Biosynthesis of Nanoparticles, Characterization and its Applications: A Review

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Abstract

Nanotechnology has developed as an adaptable stage that could provide efficient, cost-effective and environmentally acceptable solutions for the worldwide manageability challenges confronting society. The recent exploration on bio-frameworks at the Nano-scale and the nanotechnology has made a standout amongst the most powerful science and innovation areas at the conjunction of physical sciences, sub-atomic building, science, Biotechnology and Drug. Nano Bio-frameworks inquire about is a need in numerous nations and its pertinence inside nanotechnology is relied upon to increment later on. This paper summarizes the various applications of Nanotechnology and there has been a rapid increase in the fields of medicine and more specifically in targeted drug delivery. Opportunities of utilizing nanotechnology to address global challenges in Water purification, clean energy technologies, Greenhouse gases management and Cancer Therapy are discussed.

Key Words

Nanotechnology, Drug delivery, Bioframework, Applications

1. Introduction

Nanotechnology is the study of extremely small structures, having size of 0.1 to 100 nm. Nano medicine is a relatively new field of science and technology[1]. However it is also inherent that these materials should display different properties such as electrical conductance chemical reactivity, magnetism, optical effects and physical strength, from bulk materials as a result of their small size. Progression in the field of nanotechnology and its applications to the medications, pharmaceuticals and industries has upset the twentieth century [2]. Metal and metal oxide nanoparticles have been additionally investigated, and their natural applications have surprisingly been illustrated; for example, anticancer, cell reinforcement, mitigating, wound-recovering and antimicrobial exercises [3]. Green amalgamation of nanoparticles is picking up deception around the world as a result of its favorable circumstances, for example, being ecofriendly, non-poisonous, and economic, over concoction and conventional physical strategies[4,5]. A few organic techniques have been utilized for nanoparticle generation from life forms including microbes, organisms, and plant extracts[6].

Nanotechnology has potential to detect meticulously the human diseases such as HIV, malaria, TB, diabetics, cardiac problems and cancer. Drug delivery systems using nanotechnology is a promising aspect.

Nanotechnology, unlike any other technology can find applications in many areas of human life[7]. It will play an increasingly crucial role in many key technologies of the new millennium. It is gaining important in areas such as catalysis, optics, biomedical sciences, mechanics, magnetic, and energy science[8].

The development of reliable green process for the synthesis of silver nanoparticles is an important aspect of current nanotechnology research. Nanomaterials such as Ag, Au, Pt, Zn and Pb have been synthesized by different methods, including hard template, using bacteria, fungi and plants[9.] The towering environmental concerns had triggered the researchers to device novel methods of synthesizing the nanomaterials in biological systems such as bacteria, fungi and plants, termed as "green chemistry" approaches[10].

1. Methods for Synthesizing Nanoparticles

Generally Nanoparticles were delivered just by physical and chemical methods[11]. A portion of the ordinarily utilized physical and synthetic strategies are particle sputtering, solvothermal blend, and sol gel method. Fundamentally there are two methodologies for Nanoparticles blend specifically the Bottom up methodology and the Top down methodology. The Nanoparticles are amalgamation by Physical and substance strategies like Sol-gel strategy, Solvothermal blend, Chemical decrease, Laser removal, Inert gas buildup and Biosynthesis of nanoparticles[12].

2. Synthesis of Nanoparticle using Microorganisms

Microorganisms have been appeared to be essential nanofactories that hold gigantic potential as ecofriendly and financially effective devices, evading dangerous, brutal synthetic compounds and the high vitality request required for physiochemical amalgamation[13]. Microorganisms detoxify substantial metals because of different reductase catalysts, which can decrease metal salts to metal nanoparticles with a tight size passage and, in this way less polydispersity. Over the past few years, microorganisms, including bacteria (such as actinomycetes), fungi, and yeasts, have been studied extra and intracellularly for the synthesis of metal nanoparticles [14]. For the synthesis, extra cellular synthesis has received much attention, because it eliminates the downstream processing steps required for the recovery of nanoparticles15. Furthermore, these help in providing natural capping to synthesize nanoparticles, thereby preventing the aggregation of nanoparticles and helping them to remain stable for a long time, thus providing additional stability[16.]

In recent research, bacteria, including *Pseudomonas deceptionensis*, *Weissella oryzae* [17], *Bacillus methylotrophicus*, *Brevibacterium frigoritolerans* and *Bhargavaea indica* [18], have been explored for silver and gold nanoparticle synthesis. Similar potential for producing nanoparticles has been showed by using several *Bacillus* and other species[19]. As opposed to utilizing microbes, mycosynthesis is a clear methodology for accomplishing steady and simple organic nanoparticle combination, because fungi containing important metabolites with higher bioaccumulation ability and simple downstream processing are easy to culture for the efficient, low-cost, production of nanoparticles[20]. Fungal enzymes, such as the reductase enzymes from *Penicillium species* and *Fusarium oxysporum*, nitrate reductase, and /-NADPH-dependent reductases, were found to have a significant role in nanoparticle synthesis [21.]

3. Synthesis of Nanoparticle using Microorganisms

As of late, phytonanotechnology has given new roads to the synthesis of nanoparticles in an ecofriendly, simple, rapid, stable, and cost-effective method[21]. Phytonanotechnology has advantages, including biocompatibility, scalability, and the medical applicability of synthesizing nanoparticles using the universal solvent, water, as a reducing medium[22.] Recently, successfully synthesized gold and silver nanoparticles using the leaf and root extract from the medicinal herbal plant *Panax ginseng* suggested, the use of medicial plants as resources. Moreover, different plant parts, including leaves, natural products, stems, roots, and their concentrates, have been utilized for the amalgamation of metal nanoparticles. The exact mechanism and the components responsible for plant-mediated synthetic nanoparticles remain to be elucidated. It has been proposed that proteins, amino acids, organic acid, vitamins, as well as secondary metabolites, such as flavonoids, alkaloids, polyphenols, terpenoids, heterocyclic compounds, and polysaccharides, have significant roles in metal salt reduction and, furthermore, act as capping and stabilizing agents for synthesized nanoparticles[23.]

4. Characterization of Nanoparticles

UV-visible absorption spectroscopy:

Absorbance spectroscopy is used to determine the optical properties of a solution. The optical measurement of UV-visible spectrophotometer has different absorbance peak like 410nm when treated with the Nerium Obander plant extract after addition of aqueous 1mM Silver nitrate solution. In case of *Azadirachta indica* get synthesized with Iron nanoparticles by the indication of suitable surface Plasmon resonance with high band intensities and peaks was found through UV-visible spectroscopy at the range of 216- 265 nm [24.]

X-ray diffraction (XRD) analysis:

X-ray diffraction is an ordinary procedure for assurance of crystallographic structure and morphology. There is increment or on the other hand decline in force with the measure of constituent. This Technique is used to establish the metallic nature of particles gives information on translational symmetry size and shape of the unit cell from peak positions and information on electron density inside the unit cell, namely where the atoms are located from peak intensities[25.]

Fourier Transform Infrared [FTIR] spectroscopy

Measures infrared intensity vs. wavelength of light, it is used to determine the nature of associated functional groups and structural features of biological extracts with nanoparticles. The calculated spectra clearly reflect the well-known dependence of nanoparticle optical properties. The green synthesized silver nanoparticle by employing various leaf extract was analysed using Fourier Transform Infrared [FTIR] Spectroscopy showed characteristic peaks[26.]

Microscopic techniques

These techniques namely Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) mainly used for morphological studies of nanoparticles.

Transmission electron microscopy

Transmission electron microscopy is a microscopy procedure in which a light emission electrons is transmitted through a ultra-light example. A picture is shaped from the cooperation of the electrons transmitted through it; the picture is amplified and centered onto an imaging gadget, a fluorescent screen on a layer of photographic film or to be recognized by a sensor a CCD camera [27].

Scanning electron microscope

The characterization of Scanning electron microscope analysis is employed to determine the size, shape & morphologies of formed nanoparticle. SEM gives high resolution images of the surface of a sample is desired. The scanning electron microscope works as same principle as an optical microscope, but it measures the electrons scattered from the sample rather than photon. This makes the SEM capable of magnifying images up to 200.000 times. Measures the particle size and characterization, Conductive or sputter coated sample involved and the sensitivity down to 1nm [28].

Atomic Force Microscopy

This technique is also known as scanning force microscopy (technique that forms images of surfaces using a probe that scans the specimen), very high resolution type of scanning probe microscopy, with reported resolution on the order of fractions of a nanomerter, more than 100 times better than the optical diffraction limit. The atomic force microscopy is based on a physical scanning of samples at sub-micron level using a probe tip of atomic scale and offers ultra-high resolution in particle size measurement[29]. Contingent on properties, tests are normally checked in contact or noncontact mode. Amid contact mode, the geological guide is produced by tapping the test on to the surface over the example and test drifts over the leading surface in non-contact mode. One of the prime favorable positions of AFM is its capacity to picture non-directing examples with no specifi c treatment. This include permits the imaging of sensitive organic and polymeric nano and microstructures[30].

5. Applications of Nanotechnology

Water Purification

Nanotechnology offers a low-cost and effective solution to the challenge of access to clean and safe water for millions of people in South Africa and the developing world. The technology holds the potential to radically reduce the number of steps, materials and energy needed to purify water. For example, titanium oxide at nanoscale can be used to degrade organic pollutants. And silver nano-particles have the ability to degrade biological pollutants such as bacteria. Carbon nanotubes, nanoporous ceramics, magnetic nanoparticles and other nanomaterials which could be used to remove water-borne diseases such as typhoid and cholera, as well as toxic metal ions, organic and inorganic solutes[33].

Health

In both diagnosis and treatment, nanotechnology holds the key to revolutionize health care, particularly in developing countries where access to effective health care is still a challenge for millions of people living in remote areas. In the field of diagnostics, nanotechnology promises quick, early and accurate detection of diseases. Portable, but highly sensitive point-of-care test kits are under development which will offer all the diagnostic functions of a medical laboratory. Depending on how they are designed and the intended application, the hand held kits could be used to test for viruses, bacteria or hormones. Thus they will be able to test – simply and quickly for infectious diseases such as malaria, cholera, HIV/Aids and other sexually-transmitted infections and even cancer. Also known as the "lab-on-a-chip" because of their ability to emulate the services of a complete medical laboratory, these inexpensive, hand-held diagnostic kits can pick up the presence of several pathogens at once and could be used for wide-ranging screening in remote clinics[34].

Biomedical imaging

Nanotechnology applications are in development that will radically improve medical imaging techniques. For example, gold and silver nanoparticles have optical properties which make them extremely effective as contrast agents. Quantum dots which are brighter than organic dyes and need only one light source for excitation, when used in conjunction with magnetic resonance imaging, can produce exceptional images of tumour sites[35.]

Targeted drug delivery systems

Nanostructures can be used to recognise diseased cells and to deliver drugs to the affected areas to combat cancerous tumours, for example, without harming healthy cells. In obesity, nanoparticles can target and inhibit the growth of fat deposits[36.]

Slow-release drug therapy

Research shows that nano-sized biodegradable polymer capsules containing drugs for tuberculosis treatment are effectively taken up by the body's cells. The effect is a slower release of the drug into the body and a reduction in the frequency with which TB patients need to take his or her medication. In countries where drugs are not readily available and compliance is generally low due to a number of reasons, the technology holds great potential for increased drug compliance and less chance of the development of drug resistance[37.]

Cancer therapy

This technology is being evaluated for cancer therapy. Nanoshells are tuned to absorb infra red rays when exposed from a source outside the body and get heated and cause destruction of the tissue. This has been studied in both in vitro and in vivo experiments on various cell lines[31]

Diagnostic purposes

They are useful for diagnostic purposes in whole blood immunoassays e.g. coupling of gold nanoshells to antibodies to detect immunoglobulins in plasma and whole blood.

Micro metastasis

Nanoshells are currently studied for micro metastasis of tumors and also for treatment of diabetes[32]

Energy

Another impressive application for nanotechnology is energy production, conversion and storage[38]. Research is well advanced enough to establish that nanotechnology offers a viable alternative to non-renewable fossil-fuel consumption and gives us the means to achieve a "hydrogen economy". Nano-applications in this area include: solar cells; fuel cells and new energy production, conversion and storage processes. In all cases, the results are energy that is cheaper, cleaner, more efficient and renewable. In future, nano holds the potential to produce hybrid vehicles with reduced fuel consumption and a lighter motor weight.

Nanotechnology can produce cleaner process engineering which will in turn produce value-added chemicals and speciality products, including bio catalytic systems and novel heterogeneous catalysts. Nanotechnology can make catalytic converters more efficient, cheaper and more accurately controlled. Nanotechnology-based innovations can be designed that will combat air pollution remediation, detect toxic materials and leaks, reduce fossil fuel emissions and separate gases.

Nanotechnology on Wound Dressing

Efforts have been made during the last few years towards the development of new artificial wound coverings which will meet the requirements necessary for the treatment of major skin wounds. Research has been mainly focused on achieving the specifications of an ideal wound dressing, such as hydrogel technologies providing products suitable for applications in biomedical, personal care as well as nano-sensor. But as the hydrogels have low mechanical strength, recent trends have come up in the form of composite membranes, where a textile material is coated with the polymer solution. The fabric reinforcement provides strength to the dressing and the drug loaded dressings offer precise control of the release behavior[39,40.]

6. Conclusion

Based on the review in this paper, Nanotechnology can possibly be the way to a shiny new world in the fields of food and agriculture, construction materials, mechanical, medicine and electrical engineering. In spite of the fact that replication of common frameworks is one of the most encouraging regions of this innovation, researchers are as yet attempting to get a handle on their astonishing complexities. Furthermore, nanotechnology and nanomaterials is a swiftly growing area of research where new properties of materials on the nano-scale can be utilized for the benefit of industrial and a number of capable developments exist that can potentially modify the service life and life-cycle cost of construction infrastructure to make a new world in future.

References

1. Yousaf SA, SalamatA Effect of heating environment on fluorine doped tin oxide (f: SnO/sub 2/) thin films for solar cell applications. Faculty of Engineering & Technology. Islamabad.2008
2. Khan Y The great partition: The making of India and Pakistan, 2007
3. Sahayaraj K, Rajesh S. Bionanoparticles: synthesis and antimicrobialapplications. In: M_endez-Vilas A, Ed. Science against Microbial Pathogens: Communicating Current Research and Technological Advances. Badajoz: Formatex Research Center, pp. 2011. 228–244.

4. Schrofel A, Kratosova G, Safarik I, Safarikova M, Raska I, Shor LM. . Applications of biosynthesized metallic nanoparticles – a review. ActaBiomaterialia. 2014 10:4023–4042.
5. Mohanpuria P, Rana NK, Yadav SK. Biosynthesis of nanoparticles:technological concepts and future applications. J Nanopart Res.2008.10:507–517.
6. Aruna A, Nandhini R, Karthikeyan V, Bose P. Synthesis and characterization of silver nanoparticles of insulin plant (costuspictus D. Don) leaves. Asian Journal of Biomedical Pharmaceutical Sciences.2014. 4:1–6.
7. Kumar SA, Abyaneh MK, Gosavi SW, Kulkarni SK, Pasricha R, Ahmad A, Khan MI Nitrate reductase-mediated synthesis of silver nanoparticles from AgNO3 Biotechnology Letters. 2007; 29:439-445.
8. Chandrasekharan N, Kamat PV. Improving the photo-electrochemical performance of nanostructured TiO2 films by adsorption of gold nanoparticles, The journal of Physical Chemistry. 2000; 104:10851-10857.
9. Otari SV, Patil RM, Ghosh SJ, Thorat ND, Pawar SH. Intracellular synthesis of silver nanoparticle by actinobacteria and its antimicrobial activity (SpectrochimicaActa Part A: Molecular and BiomolecularSpect. 2015; 136:1175-1180.
10. Jean M, Feugang Ramey, Youngblood C, Jonathan M, Greene Abed, Fahad S. Application of quantum dot nanoparticles for potential non-invasive bio-imaging of mammalian spermatozoa, Journal ofNanobiotechnology. 2012; 10:45.
11. Sepeur S. Nanotechnology: technical basics and applications 2008.
12. Mittal J, Batra A, Singh A and Sharma MM Phytofabrication of nanoparticles through plant as nanofactories. Advances in Natural Sciences. Nanosciences. Nanotechnology.2014, 5:10
13. Jo, J.H, Singh P, Kim YJ, Wang C, Mathiyalagan R, Jin CG and Yang DC Pseudomonasdeceptionensis DC5-medi-ated synthesis of extracellular silver nanoparticles. Artificial Cells, Nanomedicine and biotechnology. Published online July 31, 2015. http:// dx.doi.org/10.3109/21691401.2015.1068792
14. Singh, P, Kim YJ, Wang C, Mathiyalagan R and Yang DC Weissellaoryzae DC6-facilitated green synthesis of silver nanoparticles and their antimicrobial potential. Artificial Cells,Nanomedicineand Biotechnology. Published online July 27, 2015. http://dx.doi.org/10.3109/21691401.2015.1064937
15. Wang C, Kim YJ, Singh P, Mathiyalagan R and Yang DC Green synthesis of silver nanoparticles by Bacillus methylotrophicus, and their antimicrobial activity. Artificial Cells,Nanomedicine and Biotechnology. Published online March 6, 2015. http://dx.doi.org/10.3109/21691401.2015.1011805
16. Singh P, Kim YJ, Singh H, Mathiyalagan R, Wang C and Yang DC Biosynthesis of anisotropic silver nano-particles by Bhargavaeaindica and their synergistic effect with antibiotics against pathogenic microorganisms. Journal of Nanomaterials 2015, 10
17. Bai H, Zhang Z, Guo Y and Jia W Biological synthesis of size-controlled cad-mium sulfide nanoparticles using immobilized Rhodobactersphaeroides. Nanoscale Research Letters.2009, 4, 717–723
18. Elbeshehy, EK, Elazzazy AMand Aggelis G Silver nanoparticles synthesis medi-ated by new isolates of Bacillus spp., nanoparticle characterization and their activity against bean yellow mosaic virus and human pathogens. Front. Microbiol.2015, 6, 453
19. Li X, Xu H, Chen ZS and Chen G Biosynthesis of nanoparticles by microorganisms and their applications. Journal of Nanomaterials 2011, 16
20. Zhang X, Yan S, Tyagi RD and Surampalli RY Synthesis of nanoparticles by microorgan-isms and their application in enhancing microbiological reaction rates. Chemosphere, 2011 82, 489–494
21. Alghuthaymi, MA, Almoammar H, Rai M, Galier ES and Elsalam KAA Myconanoarticles: synthesis and their role in phytopathogens management. Biotechnol. Biotechnol. Equip. 2015, 29, 221–236
22. Waghmare, SR Ecofriendly production of silver nanoparticles using Candida utilis and its mechanistic action pathogenic microorganisms. 2015, 3 Biotech 5, 33–38
23. Nam K T, Kim D W, Yoo P J, Chiang C Y, MeethongN, Hammond P T, Chiang Y M and Belcher A M, Virus-enabled synthesis and assembly of nanowires for lithium ion battery electrodes. Science; 2006, 312, 885–888

24. Pattanayak M, NayakP.L. Green synthesis and characterization of zero valent iron nanoparticles from the leaf extract of Azadirachtaindica (Neem). World Journal of Nano Science and Technology, 2013; 2(1): 06 09.
25. Cheng, Wang C, Liu Z. Upconversion nanoparticles and their composite nanostructures for biomedical imaging and cancer therapy. Nanoscale,2013; 5: 23 37.
26. Murugan A, Kumara K, Shanmugasundaram. Biosynthesis and characterization of silver nanoparticles using the aqueous extract of vitexnegundo. linn. World Journal of Pharmacy and pharmaceutical Science, 2014; 3(8): 1385 1393.
27. Ladj, R., Bitar, A., Eissa, M., Mugnier, Y., Le Dantec, R., Fessi, H., Elaissari, A. Individual inorganic nanoparticles: preparation, functionalization and in vitro biomedical diagnostic applications. Journal MaterialsChemistry. B,2013; 1: 1381 1396.
28. Umer, Naveed S, Ramzan N. Selection of a suitable method for the synthesis of copper nanoparticles, World Scintific Publishing Company,2012; 7(5): 18.
29. Muhlen AZ, Muhlen EZ, Niehus H, Mehnert W. Atomic force microscopy studies of solid lipid nanoparticles. Pharm Res. 1996;13:1411–6.
30. 23. Shi HG, Farber L, Michaels JN, Dickey A, Thompson KC, Shelukar SD, Hurter PN, Reynolds SD, Kaufman MJ. Characterization of crystalline drug nanoparticles using atomic force microscopy and complementary techniques. Pharm Res. 2003; 20:479–84.
31. West JL, Halas NJ. Applications of nanotechnology to biotechnology commentary. CurrOpinBiotechnol. 2000;11:215–7.
32. Kherlopian AR, Song T, Duan Q, Neimark MA, Po MJ, Gohagan JK, Laine AF. A review of imaging techniques for systems biology. BMC Syst Biol. 2008;2:74–92.
33. Wang Z, Ruan J, Cui D Advances and prospect of nanotechnology in stem cells. Nanoscale Res Lett 2009;4: 593-605.
34. Sagadevan, S., Periasamy, M. Recent trends in nanobiosensors and their applications – a review. Rev. Adv. Mater. Sci.2014; 36, 62–69.
35. Ahmed RZ,Patil G, Zaheer Z Nanosponges - a completely new nano-horizon: pharmaceutical applications and recent advances.Drug Dev Ind Pharm 2013; 39: 1263-1272.
36. Freitas RA Jr Nanotechnology, nanomedicine and nanosurgery.Int J Surg 2005; 3: 243-246.
37. SahooSK,Dilnawaz F, Krishnakumar S . Nanotechnology in ocular drug delivery. Drug Discov Today 2008 13: 144-151.
38. GardeD Chemo bomb' nanotechnology effective in halting tumors. Fierce drug delivery; 2012
39. Gupta and Agarwal, Textile based smart wound dressing, 2010; 35(2); 174-187
40. Park K R &Nho Y C, Radiation Physics and Chemistry, 67 (2003) 361.