NANOPARTICLES EMERGING THROUGH MICROBIAL ROUTES

Abstract

Green nanotechnology, characterized by reduced toxicity and environmental compatibility, leverages microorganisms for nanoparticle synthesis. This review delves into microbial mechanisms in nanoparticle production. Fungi like *Saccharomyces cerevisiae, Candida glabrata*, and *Fusarium oxysporum* employ distinct enzymatic pathways for synthesis. *Aspergillusspp* and *Pleurotusostreatus* demonstrate diverse enzymatic and reducing agent routes. Bacteria, notably *Rhodopseudomonas palustris* and *Bacillus thuringiensis*, contribute through lyases and bioreduction, respectively. *Cyanobacteria* display bioaccumulation tendencies yielding gold nanoparticles, while *Rhodopseudomonas palustris* reveals cellular-nanoparticle dynamics. This exploration illuminates the potential of microorganism-mediated nanoparticle synthesis for sustainable applications, providing insights into mechanisms and interactions.

Keywords: Green nanotechnology, nanoparticle synthesis, microorganisms, fungi, bacteria, enzymatic pathways, reducing agents, environmental compatibility, sustainable applications, bioaccumulation, cellular dynamics.

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I. INTRODUCTION

Nanoparticles, defined as particles with dimensions below 100 nanometers, have gained significant attention for their unique properties and versatile applications across various fields. However, traditional methods of nanoparticle synthesis often involve harsh chemicals and energy-intensive processes, raising environmental and sustainability concerns. In response to these challenges, the emergence of nanoparticles through microbial routes represents a groundbreaking and sustainable revolution. This article explores the world of microbial synthesis of nanoparticles, including the mechanisms, applications, and promising future of this eco-friendly approach. Microorganisms, including bacteria, fungi, and algae, possess exceptional capabilities to interact with and transform inorganic materials, leading to the formation of nanoparticles. These microorganisms offer a green and economically viable alternative for nanoparticle production. Bacteria, the smallest and most abundant organisms on Earth, play a pivotal role in microbial nanoparticle synthesis. They employ various strategies to convert metal ions into nanoparticles. Reduction enzymes, such as NADH-dependent reductases, are crucial for catalyzing the reduction of metal ions to their elemental forms. Some bacteria can accumulate metal ions within their cells, which are then transformed into nanoparticles. Others secrete biomolecules into their surroundings, facilitating extracellular nanoparticle formation.Fungi, a diverse group of microorganisms, have also demonstrated their prowess in nanoparticle synthesis, particularly yeasts and filamentous fungi. They possess various oxidoreductases, both membrane-bound and cytosolic, that reduce metal ions to nanoparticles. These enzymes often exhibit pH-dependent activities, allowing them to act as oxidases at low pH and reductases at high pH. Tautomerization of quinones and oxidases occurs at the cell membrane, facilitating nanoparticle synthesis. Inside the cytosol, fungi activate a family of oxygenases responsible for detoxification via oxygenation, resulting in the release of compounds like benzoquinones and toluquinones, contributing to nanoparticle formation.Algae, with their diverse species, offer unique avenues for nanoparticle synthesis. Cyanobacteria, a type of algae, have garnered attention for their unconventional mechanisms, including bioaccumulation of precursors within their cells. The specifics of this process are still under investigation, making it an exciting area of research. (1)(2)

Nanoparticles emerging through microbial routes have found applications across a wide spectrum of industries and scientific disciplines. In the field of medicine and healthcare, microbial-synthesized nanoparticles hold immense promise. They can be employed for targeted drug delivery, enhancing therapeutic efficacy while minimizing side effects. Additionally, microbial nanoparticles serve as crucial components in the development of diagnostic assays and medical imaging agents, improving disease detection and monitoring. Environmental scientists and engineers have tapped into the potential of microbial nanoparticles for environmental cleanup. These nanoparticles efficiently remove heavy metals from contaminated water sources through processes like adsorption and precipitation. They also play a vital role in wastewater treatment by facilitating the degradation of organic pollutants, contributing to cleaner water resources. The field of catalysis and materials science has witnessed a significant transformation thanks to microbial-synthesized nanoparticles. These nanoparticles find applications as catalysts in various chemical reactions, including the synthesis of fine chemicals and environmental catalysis. Researchers harness microbial nanoparticles in the fabrication of advanced materials with tailored properties, finding use in electronics, coatings, and energy storage, among other areas. Agriculture, a sector of paramount importance for global food security, has also embraced microbial-synthesized nanoparticles. These nanoparticles enable the controlled release of pesticides and nutrients, enhancing crop yield and reducing environmental impact. (3)(4)

Recent research endeavors have propelled microbial nanoparticle synthesis to new heights. Genetic engineering of microorganisms empowers scientists to exercise precise control over nanoparticle synthesis, including size, shape, and surface properties, opening up possibilities for tailoring nanoparticles for specific applications. Advanced bioreactor designs and optimization techniques have revolutionized the scalability and reproducibility of microbial nanoparticle synthesis, paving the way for large-scale, sustainable production. Beyond their traditional applications, microbial-synthesized nanoparticles are finding new and exciting roles in multidisciplinary research. They are being explored for use in energy storage devices, such as batteries and supercapacitors, offering high-performance, environmentally friendly energy solutions. Innovative sensor technologies benefit from the unique properties of microbial nanoparticles, finding use in fields as diverse as environmental monitoring and medical diagnostics. Despite the remarkable progress in microbial nanoparticle synthesis, several challenges remain on the horizon. Scaling up microbial nanoparticle synthesis for industrial production is a significant challenge, requiring innovative engineering solutions. Ensuring the reproducibility of nanoparticle synthesis processes is essential for their widespread adoption. Achieving this consistency demands rigorous process control. The future holds exciting prospects, including the synthesis of more complex nanomaterials and the exploration of entirely new applications for microbial-synthesized nanoparticles. This sustainable revolution promises to reshape industries, advance scientific research, and contribute to a greener and more environmentally conscious future. Despite of having tangible progress in the field of synthesis of nanoparticles, green nanotechnology(5) has emerged as an attractive feature with a reduction in toxicity values and ameliorating potential for environmental issues (6). Green nanotechnology uses microbial entities for the synthesis of nanoparticles. Many microorganisms and plants store or accumulate various inorganic materials inside or outside the cell and this property can be exploited to synthesize nanoparticles (7). The studies on enzyme structure and nucleic acids that code for these specific enzymes can demystify the mystery regarding synthesis of nanoparticles (8). Metal ions are reduced to nanoparticles by cell walls (9) and cell wall proteins of microorganisms and due to advancements in techniques infer the application of nanoparticles in a variety of fields on the basis of composition, shape, size and molecular interactions. In this article emphasis is laid on the microorganisms that can be employed for synthesis of nanoparticles along with a brief glimpse of their mechanism.

II. BIOSYNTHESIS USING FUNGI

Fungi have been extensively employed for the biosynthesis of nanoparticles and the mechanistic aspects controlling the nanoparticle formation have also been deduced for a few. Contrasting to bacteria, fungi could be used as a source for mass production of nanoparticles. This is due to the piece of evidence that fungi exude more amounts of proteins which directly decipher increased productivity of nanoparticle formation (**10**). In addition to dispersity in single dimension, nanoparticles with well illustrated dimensions can be acquired by using fungi.

In case of biosynthesis of gold nanoparticles by *V.luteoalbum*, the rate of nanoparticle formation and their size can be manoeuvred using physical parameters like pH, temperature, gold exposure time and concentration. (11).

Fungi, a diverse group of eukaryotic microorganisms, are known for their ability to adapt and thrive in various environments. This adaptability extends to their remarkable talent for nanoparticle biosynthesis. Fungi have garnered attention as green nanofactories due to several key attributes that make them ideal candidates for sustainable nanoparticle production.

1. **Mechanisms of fungal nanoparticle biosynthesis:** The biosynthesis of nanoparticles by fungi is a complex and fascinating process that relies on the unique metabolic and enzymatic pathways of these microorganisms. Several mechanisms underpin fungal nanoparticle biosynthesis:

   - **Oxidoreductases:** Fungi possess a range of oxidoreductase enzymes, both membrane-bound and cytosolic, that play a pivotal role in nanoparticle synthesis. These enzymes catalyze the reduction of metal ions to their elemental forms, facilitating the formation of metallic nanoparticles.

   - **pH Sensitivity:** Many fungal oxidoreductases exhibit pH-dependent activities, enabling them to function as oxidases at low pH and reductases at high pH. This pH sensitivity is crucial for controlling the size and stability of the synthesized nanoparticles.

   - **Tautomerization:** At the cell membrane level, the addition of certain precursor compounds triggers tautomerization of quinones and oxidases. This transformation is a critical step in the conversion of inorganic substances into nanoparticles.

   - **Cytosolic Processes:** Within the fungal cytosol, a family of oxygenases becomes activated, mainly responsible for detoxification through oxygenation. This action as reductases releases derivatives ofcompounds like benzoquinones and toluquinones, which contribute to nanoparticle formation.

2. **Advantages of fungal nanoparticle biosynthesis:** The use of fungi as green nanofactories offers several compelling advantages:

   - **Eco-Friendly:** Fungal nanoparticle biosynthesis is environmentally friendly, as it eliminates the need for hazardous chemicals and energy-intensive processes, reducing the carbon footprint of nanoparticle production.

   - **Biocompatibility**: Fungal-synthesized nanoparticles tend to exhibit high biocompatibility, making them suitable for various medical applications, such as drug delivery and diagnostic imaging.

   - **Size Control**: Fungi provide precise control over nanoparticle size and shape, allowing researchers to tailor nanoparticles for specific applications, from catalysis to materials science.

   - **Cost-Effective:** Fungal biosynthesis is cost-effective, as it relies on readily available fungal cultures and simple growth media.

3. Case studies

- **Biosynthesis by *Saccharomyces cerevisiae* and *Candida glabrata*:** Nature has provided yeasts and some other fungus with membrane bound oxidoreductases and cytosolic oxidoreductases along with quinines (12) (13). These oxidoreductases and quinones (14) are supposed to be the reason for reduction of inorganic substances to nanoparticles (15). Oxidoreductases are pH sensitive enzymes with a specific ability to work as oxidases at low pH and reductases at high pH (16) (17). The method to synthesize nanoparticles involves generation of stress. During such stressful conditions transformation takes place and this transformation is subjected to strictness at two distinct levels. At cell membrane level, as $TiO(OH)_2$ is added tautomerization of quinones and oxidases takes place. In a similar study with Candida glabrata(18.), where stress was provided using Cd ions and the tautomerization has deduced an elaboration of phytochelatin synthase (19) and HMT-1 (20) which further helped in synthesis of CdS nanoparticles from the microbe (21). Secondly, if the $TiO(OH)_2$ reaches cytosol, a family of oxygenases are activated in the endoplasmic reticulum, mainly responsible for detoxification using the process of oxygenation. The action as reductases releases derivatives of compounds popularly known as benzoquinones (22) and toluquinones (23). The above mentioned methodologies have been employed for the synthesis of metallic nanoparticles of titanium, silver and cadmium (24).

- **Biosynthesis by *Fusarium oxysporum*:** Inferences from protein assays have pointed towards NADH-dependent reductase as key factor for biosynthesis processes. The enzyme oxidizes NADH to NAD^+ by gaining electrons from NADH. Further, this enzyme gets oxidized by metal ion reductions. *Fusarium oxysporum* was used to synthesize 10-25 nm silver hydrosol by the above mentioned enzyme of molecular weight 44 kDa (25). Action of napthoquinones (26) and anthraquinones (27) as redox centres for the reduction of Ag nanoparticles has also been demonstrated (28). Conjectures from various assays for nitrate dependent reductases (29) show that the reduction potential can be utilized for the synthesis of nanpoparticles. In *Fusarium oxysporum* quinine conjugates this enzyme and reduces the metal ion to change it to elemental form (30). Interestingly, *Fusarium monoliformae* that has extracellular and intracellular reductases in the same trend as *Fusarium oxysporum* is unable to synthesize nanoparticles. The possible reason could be that reductases from *Fusarium monoliformae* are fruitful for conversion of only Fe^{3+} to Fe^{2+} not Ag^+ to Ag^0 (31).

- **Biosynthesis by *Aspergillus*:** Aspergillus flavus (32) (33.) upon challenging with silver nitrate has been found to mount up silver nanoparticles on the surface of its cell wall. The nanoparticles thus formed were monodispersed nanoparticles of size range 8.92+/-1.61 nm (34). Aspergillus flavus secretes some proteins and reducing agents that help to stabilize the nanoparticlees in extracellular state. Four high molecular proteins were found to be released by Aspergillus flavus in alliance to these nanoparticles (35) (36). *Aspergillus niger* also employed to synthesize silver nano particles of size 3-30 nm and nitrate reductase appeared to be a key mechanistic aspect (37) (38).

- **Biosynthesis by *Pleurotus Ostreatus*:** *Pleurotus ostreatus* after getting challenged from 1mM silver nitrate exuded the synthesis of silver nanoparticles. The presence of NADH dependent nitrate reductase (39) in cell filtrate provided the evidence for hypothesizing the mechanism for conversion of $Ag(NO_3)_2$to Ag nanoparticles (40) (41.).

III. BIOSYNTHESIS USING BACTERIA

Bacteria are considered to be a potent biomass for nanoparticles synthesis. Production of gypsum and calcium carbonate from S layer bacteria and production of magnetic nanoparticles from magnetotactic bacteria are well known demonstrations (42). Growth and survival of some microorganisms has been observed even at high metal ion concentrations, this survival may be the result of high level of tolerance or resistance developed in microorganisms. The reason for tolerance could be various efflux systems, bioaccumulations, removal of toxicity by reduction or oxidation or deficiency of metal transport systems (43).Bacteria, among Earth's oldest and most adaptable life forms, possess a remarkable ability to synthesize nanoparticles through their biological processes. Their simplicity, adaptability to various environments, and rapid reproduction rates make them ideal candidates for sustainable and green nanoparticle production.

1. **Mechanisms of Bacterial Nanoparticle Biosynthesis:** The synthesis of nanoparticles by bacteria is a complex and fascinating process deeply ingrained in their metabolic and enzymatic machinery. Several mechanisms underpin bacterial nanoparticle biosynthesis*:*

   - **Reduction Enzymes:** Bacteria employ various reduction enzymes, including NADH-dependent reductases, to catalyze the transformation of metal ions into elemental nanoparticles. These enzymes play a pivotal role in the creation of metallic nanoparticles.

   - **Intracellular Transformation:** Some bacteria possess the unique ability to accumulate metal ions within their cells, where these ions undergo transformation into nanoparticles. This intracellular process offers precise control over nanoparticle synthesis.

   - **Extracellular Secretion:** In contrast, certain bacteria secrete biomolecules into their surroundings, serving as reducing agents and stabilizers to facilitate extracellular nanoparticle formation. This external process influences the size and properties of the resulting nanoparticles.

2. **Advantages of bacterialnanoparticle biosynthesis**

   - **Environmentally Friendly:** One of the most prominent advantages of bacterial nanoparticle biosynthesis is its eco-friendliness. Unlike traditional chemical methods of nanoparticle synthesis, bacterial processes do not involve the use of toxic chemicals or the generation of hazardous waste. This reduces the environmental impact of nanoparticle manufacturing and aligns with the principles of green chemistry.

- **Reduced energy consumption**: Bacterial synthesis of nanoparticles occurs at or near ambient temperatures, eliminating the need for energy-intensive processes such as high-temperature reduction reactions. This significantly reduces energy consumption, making bacterial biosynthesis an energy-efficient alternative.

- **Biocompatibility:** Bacterial-synthesized nanoparticles often exhibit high biocompatibility, making them suitable for various medical and biological applications. These nanoparticles are well-tolerated by living organisms and can be used safely in drug delivery systems, medical imaging, and other healthcare-related fields.

- **Precise control over nanoparticle properties**: Bacteria provide researchers with precise control over the size, shape, and surface properties of synthesized nanoparticles. By adjusting the growth conditions, such as the type and concentration of metal ions and the culture medium's composition, scientists can tailor nanoparticles to meet specific requirements. This level of control is challenging to achieve using traditional chemical methods.

- **Cost-effective production**: Bacterial nanoparticle biosynthesis is cost-effective. Bacteria are readily available and easy to culture, and growth media are relatively inexpensive. This cost-effectiveness makes large-scale production of nanoparticles more accessible and economically viable.

- **Biological templates**: Bacteria can act as biological templates for the synthesis of complex nanoparticles. Through genetic manipulation and controlled growth conditions, researchers can engineer bacteria to produce nanoparticles with intricate structures and functionalities. This approach has led to the creation of novel nanomaterials with unique properties.

- **Low toxicity and enhanced safety**: Bacterial nanoparticle synthesis eliminates the need for harmful reducing agents and stabilizers commonly used in chemical methods. As a result, the nanoparticles produced tend to have lower toxicity profiles, which is crucial for biomedical and environmental applications. Additionally, the reduction in toxic byproducts enhances the safety of the synthesis process.

- **Versatility in applications**: Bacterial-synthesized nanoparticles find applications across various industries and scientific fields. They have been utilized in medicine for targeted drug delivery and medical imaging, in environmental science for water purification and pollution control, in materials science for advanced coatings and catalysis, and in agriculture for enhancing crop growth and protection.

- **Bioremediation potential:** Bacterial nanoparticles exhibit excellent potential in environmental remediation. They can efficiently remove heavy metals and organic pollutants from contaminated water sources. These nanoparticles can adsorb, precipitate, or catalytically degrade pollutants, contributing to cleaner and safer ecosystems.

- **Sustainable and green manufacturing:** Bacterial nanoparticle biosynthesis aligns with the principles of sustainable and green manufacturing. It reduces the reliance on harmful chemicals, conserves energy, and minimizes the generation of hazardous waste. This approach is vital in addressing global sustainability challenges.

3. Case studies

- **Biosynthesis by *Rhodopseudomonas palustris*:** Cadmium sulfide nanoparticle synthesis was revealed using *Rhodopseudomonas palustris* (44) by lyases class of enzymes. Systematically D-cysteine sulfide-lyase, which participates in cysteine metabolism, could be the key cause of this synthesis (45). The maximum absorbance peak at 425 nm demonstrated the quantum size organization of CdS particles. The causal enzyme was located in cytoplasm and *Rhodopseudomonas palustris* was found quite efficient in transporting CdS nanoparticles out of cell (46).

- **Biosynthesis by *Bacillus thuringiensis*:** Growth of multi drug resistant strains of *Streptococcus aureus* , *Pseudomonas aeruginosa* and *Escherichia coli* were inhibited by use of silver nanoparticles synthesized by utilizing bioreduction property of *Bacillus thuringiensis*. The spore crystal mixture was shown to have bioreduction property by converting silver nitrate solution to yellowish silver nanoparticles (47).

- **Biosynthesis by *Cyanobacteria*:** A *cyanobacterium* (*Plectonemaboryanum* UTEX 485) was reported to synthesize gold nanoparticles by their tendency towards bioaccumulation. Documentations reveal that *cyanobacteria* upon interaction with gold(III)-chloride solution initially resulted in accumulation of gold(I)-sulfide (48). Further treatment resulted into formation of octahedral (III) platelets. Interestingly, *Plectonemaboryanum* UTEX 485 when interacted with $Au(SO_4)_2^{3-}$ gold nanoparticles of size 10-25 nm were accumulated in the solution whereas particles of size <10 nm were accumulated inside the cell. But the presence of $AuCl_4^-$ solution resulted in octahedral gold platelets of size 1-10 micrometer and particles of size <10 nm inside the cell (49). Cyanobacteria were also incorporated in biological synthesis of palladium (50), silver (51) and platinum (52) nanoparticles.

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IV. BIOSYNTHESIS USING ALGAE

Algae, commonly found in aquatic ecosystems, are primarily known for their role in oxygen production and as a food source for aquatic organisms. However, these simple, photosynthetic organisms possess a remarkable talent – the ability to synthesize nanoparticles. This unique capability has sparked interest in the scientific community as a sustainable and eco-friendly method of nanoparticle production.

1. **Mechanisms of Algal Nanoparticle Biosynthesis:** The process of nanoparticle biosynthesis by algae is an intricate dance of chemistry and biology. Several mechanisms underlie this fascinating phenomenon:

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- **Extracellular secretion**: Algae exude a range of organic molecules, including enzymes and metabolites, into their surroundings. These biomolecules act as reducing agents and stabilizers, facilitating the extracellular formation of nanoparticles. This process allows for precise control over nanoparticle size and properties.

- **Photosynthetic pigments:** The pigments responsible for photosynthesis in algae, such as chlorophyll, can also participate in nanoparticle biosynthesis. These pigments absorb light energy and transfer it to metal ions, catalyzing their reduction and the subsequent formation of nanoparticles.

- **Cellular accumulation**: Some algae can accumulate metal ions within their cells. These ions are subsequently transformed into nanoparticles through enzymatic reactions and cellular processes. This intracellular biosynthesis provides a unique approach to nanoparticle production.

2. Advantages of Algal Nanoparticle Biosynthesis:

- **Environmental harmony:** Algal nanoparticle biosynthesis epitomizes green chemistry. It relies on the inherent biochemical processes of algae, sidestepping the use of toxic chemicals and high-energy consumption. This intrinsic eco-friendliness significantly reduces the environmental burden associated with nanoparticle production.

- **Energy efficiency**: Traditional nanoparticle synthesis often requires energy-intensive high-temperature reactions. Algal biosynthesis, on the other hand, takes place at or near ambient temperatures. This low-energy demand aligns with sustainability goals, fostering energy efficiency in nanoparticle manufacturing.

- **Harmony with life:** Algal-synthesized nanoparticles tend to exhibit remarkable biocompatibility. This quality is a boon for applications in medicine, where precision and safety are paramount. These nanoparticles seamlessly interact with biological systems, reducing potential side effects.

- **Tailored precision:** Algae offer scientists precise control over nanoparticle properties. By fine-tuning growth conditions, including the choice of algae species, metal ion concentrations, and culture medium composition, researchers can craft nanoparticles tailored to specific applications. This level of customization is a hallmark of algal biosynthesis.

- **Resource efficiency:** Algal nanoparticle biosynthesis is cost-effective. Algae, abundant in natural aquatic ecosystems, require minimal resources for cultivation. This cost efficiency makes large-scale nanoparticle production economically accessible.

- **Safety priority:** Safety concerns often shadow traditional nanoparticle production, with the use of hazardous chemicals and byproducts. Algal biosynthesis eliminates these risks, enhancing safety for researchers and the environment alike.

- **Versatile application spectrum:** Algal-synthesized nanoparticles exhibit versatility across industries and scientific domains. Their utility extends from healthcare (drug delivery, medical imaging) to environmental science (water purification, pollution control), materials science (advanced coatings, catalysis), and agriculture (crop enhancement, protection).

- **Environmental revival:** Algal nanoparticles hold great promise in environmental remediation. They efficiently sequester heavy metals and organic pollutants from contaminated water sources. Through adsorption, precipitation, or catalysis, these nanoparticles contribute to restoring cleaner and safer ecosystems.

- **Boundless horizons:** The future of algal nanoparticle biosynthesis is brimming with possibilities. Advances in genetic engineering may empower scientists to modify algae for the production of nanoparticles with precise properties, paving the way for novel nanomaterials and groundbreaking applications.

3. Case studies

- **Biosynthesis of gold nanoparticles using *Bifurcariabifurcate*:** For the first time in 2013. the brown alga (*Bifurcariabifurcata*) was used in the biosynthesis of copper oxide nanoparticles of dimensions 5–45 nm.By using UV-visible absorption spectroscopy and Fourier transform infrared spectrum analysis, the produced nanomaterial is identified. The production and crystalline character of copper oxide nanomaterial are confirmed by X-ray diffraction. Furthermore, strong antibacterial activity against two distinct types of bacteria, Staphylococcus aureus (Gram positive) and Enterobacter aerogenes (Gram negative), was discovered for these nanoparticles.(53)

- **Biosynthesis of gold nanoparticles using *Galaxauraelongate*:** Using G. elongata extract in an aqueous solution under typical air conditions, it has been discovered that stable Au nanoparticles develop quickly. The particles are spherical in shape, with a small number of rod-, triangular-, truncated-triangular-, and hexagonal-shaped nanoparticles as well, according to TEM research. The size range of the Au nanoparticles according to zeta potential studies was 3.85-77.13 nm. The use of FTIR, or Fourier transform infrared spectroscopy, revealed that alga chemicals were used to cap the nanoparticles. It was discovered that the chemical components of the algal extract, including andrographolide, alloaromadendrene oxide, glutamic acid, hexadecanoic acid, oleic acid, 11-eicosenoic acid, stearic acid, gallic acid, epigallocatechin catechin, and epicatechin gallate, may function as a reducing, stabilizing, and capping agent.(54)

V. CONCLUSION

The use of microbes as means to synthesize nanoparticles has provided a vast insight into environment friendly approaches along with opening gates for various other approaches towards micro interactions of nanoparticles with proteins. Here the emphasized microbial entities use distinct communities of enzymes for synthesis purpose. Various oxidareductases, nitrate reductases and lyases result into synthesis of different nanoparticles with definite microbial and industrial possibilities. The synthesis using *Aspergillus* incorporated the use of four proteins and these proteins can be employed to study micro-interactions of nanoparticles. Synthesis using cyanobacteria has revealed a fact that the size of nanoparticles accumulated inside the cell are independent of solution used. Whereas, the aggregating or agglomerating property of nanoparticles is quite dependent on the type of solution used as 10-25 nm particles were formed using $Au(SO_4)_2^{3-}$ and octahedral platelets formed by aggregation or agglomeration in $AuCl_4^-$. Lastly, the transfer of nanoparticles from cytoplasm to extracellular space in *Rhodopseudomonas palustris* illustrates the membrane structure that favors the to and fro motion of nanoparticles. On the other handG. elongata, a red alga, successfully recovered and reduced Au (III) to Au (0). Gold nanoparticles were generated as a result of the technique. Gold reduction with G. elongata is efficient, nutrient-free, uses no harmful chemicals, and happens at neutral pH levels.

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