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REVIEW ARTICLE

Biosynthesis of Nanoparticles from Microorganisms

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ABSTRACT:
Currently nanoparticle synthesis has been a major area of research since nanoparticles are high in demand and used in many applications like targeted drug delivery, treatment of diseases, nanodevices, food industries, electronic devices and in many other fields. The size of the nanoparticles and their unique physical and chemical properties are an added advantage for their use in various fields. Due to the increased demand synthesis of nanoparticles from different sources and different methods are being explored. Among them biological method of nanoparticle synthesis is highly cost efficient and easier compared to physical and chemical methods of nanoparticle synthesis. In biological methods use of microorganisms are the widely used source that is highly efficient for the synthesis of nanoparticles. This review deals with the production of nanoparticles from microorganisms and their applications in various fields.

KEYWORDS: Nanoparticle, biological method, microorganism, cheap and cost efficient.

INTRODUCTION:
Nanoparticles are particles with size of 1-100 nM and are of great importance due to their reduced size and application in various fields. In nature, nanoparticles are found in fine sand, dust, ash from volcanic eruptions[1]. In the laboratories, various physical, chemical, biological methodologies are followed for the synthesis of nanoparticles. Nanoparticles synthesized from physical and chemical methods involve the use of various toxic chemicals limiting their usage in various fields. Biological involves the usage of plants, microorganisms, enzymes and agricultural wastes, for the production of nanoparticles. The biological method of nanoparticle production is considered to be cheap, ecofriendly and reliable. Syntheses of nanoparticles from microorganisms are of growing importance due to their easy availability, feasibility and are cheaper to produce [2].

Many different types of nanoparticles are being synthesized and used in various industries. Silver nanoparticles, the most widely produced and utilized nanoparticle. Because of their anti microbial effects, anti cancer, anti-inflammatory effects they are widely utilized for biomedical industries. In addition, silver nanoparticles are used in cosmetic industries, paint, water filters, and diagnostic purposes. Gold nanoparticles are mainly used in medical industry for the detection of cancer, DNA fingerprinting, biosensors. Magnetic nanoparticles used in cancer diagnosis, targeted drug delivery, gene therapy. Iron nanoparticles are used in magnetic resonance imaging, drug delivery. Titanium nanoparticles are used in sensors and solar cell. Cadmium sulfide nanoparticles are widely used in light emitting diodes, photo catalysis and sensors[3,4].

Evaporation-condensation and laser ablation are the widely used physical methods of nanoparticle synthesis. However laser ablation is costly, needs high energy and is not suitable for production of nanoparticles in industrial scale[5]. Other disadvantages of physical method are it require high temperature, vacuum and expensive equipments[6]. Chemical method of nanoparticles production requires costly solvents, toxic chemicals making them unsuitable for large scale synthesis of nanoparticles. Production of nanoparticles from plants has main disadvantage of low synthesis rate. Synthesis of nanoparticles from microorganisms involve bottom up approach. Bottom up approach involves the production of nanoparticles from individual atom and molecules. Microorganisms like bacteria, actinomycete,

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fungi, and algae are easily available sources and can be manipulated for the synthesis of nanoparticles.

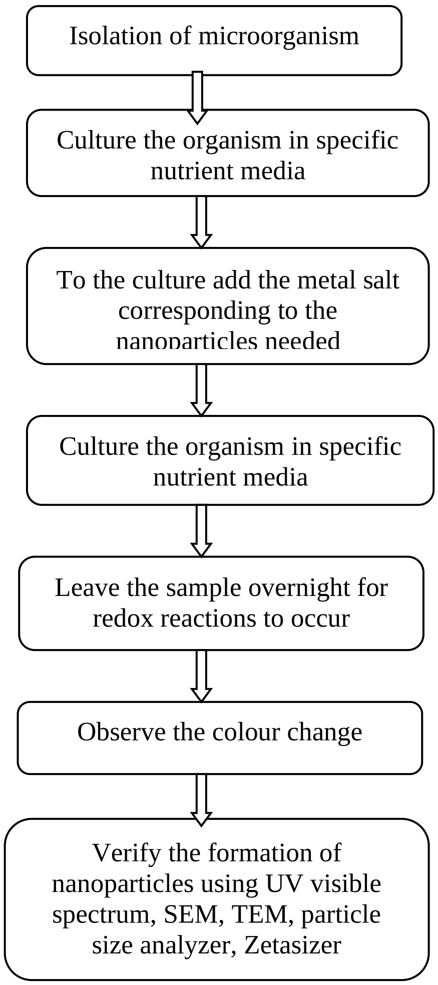


Figure 1: Steps in production of nanoparticles from microorganism

Nanoparticles from Microorganisms:

Many microorganisms like bacteria, fungi, algae and yeast are studied for their ability to produce nanoparticles. The advantages of using microorganisms for nanopartheyicle synthesis is that are easy to isolate, grow in the laboratory conditions and microbial cultures are cheaper to maintain compared to plant cultures. In addition microorganims have the potential to grow under toxic metal ion conditions and have the ability to breakdown heavy metal ions to produce naoparticles. Many microorganisms have been exploited for the production of silver, gold, titanium, iron nanoparticles.

Synthesis of Silver nanoparticles from Microorganism:

For producing silver nanoparticles, the microbe of interest is cultured in the nutrient media. After sufficient growth, the freshly grown cultures are centrifuged at 10,000 rpm for 10 minutes. Then the centrifuged sample is filtered. To the filtrate, silver nitrate ($AgNO_3$) is added. The formed silver nanoparticles are subjected to further characterization studies and are used for various applications.

Table 1: List of organisms used in silver nanoparticles synthesis

Organism	Size (nM)	Uses
Bacteria		
Bacillus subtilis	28-122	Antibacterial activity, anti fungal activity[7]
E.coli	5-25	Antimicrobial[8]
Alcaligenes faecalis	27	Anti microbial activity[9,10]
Pseudomonas aeruginosa	15-35	Antimicrobial[11]
Streptomyces rochei	22–85	Anti cancer activity, anti microbial activity[12]
Corynebacterium glutamicum	15-20	Antimicrobial[13]
Bacillus pumilus	20.12 to 29.48	Antimicrobial and nematicide[14]
Pseudomonas stutzeri	8	Antimicrobial[15]
Haemophilus influenzae	80.05-101.15	Antimicrobial[16]
Fungi		
Aspergillus fumigatus	10-15	Anti bacterial activity[17]
Fusarium oxysporum	10-40	Antimicrobial[18]
Arthroderma fulvum	15.5	Anti fungal activity [19]
Aspergillus fumigatus	5-95	Anti bacterial[20]
Aspergillus niger	25–175	Antimicrobial activity[21]
Aspergillus flavus	45–185	Antimicrobial activity[22]
Cunninghamella phaeospora	12.2	Anti bacterial[23]
Algae		
Caulerpa racemosa	5–25	Anti bacterial[24]
Padina pavonia	10-72	Anti bacterial[25]
Acanthophora specifera	33	Anti microbial[26]
Caulerpa serrulata	10	Anti bacterial[27]
Spirulina platensis	11.5	Anti bacterial[28]
Aphanothece sp, Phormidium sp, Lyngbya sp, Gleocapsa sp, Synechococcus sp	40- 80	Anti bacterial[29]
Yeast		
Cryptococcus laurentii	35-400	Anti fungal [30]
Rhodotorula glutinis	15-220	Anti fungal [30]

Synthesis of Gold nanoparticles from microorganisms:

Gold nanoparticles are commercially used in medical field for various purposes. Bacterai are cheap and easy source for the synthesis of gold nanparticles. Bactera of interest are cultured in the respective media and after sufficient growth, the culture is cnrifuged at 7000 rpm for 10 minutes. To the biomass, $HAuCl_4$ is added and incubated for gold nanoparticle synthesis[31]

Table 2: List of microorganisms used in gold nanoparticles synthesis

Organism	Size (nM)	Uses
Bacteria		
Bacillus megaterium	16	Anti microbial[32]
Bacillus niabensis	10–20	Anti microbial[33]
Lactobacillus kimchicus	5-30	Diagnosis of cancer, drug delivery systems, photothermal therapy, biosensing, and medical imaging[34]
Bacillus subtilis	5-25	Anti bacterialand anti fungal[35]
Bacillus cereus	20-50	Anti cancer activity[36]
Fungi		
Alter-naria alternata.	15-72	Anti bacterial, Anti fungal activity[37]
Aspergillus terreus	10–19	Anti bacterial[38]
Aspergillus niger	10-30	Anti larval[39]
Fusarium oxysporum	22	Anti bacterial[40]
Endophytic fungi	15 - 35	Anti bacterial, anti cancer[41]
Yeast		
Magnusiomyces ingens	20.3	Reduction of nitrophenols[42]
Pichia jadinii	30-100	Anti microbial[43]
Yarrowia lipolytica	20	Antibiofilm[44]
Algae		
Cystoseira baccata	8.4	Anti cancer[45]
T. conoides	12-57	Reduction of aromatic nitro compounds and organic dye molecules[46]

Synthesis of Magnetite nanoparticles from microorganisms:

In general, iron nanoparticles are known as magnetite nanoparticles, because of their magnetic properties. Iron nanoparticleas are produced from bacteria by culturing the bacteria of interest in the suitable media. After sufficient growth, the cells are harvested by centrifugation. To the biomass $FeSo_4$ is added and incubated for the production of magnetite nanoparticles [47]

Table 3: List of bacterial species used in magnetite nanoparticles synthesis

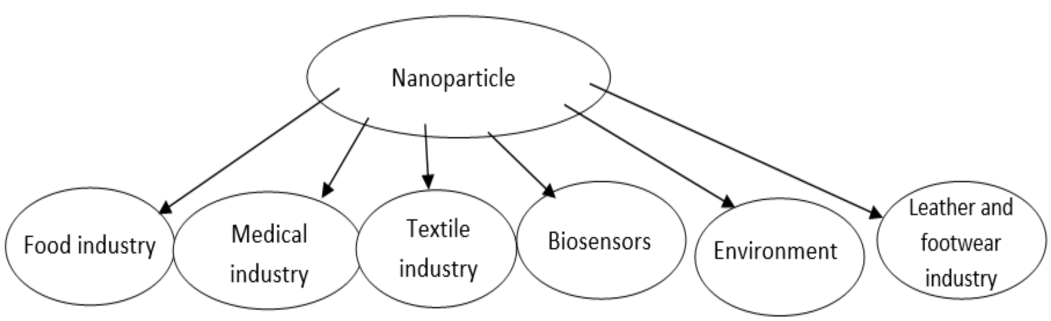
Organism	Size (nM)	Application
Bacteria		
E.coli	104	Antimicrobial[48]
Fungi		
Fusarium oxysporum	20-40	Anti microbial[49]
Alternaria alternata	9	Anti microbial[50]
Yeast		
Saccharomyces cerevisiae	8-9	Drug delivery[51]

Other nanoparticles from microorganism:

Microbial sources are utilized for various other sources of nanoparticle synthesis like *Pochonia chlamydosporium*, *Aspergillus fumigates* have been reported to produce magnesium nanoparticles[52]. Titanium nanoparticles are used in food industries, cosmetic and pharmaceutical purposes. Bacteria, *B.subtilis*, baker's yeast and fungal species *Aspergillus tubingensis* have been reported to produce titanium nanoparticles[53-55]. Production of Au-Ag alloy nanoparticle by yeast has been determined [56]. *Saccharomyces cerevisiae* has been reported to produce antimony oxide nanoparticles.

Applications of nanoparticles:

Nanoparticles are used in biosensors, used as coatings on wood, plastics, textile industry, food industry and many other applications. Silver and gold nanoparticles are widely used as antimicrobial agents due to their increased efficiency in inhibiting microbial growth. Nanoparticles due to their smaller size are capable of delivering the drugs specifically. They also have increased surface area, thereby increases the bioavailability of drugs. Nanoparticles also proved to cross the blood brain barrier due to their small size and hence can be used for brain related problems. In addition, nanoparticles are used in textile industry, leather and footwear industry, food industry for packaging, reducing pesticides[57].



Nanoparticles are on continuous demand due to their various uses and applications. Hence cheaper source of synthesis of nanoparticles are needed to be identified to overcome the demand for nanoparticles. Microorganisms are widely used for synthesis of different types of nanoparticles. The nanoparticles from microorganisms are exploited in various industries for various purposes.

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