistency and reproducibility guarantee the dependability of medical interventions and diagnostics, which is essential for regulatory approval and clinical application. Furthermore, the chemically produced nanoparticles' functional diversity allows for the attachment of diverse functional groups, increasing their versatility for a range of biomedical applications, such as the targeted delivery of medicines. These approaches for chemical synthesis remain the focus of much study, which is pushing the frontiers of biomedical innovation with the discovery of new materials and processes [9].

As salt precursors, $Zn(NO_3)_2.6H_2O$, $Zn(CH_3COO)_2.2H_2O$, and $ZnSO_4.7H_2O$ were used in the chemical synthesis. NaOH, PVA, and KOH were used as reducing agents. Zinc oxide nanoparticles were made using the method described in Brar et al. [9]. By using a beam balance, all of the zinc salts and reducing agents were analyzed. Twelve grams of the sodium hydroxide (NaOH) solution were mixed with 70 milliliters of

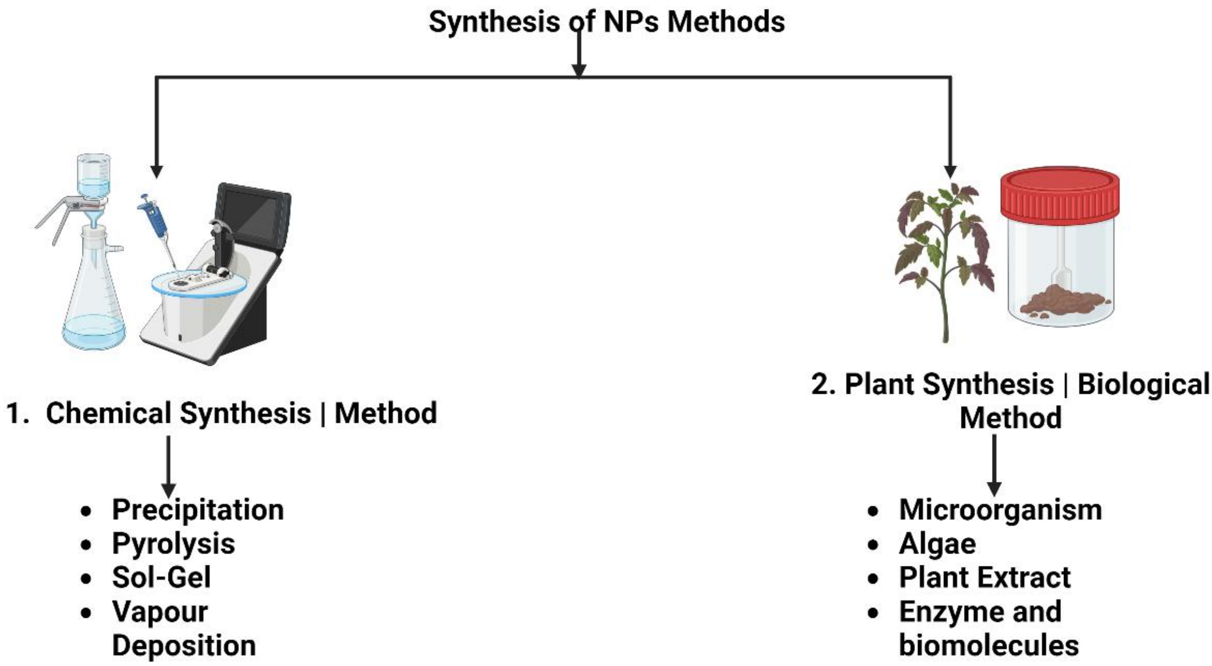

Figure 1 Chemical and plant methods for the synthesis of nanoparticles.

water distilled twice—thirty minutes under a soft magnetic mixer. Again, 4 g of $Zn(NO_3)_2.6H_2O$ was mixed into 30 mL of double-distilled water and stirred for 20 minutes. Drop by drop, the $Zn(NO_3)_2.6H_2O$ solution was added to the NaOH solution, which was constantly mixed for 2 hours at 60°C. At this point, gel-like solutions were made and left to cure in a 160°C oven for 10 hours overnight. Then, the sample was put in a kiln (Model: MC2-5/5/10-12, BIOBASE, China) and calcined at 300°C for 6 hours. Upadhyay et al., [8], did the same thing with zinc acetate ($Zn(CH_3COO)_2.2H_2O$) and zinc sulphate hydrate ($ZnSO_4.7H_2O$).

4. Economic Impact Synthesis of Green and Chemical Nanoparticles

The economic impact of green and chemical nanoparticles is multifaceted. Green nanoparticles, crafted through environmentally friendly processes, hold the promise of reducing environmental costs, opening up novel market opportunities, fostering innovation, and potentially offering cost efficiencies. As global sustainability gains prominence, demand for green nanoparticles in agriculture, energy, and healthcare is growing, stimulating economic growth. Moreover, these eco-friendly materials can navigate regulatory pathways more smoothly, further contributing to economic benefits [10]. On the other hand, chemical nanoparticles, renowned for their diverse applications, advanced materials, and research-driven innovations, play a pivotal role in industries ranging from electronics to pharmaceuticals. This versatility generates economic impacts through enhanced product quality, job creation, and participation in a global market. Ultimately, the economic impact of both green and chemical nanoparticles is influenced by market dynamics, governmental policies, and the quest for sustainable solutions. Balancing economic gains with environmental and health considerations is imperative for ensuring the long-term viability of the nanoparticle industry [9]. Certain conditions must be met when making nanoparticles to get the best results and shape you want. Some of these conditions and factors are the ratio of the volume of the extracting solvent to the amount of plant material, the temperature, the concentration of the precursor solution, the pH of the solution, the reaction, and the time it is left to sit. Iron oxide NPs are one of the most common metal oxide NPs. Because ferrous oxide nanoparticles (IONPs) have a unique property, they can be used in medicine and many other fields, like gas monitors, electrochemical, magnetic, and energy storage [10, 11].

4.1. Cost of nanoparticles

Facilitating the widespread utilization of nanoparticles in contemporary applications necessitates regulating and controlling their production costs. Hence, a pivotal factor influencing nanoparticle manufacturing is the cost-effectiveness of the production process. While the chemical synthesis method offers rapid returns, it aligns poorly with cost-saving endeavours. Consequently, the feasibility of producing nanoparticles through chemical and physical approaches may be constrained, whereas the biological approach presents a more economical and scalable alternative [11].

The properties of nanoparticles are intricately linked to their size. Akbari et al. [11] established that their melting points decrease as nanoparticles reach the nanometer scale. Moreover, nanoparticles exhibiting different shapes possess comparable energy levels, rendering them amenable to shape alteration. The energy typically employed for nanoparticle investigation plays a role in inducing shape changes. Baer et al. [12] demonstrated that the morphology and mobility of synthesized nanoparticles significantly impact their chemical properties, underlining the significance of such aspects.

4.2. Time

The duration the reaction medium can remain undisturbed significantly influences the quality and characteristics of nanoparticles produced through green technology. Baer et al. [12] observed that the attributes of the synthesized nanoparticles also underwent alterations over time, with substantial sensitivity to the synthesis method, light exposure, storage conditions, and similar factors. Temporal variations can manifest in various ways, such as particle aggregation due to prolonged storage, size alteration due to extended storage duration, or even due to inherent shelf-life effects, all collectively impacting their potential [11].

4.3. pH

The pH level becomes a crucial factor when employing green technology approaches to synthesize nanoparticles. Studies have revealed that the size and morphology of the resulting nanoparticles are significantly influenced by the pH of the solution medium [13]. Consequently, adjusting the pH of the fluid can lead to modifications in the size of nanoparticles. Specifically, in the case of silver nanoparticles, altering the pH can directly impact their shape and size during the synthesis process [14].

It has been found that the pH, which is a measure of how acidic or basic the reaction medium is, is an important factor in making IONPs and other metal oxide NPs from plant materials. Jacob et al. [15] have written about how the pH of the solution medium affects the size and shape of NPs made from plant extract. So, Huang et al. [16] found that changing the pH of the fluid was a good way to control and change the shape and size of the NPs that were made. Lenders et al. [17] found that the best way for Aeromonas hydrophile to make IONPs was when the pH of the basic medium was between 7 and 9. It has been said that the biosynthesis that happens at pH 12 and 4 totally slows down the making of IONPs. This showed that conditions that are too acidic or too basic are not good for making IONPs from plant material [17].

4.4. Temperatures

Temperature stands out as one of the paramount factors influencing the physical, chemical, and biological methods of nanoparticle (NP) synthesis. According to Patra et al. [18], the green production of iron oxide nanoparticles (IONPs) via plant extracts necessitates a temperature range spanning 25 to 100 °C. However, many researchers lean towards room-temperature synthesis for IONPs due to the instability of secondary molecules within plant extracts required to bio-reduct iron ions at elevated temperatures. Notably, the shape of NPs is influenced by the temperature of the reaction solution, as highlighted by results from Patra et al. [18].

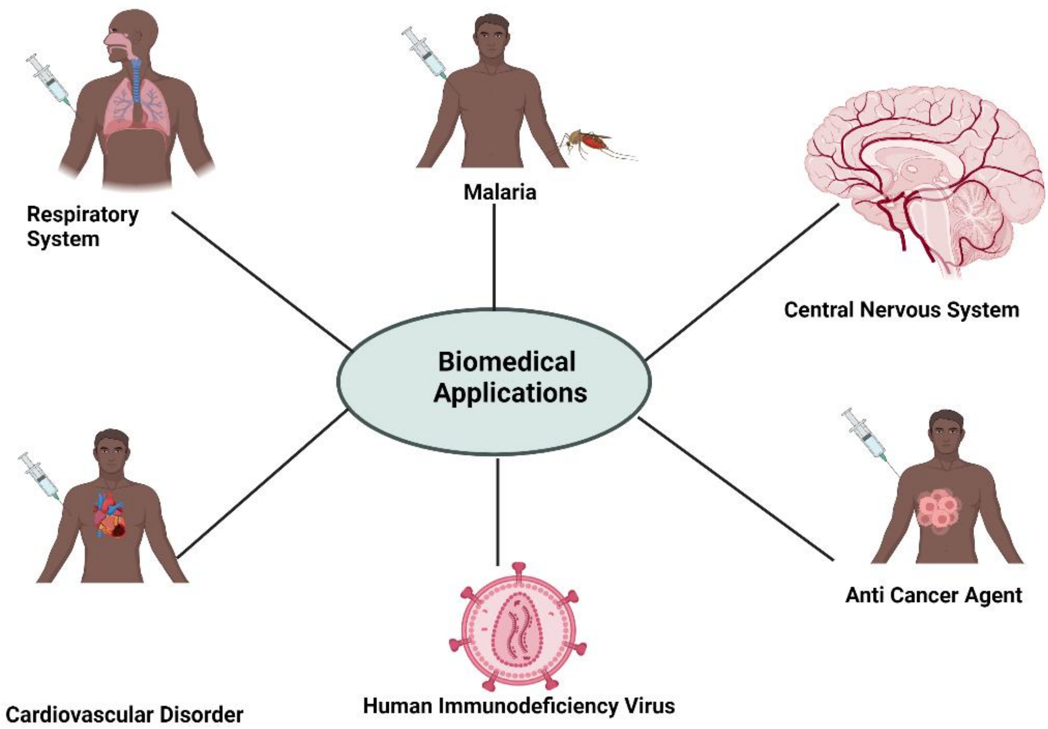

Figure 2 Green synthesis of metal nanoparticles and their applications

UV-visible studies of IONPs produced from various plant components within the temperature range of 30 to 40 °C demonstrated that completion of the synthesis occurred at 48 to 72 hours, indicating accelerated synthesis at higher temperatures. Conversely, the study revealed suboptimal IONP synthesis above 40°C due to the deactivation of biomolecules responsible for reducing the iron precursor, as elucidated by Rajendran & Sen [19].

4.5. Environment

The surrounding environment profoundly shapes the properties of nanoparticles, emerging as a pivotal determinant. Frequently, the transformation of a solitary nanoparticle into a core-shell nanoparticle occurs due to its interaction with the external milieu. This interaction involves absorbing materials from the surroundings or engaging with other substances, a process often facilitated by factors such as oxidation. This phenomenon underscores the intricate interplay between nanoparticles and their environment in sculpting their characteristics and behavior [21]. In biological systems, manufactured nanoparticles tend to develop a thicker and larger coating, altering their characteristics [22]. Additionally, the environment significantly impacts the resulting nanoparticles' physical shape and chemical composition. While limited instances demonstrate how the environment influences nanoparticle synthesis, specific observations stand out. For instance, their crystallinity immediately changed when zinc sulfide nanoparticles were transferred from a wet environment to a dry one. Similarly, the chemical properties of cerium nitrate nanoparticles vary according to the concentration of peroxide present in the surrounding fluid [13].

5. Biomedical Applications

Nanoparticles find extensive applications across diverse industries, the realm of biomedical sciences, the electronics sector various markets, the energy domain, and notably in the field of chemistry [23]. This multifaceted utility has sparked an escalating commercial demand for nanoparticles. Mainly, nanoparticles such as silver and gold, which rank among the most prevalent, have garnered significant attention due to their utilization in biomedical applications, the emergent nanotechnology field, and beyond [9].

Researchers have identified that naturally synthesized nanoparticles exhibit superior efficacy in treating diseases than nanoparticles produced through other physicochemical techniques. Plant-extracted metal nanoparticles manifest stability and easy degradability into distinct types, achieved by controlling variables like pH, temperature, retention time, and mixing proportions. Noteworthy examples of green metal nanoparticles stem from plant sources such as neem (Azadirachta indica) leaves, tulsi (Ocimum tenuiflorum) leaves, curry (Murraya koenigii) leaves, guava (Psidium guajava) leaves, and mango (Mangifera indica) leaves [25].

Metallic nanoparticles synthesized from various medicinal plants have demonstrated significant therapeutic attributes encompassing antimicrobial, insecticidal, antioxidant, wound-healing, antidiabetic, immunomodulatory, hepatoprotective, and anticancer activities (Fig. 2) [23]. Notably, Muhammad et al. [22] established that metallic nanoparticles sourced from medicinal plants offer substantial benefits within the biomedicine domain. The core concept driving the integration of green nanotechnology into agriculture revolves around its potential to mitigate environmental harm and reduce the expense associated with chemical applications. Green nanoparticles (GNPs) derived from diverse plant sources have additionally shown efficacy in curbing harmful emissions such as carbon dioxide, nitrous oxide, and methane. Furthermore, these nanoparticles augment agricultural productivity and mitigate health concerns among farmers.

The inherent phytochemical constituents within plants make them a valuable resource for this approach. Such constituents are cost-effective and environmentally benign. Green nanoparticles play a pivotal role in addressing the imperative of eliminating heavy metal pollutants from the environment. Notably, Jadoun et al. [23] demonstrated green nanoparticles' role in alleviating environmental toxicity, especially concerning heavy metal contamination in soil and water.

Given that various phytochemicals are distributed across different plant parts—roots, stems, leaves, seeds, and fruits—the method of synthesizing metallic nanoparticles through green synthesis is not only cost-effective but also less environmentally detrimental, proving more efficacious than other biological methods [9]. Generating green nanoparticles involves washing specific plant parts with tap or distilled water following extraction, filtration, and introducing specific salt solutions. Observable changes in solution colour signify successful nanoparticle production. Throughout the metallic nanoparticle synthesis process, phenolic acids such as ellagic acid, caffeic acid, protocatechuic acid, and gallic acid play a crucial role. Ali et al. [24] elaborate on the role of phytochemical agents that facilitate the reduction and stabilization of laboratory-produced metal nanoparticles.

6. Conclusion

Nanoparticles are being used more and more in the medical, food, pharmaceutical, and agricultural industries. There is much interest in developing more manageable ways to make eco-friendly, non-toxic, and harmless nanoparticles using tools from green biotechnology. The use of plants for green production of nanoparticles is an exciting and growing part of nanotechnology. It significantly impacts the environment and the field of nanoscience, making it more sustainable and allowing for more progress. Green nanotechnology research going on now and, in future, will give us a better understanding of the different factors that affect the green synthesis of nanoparticles and the most advanced technology that can be used to characterize the synthesized nanoparticles so that they can be used more effectively in the biomedical and pharmaceutical industries in the future.

Data Availability statement

The data presented in this study are available on request from the corresponding author.

Conflicts of Interest

All authors declare that, they have no conflict of interest.

Author Contributions

Mahreen Fatima - Methodology, original draft preparation ; Maham Fatima - Helped in revision, give suggestion and correction. Both authors read and granted to the published this version of manuscript.

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