BIOSYNTHESIS OF METAL NANOPARTICLES AND THEIR APPLICATION IN THE FIELD OF AGRICULTURE

Abstract

Nanotechnology has revolutionized various industries and its potential in agriculture holds significant promise for sustainable and efficient crop production. This in-depth analysis investigates the biosynthesis of nanoparticles, which concentrates particularly on green synthesis techniques employing plant extracts, microbes, and other biological agents. These green synthesis techniques are especially appealing for agricultural applications because of how cost-effective and environmentally friendly they are. With the world's population currently hovering around 7 billion, food scarcity is an issue in many developing nations. The use of agro nanotechnology, which has applications from better food quality to reducing agricultural inputs, may significantly enhance crop productivity. Innovative methods like the detection and treatment of illness, the delivery of nanopesticides, the use of biopesticides and green pesticides, the gradual and continuous release of micronutrients, and fertilisers, etc. may be made possible by nanotechnology for the agro-food industry. By using nanobiotechnology to develop various crops' vital biological components, it is hoped that the related nutritional qualities would improve. Additionally, these concepts will support efforts to address environmental and food security concerns.

I. Introduction

The process of creating nanoparticles utilizing biological agents, such as plants, bacteria, fungus, algae, or other biomolecules, is known as "biosynthesis of nanoparticles"[1]. Compared to conventional chemical and physical methods, this green synthesis strategy has a number of benefits, such as cost-effectiveness, the capacity of customizing the characteristics of nanoparticles for particular applications, and environmental friendliness. Nanoparticle biogenesis has been investigated in a variety of biological systems [2]. A variety of bioactive substances, including polyphenols, flavonoids, and terpenoids, are present in plant extracts, particularly those from the leaves, stems, and roots. These substances are good reducing and stabilizing agents for nanoparticles. The reduction and stabilization processes are made easier by the enzymes and proteins that microorganisms like bacteria and fungi have. Algae and other biological agents have further demonstrated potential for nanoparticle production [3]. The synthesis of nanoparticles is in great demand nowadays as nanotechnology has emerged as a game-changing field with extensive applications in several sectors. The biosynthesis of nanoparticles and their potential use in agriculture is one of the most exciting and quickly developing fields of nanotechnology [4]. It is possible to increase nutrient absorption efficiency and decrease waste by the regulated and targeted administration of agrochemicals, such as fertilizers and pesticides, through nanocarriers, that can increase crop yield and minimize environmental pollution [5].

II. Nanoparticles

Nanoparticles are extremely small particles that generally vary in size from 1 to 100 nanometres (1 nanometre is equivalent to one billionth of a meter). Since they are so little, they display special traits and behaviour that set them apart from their bulk counterparts. Nanoparticles can be synthesized from various materials, such as metals, metal oxides, polymers, and carbon-based materials [6].
Nanoparticles are referred to as being "biosynthesized" when microorganisms extract target ions from their environment and change those metal ions into the element metal utilizing enzymes created by cell processes [7]. Production may be classified as intracellular or extracellular depending on where nanoparticles are produced. Delivering ions within the microbial cell, where they mix with enzymes to generate nanoparticles, is the intracellular strategy [8]. Nanoparticles are created extracellularly by trapping reducing ions in the presence of enzymes and metal ions on cell surfaces. The biosynthesized nanoparticles have been applied in a wide range of sectors that covers biosensors, speeding reaction speeds, separation research, cancer treatment, gene therapy, targeted administration of medicine, agriculture, pharmaceutical carriers, DNA analysis, antimicrobial compounds, and MRI [9].
Since the beginning of life on Earth, inorganic substances and biological ones have been interacting constantly. This continuous interaction made it possible for life to coexist with a well-organized mineral deposit on this planet [10]. Scientists' interest in the interactions between inorganic substances and living things has increased recently. Numerous bacteria can create inorganic nanoparticles via extracellular or intracellular pathways, according to studies. This section covers the categories of oxide nanoparticles made up of magnetic and nonmagnetic oxide nanoparticles, sulphide nanoparticles, and other ad hoc nanoparticles [11]. It also discusses the synthesis of various nanoparticles via biological processes. The topic also includes metallic nanoparticles like gold, silver, alloy, and other metal nanoparticles [12].
Fungi may be utilised to make a variety of nanoparticles, which includes gold, silver, zinc oxide, and others [13]. Although nanoparticles have been utilised since the fourth century, Michael Faraday first scientifically characterised them in his study "The E xperimental Relations of Gold and Other Metals to Light" published in 1857. These are of enormous scientific interest because they serve a significant role in acting as the connecting link between bulk materials, atomic, or molecular structures. American physicist Richard Feynman's presentation, "There's Plenty of Room at the Bottom," delivered on December 29, 1959, at a conference of the American Physical Society held at Caltech is widely credited for inspiring the development of the area of nanotechnology. This talk marked the official beginning of nanoparticle research [14].
The biogenesis of nanoparticles includes two important categories.
The first process is called "Bioreduction" (in which metal ions are chemically reduced by living things into more stable forms), while the second is called "Biosorption" (in which nanoparticles from the environment adhere to living things) [15]. Numerous creatures with the potential to produce nanoparticles have not yet been fully investigated. In this work, we are aiming to identify fungi that can produce these nanoparticles as well as how to characterise them.

II a. Trends for formulation of Nanoparticles:

There are basically two important trends in nanoparticle production [16]. these are following:-

i. Top down approach:

In a top-down technique, a bulk material is sliced into smaller and smaller pieces until a nano-sized particle is obtained. Typically, this approach is used in the physical production of nanoparticles [17]**.** The figure 1 shows the top down approach for nanoparticles production.

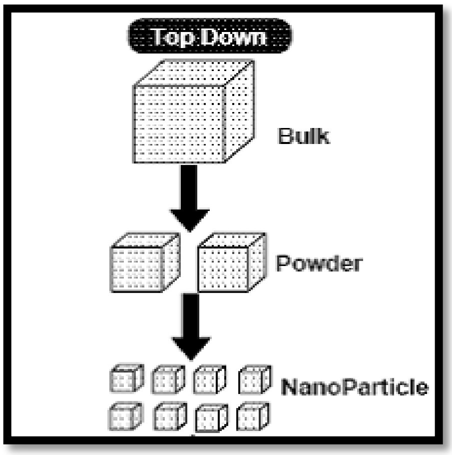

Fig 1. Bottom down approach of nanoparticles synthesis

ii. Bottom up app approach:

In the bottom up technique, the substance is built up from the bottom up, or "bottom up." The creation of clusters or molecules as a result of atom-by-atom deposition results in the production of clustered monolayers on the surface of the substrate. It is usually done using chemical and biological methods [18]. The figure 2 shows the approach for nanoparticle production.

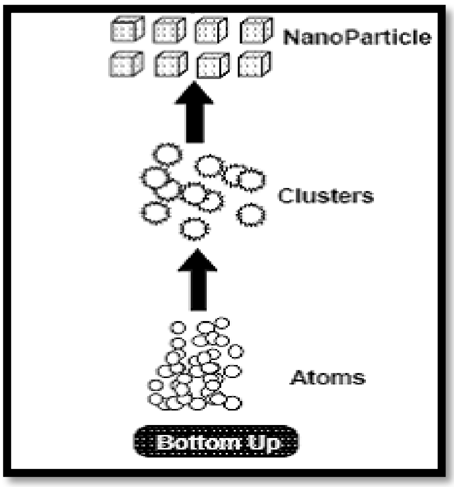

Fig 2. Bottom up approach of nanoparticle synthesis

III b. Methods used for nanoparticle fabrication:

i. Physical methods:

The nanoparticles are synthesized using physical or mechanical processes are referred to as physical methods. Some of the important procedures include mechanical ball milling, vapor condensation, thermal decomposition, arc discharge, photo irradiation, laser ablation, ultrasonication etc [19].

ii. Chemical methods:

The production of nanoparticles by the action of various chemical processes are referred to as chemical methods. Some of the chemical methods include sol gel method, solvothermal process, electrochemical process, sonochemical process, thermal plasma synthesis etc [20].

iii. Biological method:

"Biosynthesis of nanoparticles" refers to the method of making nanoparticles with biomedical applications that utilizes microbes and plants. This approach is cost-effective, secure, compatible with biological systems, environmentally friendly, and secure [21]. The term "green synthesis" refers to synthesis that involves the use of plants, bacteria, fungi, algae, etc. They make it possible to produce industrial-scale, large quantities of pure ZnO NPs [22]. When NPs are produced via a biomimetic method, which also lessens the requirement for costly and hazardous chemicals, more catalytic activity may be seen [23]. The biogenic enzymatic method is more preferred in comparison of chemical methods in a number of aspects for producing nanoparticles. Although the latter methods may quickly create huge quantities of nanoparticles with certain sizes and shapes, they are challenging, antiquated, costly, and ineffectual, and they produce dangerous toxic wastes that are terrible for the environment as well as the human health [24]. Enzymatic processes reduce the need for pricey chemicals, and the more socially acceptable "green" alternative uses less energy and is better for the environment.

IV. Methodology

There are so many methods for the biosynthesis of nanoparticles. Here we have preferred biosynthesis of nanoparticles using fungi. Soil samples has been collected from the mining area. The soil present in mining area is capable of degrading more variety of metals so it can be used for various metals degradation [25]. Isolation of fungi by serial dilution method has been performed. For this, take 1 g of soil, weighed, should be added to a test tube with 10 ml of distilled water and thoroughly mixed. Prepare five test tubes with a 9 ml capacity each for distilled water. Take now 1/11 of a ml of Stoke into the first tube for the initial dilution. Take 1 ml of the first dilution once more and add it to the second tube, which will contain the second dilution. For the remaining three test tubes, which will represent the third, fourth, and fifth dilutions, repeat this procedure. Now Place 1 ml of each filtrate dilution in a Petri plate, add the culture media, and then tilt the dish to evenly distribute the sample and media [26]. Perform the Identification of fungi by morphology and molecular method. The morphospecies of fungi will initially be determined from their cultures. Depending on their capacity for sporulation, the selected cultures will be injected on various medium. On PDA (Potato dextrose agar)-containing Petri plates, the isolates are inoculated and incubated at 24 ± 2^0C for around one week. Lactophenol cotton blue staining was used to identify fungi growing out of the explants when they were in the sporulation stage. In molecular method, for acquiring the fresh mycelia for DNA extraction, liquid cultures of fungal isolates were created using 50 mL of Potato Dextrose Broth medium (Hi Media, pH 7.3) in 100 mL Erlenmeyer flasks. Centrifugation at 8,000 rpm and 40C for 10 min was used to separate the mycelia. Mycelia were gathered and physically crushed in liquid nitrogen. From 100 mg of fungus mycelia, genomic DNA was isolated [27]. Screening of potential fungi for nanoparticle production has been done once the identification is done. Screening is the process of choosing and assessing various fungal species according to how well and quickly they can synthesize nanoparticles. This screening procedure helps in the discovery of fungi that might be good candidates for the manufacture of green nanoparticles [28]. Now ZnO nanoparticles from the fungi has been synthesized. For this, the precursor material used was zinc nitrate hexahydrate [Zn (NO3)2.6H2O]. 1 g of Zn(NO3)2.6H2O was dissolved in 2–10 mL of fungal extract. After being extensively swirled with the use of a magnetic stirrer and kept in a pre-heated muffle furnace maintained at t 400±10°C for two hours, the completed product was then further calcined at 700°C. So, it was also necessary to undertake a structural study on the synthesized ZnO NPs [29]. The size and architectures of the ZnO nanoparticles determine how much energy is required for the nucleation and growth of a supersaturated arrangement throughout various processes including coarsening, focused connection, and accumulation. Lastly, Purification and characterization of ZnO nanoparticles by spectroscopic and microscopic methods. (UV Visible spectroscopy, SEM, TEM, XRD) has been done. In a conventional UV-Vis spectrophotometer, one half of a light beam is sent through a transparent cell holding a solution of the material being tested, and the other half is directed through a cell that is similar to the sample cell but contains the solvent instead of the substance. The device is designed to travel throughout the required wavelength range, allowing comparison of the intensity of the two beams [30]. If the substance absorbs light of a specific wavelength, the intensity of the sample beam (IS) will be lower than the intensity of the reference beam. The production of the spectrum involves measuring the absorption of radiation by a sample at various wavelengths and recording the findings. The wavelength of the whole area is plotted against the absorption (A) of light at each wavelength to form the spectrum. The graph between (hv versus h) may also be plotted along the x-axis to determine the sample's band gap. Calculating the quantity of a component known to be present in the sample using UV-Vis spectrometry is almost exclusively employed for quantitative analysis. Usually, a solution is used to analyze the substance [31].

V. Conclusion

Biological entities may be used to biosynthesize nanoparticles, which presents a potential and sustainable solution to some of the major problems facing contemporary agriculture. The green synthesis techniques provide a number of benefits over conventional chemical and physical procedures, including the use of plant extracts, microbes, fungus, or other biomolecules. The exact control of nanoparticle characteristics made possible by this economical and environmentally friendly technology makes them the best possible choice for agricultural applications. Biogenic nanoparticles have a wide range of uses in agriculture and have the potential to revolutionize crop production and environmentally friendly agricultural methods. Improved nutrient absorption efficiency, reduced waste, and reduced environmental effect are the results of the controlled and targeted dispersion of agrochemicals that use nanocarriers, including as fertilizers and pesticides.

Refence

1. Pandit, C., Roy, A., Ghotekar, S., Khusro, A., Islam, M. N., Emran, T. B., ... & Bradley, D. A. (2022). Biological agents for synthesis of nanoparticles and their applications. Journal of King Saud University-Science, 34(3), 101869.
2. Samuel, M. S., Ravikumar, M., John J, A., Selvarajan, E., Patel, H., Chander, P. S., ... & Chandrasekar, N. (2022). A review on green synthesis of nanoparticles and their diverse biomedical and environmental applications. Catalysts, 12(5), 459.
3. Ishak, N. M., Kamarudin, S. K., & Timmiati, S. N. (2019). Green synthesis of metal and metal oxide nanoparticles via plant extracts: an overview. Materials Research Express, 6(11), 112004.
4. Enamala, Manoj Kumar, Bhulakshmi Kolapalli, P. Divya Sruthi, Silpi Sarkar, Chandrasekhar Kuppam, and Murthy Chavali. "Applications of nanomaterials and future prospects for nanobionics." Plant Nanobionics: Volume 2, Approaches in Nanoparticles, Biosynthesis, and Toxicity (2019): 177-197.
5. Vasseghian, Y., Arunkumar, P., Joo, S. W., Gnanasekaran, L., Kamyab, H., Rajendran, S., ... & Klemeš, J. J. (2022). Metal-organic framework-enabled pesticides are an emerging tool for sustainable cleaner production and environmental hazard reduction. Journal of Cleaner Production, 133966.
6. Findik, F. (2021). Nanomaterials and their applications. Periodicals of Engineering and Natural Sciences, 9(3), 62-75.
7. Bahrulolum, H., Nooraei, S., Javanshir, N., Tarrahimofrad, H., Mirbagheri, V. S., Easton, A. J., & Ahmadian, G. (2021). Green synthesis of metal nanoparticles using microorganisms and their application in the agrifood sector. Journal of Nanobiotechnology, 19(1), 1-26.
8. Li, Xiangqian, et al. "Biosynthesis of nanoparticles by microorganisms and their applications." Journal of nanomaterials 2011 (2011): 1-16.
9. Ovais, M., Khalil, A. T., Ayaz, M., Ahmad, I., Nethi, S. K., & Mukherjee, S. (2018). Biosynthesis of metal nanoparticles via microbial enzymes: a mechanistic approach. International journal of molecular sciences, 19(12), 4100.
10. Cowen, Richard. History of life. John Wiley & Sons, 2013.
11. Singh, Anirudh, et al. "Green synthesis of metallic nanoparticles as effective alternatives to treat antibiotics resistant bacterial infections: A review." Biotechnology Reports 25 (2020): e00427.

12. Jamkhande, Prasad Govindrao, et al. "Metal nanoparticles synthesis: An overview on methods of preparation, advantages and disadvantages, and applications." Journal of drug delivery science and technology 53 (2019): 101174.
13. Król, A., et al. "Zinc oxide nanoparticles: Synthesis, antiseptic activity and toxicity mechanism." Advances in colloid and interface science 249 (2017): 37-52.
14. Thomas, J., Thomas, S., Kalarikkal, N., & Jose, J. (Eds.). (2018). Nanoparticles in polymer systems for biomedical applications. CRC Press.
15. El-Seedi, Hesham R., et al. "Metal nanoparticles fabricated by green chemistry using natural extracts: Biosynthesis, mechanisms, and applications." RSC advances 9.42 (2019): 24539-24559.
16. Biswas, Abhijit, et al. "Advances in top–down and bottom–up surface nanofabrication: Techniques, applications & future prospects." Advances in colloid and interface science 170.1-2 (2012): 2-27.
17. Usman, Ken Aldren S., et al. "Downsizing metal–organic frameworks by bottom-up and top-down methods." NPG Asia Materials 12.1 (2020): 58.
18. Capek, Ignác. Nanocomposite structures and dispersions. Vol. 23. Elsevier, 2019.
19. Ghorbani, Hamid Reza. "A review of methods for synthesis of Al nanoparticles." Orient. J. chem 30.4 (2014): 1941-1949.
20. Rane, Ajay Vasudeo, et al. "Methods for synthesis of nanoparticles and fabrication of nanocomposites." Synthesis of inorganic nanomaterials. Woodhead Publishing, 2018. 121-139.
21. Jan, Hasnain, et al. "A detailed review on biosynthesis of platinum nanoparticles (PtNPs), their potential antimicrobial and biomedical applications." Journal of Saudi Chemical Society 25.8 (2021): 101297.
22. Agarwal, H., Kumar, S. V., & Rajeshkumar, S. (2017). A review on green synthesis of zinc oxide nanoparticles–An eco-friendly approach. Resource-Efficient Technologies, 3(4), 406-413.
23. Sharma, D., Kanchi, S., & Bisetty, K. (2019). Biogenic synthesis of nanoparticles: a review. Arabian journal of chemistry, 12(8), 3576-3600.
24. Mughal, B., Zaidi, S. Z. J., Zhang, X., & Hassan, S. U. (2021). Biogenic nanoparticles: Synthesis, characterisation and applications. Applied Sciences, 11(6), 2598.
25. Saif, Sadia, Arifa Tahir, and Yongsheng Chen. "Green synthesis of iron nanoparticles and their environmental applications and implications." Nanomaterials 6.11 (2016): 209.
26. Ukpaka, C. (2016). Development of model for bioremediation of crude oil using moringa extract. Chem. Int, 2(9).
27. Senanayake, I. C., et al. "Morphological approaches in studying fungi: Collection, examination, isolation, sporulation and preservation." Mycosphere 11.1 (2020): 2678-2754.
28. Flieger, Jolanta, et al. "Antioxidants: Classification, natural sources, activity/capacity measurements, and usefulness for the synthesis of nanoparticles." Materials 14.15 (2021): 4135.
29. Sumanth, Basavaraju, et al. "Mycogenic synthesis of extracellular zinc oxide nanoparticles from Xylaria acuta and its nanoantibiotic potential." International Journal of Nanomedicine (2020): 8519-8536.
30. Jayachandran, Ashwini, T. R. Aswathy, and Achuthsankar S. Nair. "Green synthesis and characterization of zinc oxide nanoparticles using Cayratia pedata leaf extract." Biochemistry and Biophysics Reports 26 (2021): 100995.
31. Khan, Shahid Ali, et al. "Fourier transform infrared spectroscopy: fundamentals and application in functional groups and nanomaterials characterization." Handbook of materials characterization (2018): 317-344.