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Green Synthesis: Nature's fingerprint in the world of nanotechnology (Review)

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Abstract

Abstract:
The field of nanomaterials This field is a promising area with diverse applications in industry, medicine, agriculture, food, and related sectors. Nanomaterials are characterized by dimensions ranging from(1- 100) nm and exhibit unique properties that differ significantly from traditional materials. Their properties can be controlled according to their shape, size, and synthesis conditions. Traditional methods for preparing nanomaterials, such as mechanical and chemical methods, are fraught with many drawbacks in terms of pollution and the use of hazardous chemicals. Therefore, researchers have turned to "green synthesis" methods, which rely on the use of plant natural and extracts materials, contributing to reducing the toxicity of synthesized nanomaterials, minimizing environmental impact, and increasing the effectiveness of drugs against microorganisms and in treating diseases. Research shows that nanoparticles prepared using green methods and plant extracts are highly effective, especially in medical applications as antimicrobial and antioxidant agents. This encourages reducing the use of chemical additives in food products. These particles have been characterized using several sophisticated instruments, including UV, SEM, AFM, XRD, FTIR, and TEM. The factors affecting green methods, such as temperature and pH , reducing agent concentration, and reaction time, have also been discussed.

Keywords: *Green Synthesis,Nanomaterials, Medical Applications, Plant Extracts, Bioactivity*

المستخلص:

مجال المواد النانوية هو من المجالات الواعدة ذات التطبيقات المتنوعة في المجالات الطبية والصناعية والزراعية والغذائية والمواد النانوية تمتاز بكونها تملك أبعادًا تتراوح بين (1-100 nm) وتظهر خصائص فريدة تختلف تمامًا عن المواد التقليدية، ويمكن التحكم في خصائصها حسب الشكل والحجم وظروف التركيب.
تُعتبر الطرق التقليدية لتحضير المواد النانوية، مثل الطرق الميكانيكية والكيميائية، محفوفة بالكثير من المساوئ من حيث التلوث واستخدام المواد الكيميائية الخطرة. لذا فقد اتجه الباحثون لاستخدام أساليب "التخليق الأخضر" التي تعتمد على استخدام المستخلصات النباتية ومواد طبيعية، مما يساهم في تقليل سمية المواد النانوية المخلقة وتقليل الأثر البيئي وزيادة فعالية الأدوية ضد الكائنات الدقيقة ومعالجة الامراض .
تظهر الأبحاث أن الجسيمات النانوية المُحضرة بالطرق الخضراء والمستخدم فيها مستخلصات نباتية ذات فعالية عالية ، خصوصا في التطبيقات الطبية كعوامل مضادة للميكروبات ومضادات أكسدة، وهذا يشجع على تقليل استخدام المضافات الكيميائية في المنتجات الغذائية ، وتم كذلك تشخيص وتوصيف تلك الجسيمات بالعديد من الاجهزه الدقيقة منها (,FTIR, UV, SEM,AFM,XRD جهد زيتا ,TEM)، ووكذلك التطرق للعوامل المؤثرة على الطرق الخضراء ومنها (Ph ودرجة الحرارة وتركيز المواد المختزلة وزمن التفاعل).

الكلمات المفتاحية: التخليق الاخضر، المواد النانوية،التطبيقات الطبية،المستخلصات النباتية ، النشاط الحيوي

1. Introduction

Nanomaterials are highly efficient in a wide range of medical, industrial, agricultural, and food applications. They must be at least one-dimensional. Nanomaterials can be prepared with distinct electromagnetic, catalytic, optical, and mechanical properties that differ significantly from conventional materials. Their properties can be tailored as desired. This Scientists can achieve this by controlling their size, shape , composition, and function. The most common methods for preparing nanomaterials are top-down and bottom-up. There are many different types of nanomaterials synthesized using various methods, these include fluorenes, graphene, carbon nanotubes, carbon quantum dots, shell-nucleus nanoparticles, porous nanomaterials, and metal-based nanomaterials (Nadeem *et al*., 2021).

Several methods have been used to prepare nanoparticles. These include, physical, chemical and green methods, among others. Green methods have gained wider acceptance than other methods. This is because they are environmentally friendly and reduce the toxicity produced by chemicals used in chemical preparation. Natural extracts from various plants have been used to prepare nanoparticles. These extracts have played a significant role in eliminating a wide range of bacteria that cause human diseases (Al-Kalifawi *et al*., 2017).

Plant extracts contain potent reducing agents, including alkaloids, flavonoids, phenols, tannins, and alcohols. These agents possess a high capacity for reducing metal ions into very small and stable nanoparticles (Makarov *et al*., 2014). Plant extracts are also characterized by containing active compounds with stabilized and anti-caking properties. These active compounds help prevent agglomeration. They transform the extracts into nanoparticles and surround them (Ali *et al*., 2021).

Plants are wealthy materials of medicinal substances. They possess the ability to produce simple ions, by reducing the amount of degraded metals, they can be used. Highly effective rice husks have been used in the treatment of industrial wastewater. They are a well-documented and widely used technique in flocculation and reverse osmosis. They also represent a safe and sustainable alternative to other water treatment methods. (Sulaiman *et al*., 2025).

Nanoparticles prepared using green methods have shown significantly greater antimicrobial activity compared to those prepared using physical and chemical methods. This is due to the toxic nature of the chemicals used in the preparation of these nanoparticles. These toxins cannot be completely removed, which limits their biological applications. Therefore, nanoparticles prepared using green methods are more active in antimicrobial, antioxidant, and anticancer properties (Alarifi *et al*., 2016; Khan *et al*., 2020).

The current study aims to review green Synthesis, nature's fingerprint in the world of nanotechnology.

Traditional Methods for Preparing Nanomaterials

1. Mechanical and Physical Methods:

There is a wide range of mechanical methods for preparing nanomaterials, such as hard grinding using steel balls. This method grinds the material into an extremely fine powder. The particle diameters reach the nanoscale (1-100). This grinding differs from the traditional ball milling method (Rajendran *et al*., 2013). Also, the rubbing method, where metal sheets are placed in chemical solutions. These sheets are rubbed to obtain nanoparticles. Another method is the electrochemical method. In this method, two electrodes are used, one positively containing silicon and the other negatively containing polycarbonate. They are placed in a chemical bath to obtain nanoparticles (Al-Hadidi, 2019). Additionally, the spray and evaporation method is used to prepare nanomaterials using thermal means in the spray process. In this process, atoms and molecules are displaced from the solid target through the action of ions. The gaseous (plasma) method can also be further divided into several approaches, depending on the specific techniques used to activate the source atoms or molecules, or the preparation objective, in addition to the applied deposition conditions (Cardenas *et al*., 2007).

2. Chemical Methods:

These are among the most commonly used methods for preparing nanomaterials and small-sized particles. The most important of these methods are reduction of transition metal salts chemically, thermal decomposition, photochemical decomposition, and reduction and displacement methods. using organic metals, and electrochemical reduction methods. The solvent-dispersed nanoparticle method is the most common (Rajendran *et al*., 2013). The nanoparticles produced by these methods are approximately uniform in size. In contrast, other methods produce nanoparticles with varying sizes (1-100) (Lane *et al*., 2002). However, despite the precision of chemical methods, they are not entirely free from toxicity due to the use of hazardous chemicals during particle preparation. Therefore, nanoparticles are often prepared using environmentally friendly methods, such as sugar, plant extracts, starch, and amino acids (Oremland *et al*., 2004).

Disadvantages of Using Traditional Methods in Nanomaterial Production:

Nanotechnology plays a crucial role in the scientific community, and due to its numerous applications and increasing demand, traditional synthesis techniques have been employed. These techniques rely on carcinogenic materials, in addition to significant energy consumption for producing nanomaterials and the resulting pollution. These traditional synthesis methods necessitate the development of less harmful, environmentally friendly synthesis methods. Therefore, scientists are working diligently to find suitable solutions, to mitigate the harmful effects of these hazardous industrial methods. Natural biological systems have been developed for synthesizing nanomaterials, known as "green" nanomaterial synthesis, comparing green synthesis to traditional synthesis, it becomes clear that the former is just as effective, or even more so, using energy-efficient methods and natural raw materials, it also provides a sustainable way to produce nanomaterials, according to recent research, introducing active chemicals into natural biological systems, such as bacteria, yeast, algae, and fungi, has led to the production of diverse arrays of useful nanoparticle systems. Therefore, the application of green synthesis in research and production has been considered an effective and large-scale method, to overcome the drawbacks of traditional synthesis methods (Mustafa *et al*., 2024). Nanoparticles prepared using green methods have demonstrated significant effectiveness against microorganisms, compared to those prepared using physical , chemical methods. This is due to the toxic nature of the chemicals, used in the preparation of these nanoparticles, as these toxins cannot be completely removed, which limits their biological applications. Therefore, nanoparticles prepared using green methods, are more suitable for biological applications because they are less toxic and possess high antimicrobial, antioxidant, and anticancer activity (Khan *et al*., 2020).

The Role of Plants in Nanomaterial Production:

Researchers have recently focused on using various biological systems, including plants, to achieve high production of nanomaterials of specific sizes. Green synthesis is a significant branch of nanotechnology. It is safe for food applications, low-cost, and environmentally friendly, in addition, plants are abundant (Al-Hadidi, 2019). Green methods have gained considerable importance due to their use of plant extracts. These extracts are considered an inexpensive, simple, and applicable alternative in physical and chemical experiments. Green methods utilize non-toxic, natural materials to synthesize nanomaterials. These methods employ natural materials, with high reducing capacity and non-toxic solvents such as water (Ramesh *et al*., 2012).

Despite the existence of numerous complex and costly methods for preparing nanomaterials, such as ultrasonic methods (Kumar *et al*., 2014), microwave methods (Yao *et al*., 2010), wet chemical methods (Banerjee *et al*., 2014), and sol-gel methods (Gamez *et al*., 2013), these methods are undesirable due to their use of toxic substances and high costs. They also produce hazardous and toxic waste. Therefore, recent studies have focused on biological methods, which are safer for producing large quantities of nanoparticles in non-toxic aqueous media, using plant materials, including leaves (Kumar *et al*., 2014).

Plants have demonstrated a remarkable capacity for detoxification. This is due to their ability to eliminate heavy metals. They utilize this capacity through their tissues, which contain cellular structures. In addition, they employ physiological processes to detoxify metals, these processes involve inhibiting ion movement and eliminating them. One of the most important mechanisms responding to stress is the presence of oxidation-reduction metabolites. These metabolites play a key role as reducing agents in the biosynthesis of nanoparticles (Al-Hadidi, 2019).

Plants, algae, and fungi have been used to prepare low-cost, non-toxic, and environmentally friendly nanomaterials (Kushik *et al*., 2010). Therefore, green methods are considered among the traditional approaches. The nanomaterials consumed and prepared using these methods are not hazardous. Thus, they are considered an effective, easy, low-toxicity, and environmentally friendly method (Mary and Inbathamizh, 2012). Methods using sucrose via plant extracts and microorganisms have emerged as a straightforward and convenient alternative to traditional chemical and physical approaches. (Sri Sindhura *et al*., 2014). Plant-mediated preparation of nanoparticles is safer and more beneficial than other biological methods. There are no issues with their preservation, and they are easy and straightforward to produce using a single method. There are also no opportunities for mutation, unlike in microorganisms. Often, the preparation of nanomaterials using microorganisms is more expensive than that using plant extracts (Veerasamy *et al*., 2011). The flavonoid terpenoids and alkaloids found in plant extracts play an important role. They are primarily responsible for the stability of nanoparticles (Dubey *et al*., 2009).

Plant Extracts and Their Role in Reduction:

Due to the specific conditions and high costs required by traditional methods for synthesizing nanoparticles, researchers have turned to using plant extracts for this purpose. Plant extracts possess important characteristics, such as their role as reducing and stabilizing agents, their low cost, and their environmental friendliness. In addition to their important biological and pharmacological properties, they have become widely used in food applications (Harjeet *et al*., 2023). The synthesis of nanomaterials is carried out, using plant extracts under uncomplicated ambient conditions of pressure and temperature, resulting in energy savings and harm to humans or reduced toxicity and the environment. Plants are a renewable resource containing important and powerful reducing agents, enabling the stability and required sizes of nanomaterials. This eliminates the need for chemical materials (Bandeira *et al*., 2020; Galdopórpora *et al*., 2021).

Using plant extracts is a faster and more efficient method than microbial methods for synthesizing nanoparticles. It is more efficient, produces larger quantities, and results in more stable nanoparticles (Al Salman and Al-Gharawi, 2019; Santo-Orihuela *et al.*, 2022). Plant extracts contain powerful reducing agents, including alkaloids, flavonoids, phenols, tannins, and alcohols. These agents have a high capacity to reduce metal ions into very small and stable nanoparticles. Furthermore, plant synthesis plays a significant role in obtaining nanoparticles with desirable and distinctive properties (Krestinin *et al.*, 2015). Plant extracts are also characterized by containing active ingredients with stabilizing and anti-caking properties (Ali *et al*., 2021).

Plants are have Active Compounds medicinal substances and possess the ability to produce simple ions, by reducing reduced metals. Several plant extracts have been used in nanoparticle synthesis, for example, hibiscus and lime extracts have been used to synthesize Cr_2O_3 nanoparticles (Obodi *et al*., 2017). Green synthesis of chromium oxide nanoparticles has also been employed. An extract of the leaves of the plant Abutilon indicum was used as a reducing agent to prepare these particles (Shakeel *et al*., 2021). Cauliflower extract has also been used as a plant reducing agent, for the purpose of synthesizing Cr_2O_3 nanoparticles. This resulted in nanoparticles with very small diameters (Ali *et al*., 2021).

Studies have shown that prickly‑ pear extract can act as an efficient reducing agent in the synthesis of Cr_2O_3 nanoparticles. The resulting particles exhibit potent antimicrobial and anticancer activities (Javed et al., 2020). A separate investigation reported that an extract of R. virgata can also be used to produce chromium‑ oxide nanoparticles, where the extract functions as both a reducing and a stabilizing agent. These nanoparticles have been found to be effective against a variety of human parasites. (Javed *et al.*, 2020).

Active Compounds and Their Role in Nanoparticle Preparation:

Extraction is a necessary and crucial step in the isolation, identification, analysis, and utilization of active compounds. Unsuitable extraction conditions lead to a decrease in the yield of active compounds, or cause undesirable changes in their biological activity (Dai and Mumper, 2010). The choice of solvent influences the extraction of active compounds because the polarity of the compounds differs among chemical groups. Low‑molecular‑weight phenolic acids and flavanols are efficiently extracted with water or alcohols such as ethanol or methanol, whereas polymerized procyanidins are best obtained using an aqueous acetone solution. Commonly employed solvents include methanol, ethyl acetate, ethanol, acetone, and various mixtures of these with water in differing ratios to optimize the retrieval of active constituents from plant material. (Ramirez-Coronel *et al*., 2004).

Phenolic compounds were obtained twice as high, and in the same study it was shown that the use of hexane solvent leads to slightly higher phenolic compounds than the use of water, but its efficiency is lower than that of ethanol (Kivrak *et al*., 2017).

Higher phenolic compounds were also obtained in boiling water after 3 hours, compared to water at room temperature after 3 days. Phenolic compounds were also higher in water at 80°C for 45 minutes (Bulut *et al*., 2020). High temperatures improve the yield of important active compounds in the reduction process. However, extraction at high temperatures increases the likelihood of undesirable reactions, such as oxidation and hydrolysis of phenolic compounds. Consequently, their yield in the extract is reduced (Biesaga and Pyrzy, 2013).

At the same time, the extraction time factor cannot be ignored, as it is crucial. Similarly, the solvent quantity is important because increasing the solvent concentration enhances the extraction process. However, it is advisable to determine an optimal solvent ratio when using any extraction method. This is to minimize interference and the saturation effect. Various ratios have been used in extraction experiments for reducing active compounds from plant materials. A 1:12 ratio (solvent: plant material) has been found to be the most commonly used ratio in extraction experiments (Wong-Paz *et al*., 2017). Other studies have shown that a 6:1 ratio (plant material: solvent) is sufficient for extracting most reducing phenolic compounds from plant tissues (Al-Farsi and Lee, 2008).

Traditional extraction techniques require large quantities Solvents that contribute to environmental pollution and longer extraction times. Furthermore, they have low extraction selectivity, due to these limitations, several modern techniques have been developed to reduce organic solvent consumption, prevent sample degradation, minimize additional steps after extraction, increase extraction efficiency, and generally improve selectivity (Huie, 2002). In traditional extraction processes for phenolic active compounds from bay leaves, the ratio between plant material and liquid (1:10, 1:20) was most commonly used in many experiments. This was particularly true when the liquid used was acetone (Batiha *et al.*, 2020).

Green Synthesis of Nanomaterials and its Promising Medical and Environmental Applications. Green synthesis of nanoparticles has wide-ranging applications in diverse fields, such as biomedicine, chemical catalysis, drug delivery, cosmetics, environmental applications, enzyme industries, and the food industry (Rana *et al.*, 2020). It is a technology that has gained significant traction in many different applications and sciences for various purposes, including diagnostic and therapeutic uses (Sargazi *et al*., 2022). Nannoparticles are characterized by remarkable chemical and physical properties, most importantly, their small size and large surface-to-volume ratios. They also possess size-dependent optical properties. They have received considerable attention in the growing field of biological applications (Sengul and Asmatulu, 2020).

Traditional nanoparticle synthesis methods are harsh, costly, and polluting. Consequently, researchers are developing sustainable, eco‑friendly alternatives—so‑called "green synthesis"—with plant extracts serving as reducing and stabilizing agents. This approach yields low‑cost, highly stable nanoparticles with uniform size and distinct pharmacological properties thanks to their biocompatibility and nanoscale dimensions. Studies highlight that phytochemicals such as phenolics, proteins, and terpenoids influence particle size, stability, and functionality. The plant‑derived nanoparticles show promise for drug delivery, agriculture and disease management, and biodegradation. Ongoing work focuses on elucidating the roles of phenolics, proteins, and terpenoids in the synthesis, and the field of nanobiology has advanced markedly over the past fifteen years. (Harjeet *et al*., 2023).

Biological methods for preparing nanoparticles, carried out by plants, have replaced traditional chemical methods for preparing these particles, as the extract of the leaves of the Mentha pulegium plant was used to prepare many metal oxide nanoparticles (Musa and Babiker, 2024).

Kothari, and Soni (2022) used cinnamon extract to synthesize nanopowders. Tests confirmed the formation of widely spaced crystalline nanoparticles with diameters of 48 nm. The experiment demonstrated the high efficacy of these particles against microorganisms. It also showed their antioxidant activity. Therefore, the green synthesis of these particles using an aqueous cinnamon extract, at appropriate stoichiometric ratios is a promising method for synthesizing highly effective and bioactive agents, which will be adopted in many different pharmaceutical applications. *Nigella sativa* seeds were also used as a raw material and reducing agent to prepare nanoparticles. Their antibacterial properties were determined. They were shown to have a clear effect on *Klebsiella pneumoniae*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* (Duraivathi *et al*., 2022).

(Shakeel *et al* 2021) prepared chromium oxide nanoparticles using the green bioassay. They used Aptilon indicum as a reducing agent, while others were prepared using the chemical method. The experiment showed that the nanoparticles prepared using the green bioassay exhibited Exhibit potent activity against a broad spectrum of Gram-negative and Gram-positive bacteria. These included four different strains of bacteria: *E. coli*, *B. bronchiseptica*, *S. aureus*, and *B. subtilis*. Furthermore, these nanoparticles prepared using the green bioassay demonstrated, high activity against cancer cells compared to those prepared using the chemical method. Therefore, green nanoparticles are promising candidates for many future biomedical applications.

Similarly, when using the extract from the bottle brush flower, researchers have shown that the extracted particles have a significant inhibitory effect against a wide range of bacteria, most notably *V. cholera*, *K. pneumoniae*, and *P. vulgaris*. These prepared particles also demonstrated high efficacy against leishmaniasis, in addition to their antioxidant activity (Dilawar *et al*., 2019). Al-Kalifawi *et al*. (2017) explained that when chromium oxide nanoparticles were prepared from plant extracts as a raw material and reducing agent for both lemon and hibiscus, these prepared particles showed high activity against a wide range of bacteria, albeit to varying degrees. These bacteria included *E. coli*, *S. aureus*, *Pseudomonas aeruginosa*, *Proteus mirabilis* and *Klebsiella pneumoniae*.

Researchers have demonstrated that the preparation of chromium oxide nanoparticles from extracts of the leaves of the plant *Rhamnus virgata* (RV), has a significant effect on the parasitic microorganisms that cause leishmaniasis. The extract of these leaves was used as a reducing agent to prepare these nanoparticles. This gives them a high capacity to inhibit and eliminate the pathogens, in addition to their effective nanoparticle properties (Javed *et al.*, 2020).

Reheem *et al*. (2018) successfully prepared nanomaterials using the green method. They used these materials to treat burns in laboratory animals. Deep partial-thickness wounds typically healed after 35 days, with the nano-treatment, the wounds healed in 27 days in the animals. In contrast, treatment with sulfadiazine took 30 days. Untreated wounds required 33 days to heal. The green method has also been used as an antibacterial agent and in bone grafting procedures to prevent infection. Infection is a common complication after grafting and a leading cause of graft failure (Qing *et al*., 2018).

Characterization and Development of Nanomaterials Prepared by Green Methods:

Nanoparticles prepared using green methods are characterized using:

1. UV-Visible Spectrometer: The first evidence of nanoparticle formation (especially metallic) is obtained through surface plasmon resonance (SPR) phenomena. The sample is placed in the photovoltaic cell of the device, and the light absorption is then measured (Fatema *et al*., 2019).

2. Scanning Electron Microscopy (SEM): To determine the surface morphology of the material. The nanomaterial is examined by placing a drop of the pre-prepared solution (before drying the sample) on a piece of glass measuring 1 x 1 cm. After drying the sample under a heat lamp, it is transferred to a Petri dish., which is sealed to prevent dust ingress until examination (Oda *et al*., 2019).

3. Zeta Potential: To determine the stability of nanoparticles in solution. The analysis is performed at room temperature (25°C) (Bajelan *et al*., 2012).

4. X-Ray Diffraction (XRD): To confirm the crystalline nature of nanoparticles using an X-ray diffraction spectrometer and to obtain X-ray diffraction patterns (Abduliah *et al*., 2019).

5. Transmission Electron Microscopy (TEM): To accurately determine the size, shape, and distribution of nanoparticles (Aliakbar, 2020).

6. Fourier Transform Infrared Spectroscopy (FTIR): To demonstrate the presence of functional groups from the plant extract on the surface of nanoparticles, providing strong evidence that they are bioencapsulated (Aliakbar, 2020).

7. Atomic Force Microscopy (AFM) : The AFM provides three-dimensional surface characterization at the nanoscale by measuring the force between a sharp probe (less than 5 nm) and the surface at a very small distance (0.2–10^{-5} nm) (Lang *et al*., 2004).

Green synthesis and the factors affecting it:

Several factors influence the characterization of nanoparticle morphology, including pH, reaction time, temperature, and reactant concentration. These factors have demonstrated a significant impact on nanoparticle synthesis and have played a key role in improving the synthesis of metallic nanoparticles (Zhang *et al*., 2020).

1. pH: Although these methods are simple, inexpensive, environmentally friendly, and biologically effective, pH plays a fundamental role. The alkalinity of the reaction has a positive effect on the synthesis of nanomaterials. This is due to its effect on biomolecules (flavonoids, polyphenols), this helps increase their reduction and encapsulation capabilities. Therefore, nanoparticles with small sizes are produced compared to reactions in an acidic medium, this leads to the production of large, agglomerated nanoparticles (Mofida *et al*., 2024). Furthermore, pH plays an important role in the structure of nanoparticles. It controls the crystallization centers, and a higher pH level leads to an increase in the number of crystallization centers, which is very important in nanoparticle synthesis (Rana *et al*., 2020). The pH reaction of the medium is a key function in nanoparticle formation (Mosquera-Romero *et al*., 2022).

2. Reaction Time: The time required for the reaction to synthesize nanomaterials plays a significant role in the success or failure of the synthesis process. This is especially true when synthesizing nanoparticles with magnetic properties (Razali *et al*., 2022). Karade *et al*. (2018) demonstrated that reaction time plays a crucial role in controlling the structure of nanoparticles. In the green synthesis process of nanoparticles, reaction time is a key factor influencing the size, shape, and yield of the manufactured nanoparticles (Mughal and Hassan, 2022).

3. Temperature: Temperature has a significant impact on the green synthesis of nanoparticles and plays a major role in controlling the structure of nanoparticles during the synthesis process, including their size, shape, and the production of the manufactured nanoparticles (Mughal and Hassan, 2022). Temperature is considered one of the most important factors for controlling nanoparticle synthesis. The diameters of the synthesized particles also depend on it, and by controlling temperature, different shapes of nanoparticles can be obtained, such as spheres, tubes, sheets, etc. (Rana *et al*., 2020).

4. Reducing Agent Concentration: The concentration of reducing agents and metal ions plays a crucial role in the green process synthesis of nanoparticles, determining their size, shape, and quantity. (Rana *et al*., 2020).

Toxicity of Green Nanoparticle Synthesis:

Green nanoparticle synthesis has proven effective in a wide range of applications. This is due to the size and shape of the nanoparticles and their catalytic activity. However, these properties are sometimes undesirable. This is because these properties are non-selective for microorganisms. This increases the likelihood of toxic effects on eukaryotic cells, because nanoparticles have dimensions similar to those of biomolecules, such as proteins, nucleic acids and, enzymes. This allows them to easily enter eukaryotic cells and then affect their vital functions (Rana *et al*., 2020).

Conclusions:

Nanomaterials possess numerous benefits and unique properties that make them valuable in a variety of medical and industrial applications. Traditional methods for preparing nanomaterials may pose toxic and environmental risks, necessitating the adoption of safer techniques such as green synthesis. The use of plant extracts in nanoparticle synthesis has proven highly efficient compared to traditional methods, facilitating the entry of these synthesized materials into effective, low-risk industrial, medical, and pharmaceutical applications. Green synthesis is a preferred sustainable option that reduces environmental pollution and enhances efficacy in medical applications. Despite advancements in nanomaterial synthesis, there is still a need to assess toxic risks and the impact of nanoparticles on living cells to avoid undesirable side effects. The field requires further research to better understand the health and environmental impacts and to develop more efficient and less harmful synthesis techniques. Research shows that green synthesis is likely to be the right path for future nanotechnology applications, making sustainable use of natural resources.

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