

Biosynthesis of metal nanoparticles by probiotic bacteria

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ABSTRACT

Nanoparticle synthesis requires a clean, non-poisonous and environmental-compatible methods. Cations are absorbed on the surface layer of probiotics due to negative electro-kinetic potential of cell wall and this leads to biosynthesis of metal particles (usually nanoparticles). This review aims to track the field of biosynthesis of nanoparticles by probiotic bacteria. Therefore, after some introduction about nanoparticles and the microbial synthesis, all metal nanoparticles/oxide nanoparticles produced by probiotics are reviewed including silver, zinc, zinc oxide, titanium, titanium oxide, selenium as well as Sb₂O₃, Gd₂O₃, CdS nanoparticles. Production of nanoparticles gives antibacterial properties to the microorganism. Consequently, such extraordinary properties for probiotics with their own several health beneficial effects is killing two birds with one stone. It can be concluded that the capability of microorganisms to make metal nanoparticles with favorable morphological features and ideal size ranges has introduced a new and interesting approach to nanoparticle synthesis.

Keywords: nanoparticle, probiotic bacteria, AgNPs, ZnNPs, TiNPs.

1. INTRODUCTION

In recent years nanotechnology has been applied in various fields. Nanoparticles are being used in medicine, pharmacy, food industry and electronics [1]. Metal nanoparticles are one of the most important particles due to their physio and chemical properties [2]. The reduced dimensions of the nanoparticles have positive effects on the physical properties that are markedly different than the bulk material [3].

There are a variety of diverse approaches to synthesize different types of nanoparticles, such as physical, chemical, biological and even hybrid methods [3, 4]. Because of the high cost and possibility of producing toxic materials in other approaches such as the chemical method, biological methods are preferred. Microorganisms such as bacteria, fungi and algae can be used for metal nanoparticles production. The low cost of the process aligned with mass production feasibility and being environment-friendly are the advantages of the biological method [2].

2. BIOSYNTHESIS OF NANOPARTICLES

Currently, a number of physical and chemical methods are being widely used to produce monodispersed nanoparticles. However, the consistency of the products and the use of toxic chemicals are the main subjects of concern. Application of toxic material and volatile organic solvents in the clinical fields have been limiting the usefulness of some nanoparticles. This makes the development of clean, biocompatible, harmless and the green methods for nanoparticles synthesis of prime importance. Biological methods are characterized by nontoxic, practical, sustainable and environmentally-safe processes [3]. Microbial method is regarded as a resourceful and cost effective alternate as

Nanoparticles are usually synthesized by two strategies: top-down and bottom-up. In the top-down method bulk substances are split to nanosized materials, while in the bottom-up approach molecules are congregated to structures in the nanometer size range.

Another advantage of the bottom-up method is the production of metallic nanoparticles with the possibility of obtaining particles with relatively fewer imperfections and more homogeneous structures. A main disadvantage of the top-down approach is the deficiency of the surface structure, which can have a significant impact on the physical properties and surface chemistry of the metallic nanoparticles due to the high aspect ratio [5].

Bacteria can produce intra and extracellular nanoparticles [6]. Probiotic bacteria are well-known to improve health in Human. They help to reclaim gastrointestinal action and boost the function of immune system [7].

it requires low energy and material and produces small amount of waste byproduct [8].

It has been discovered that one of the most promising areas of research in modern nanoscience and nanotechnology is the interaction between inorganic nanoparticles and biological structures [9].

A crucial role in toxic remediation has been proven to be played by numerous microorganisms such as bacteria, fungi, yeast, etc., via reduction of metal ions [8]. Nanoparticles are synthesized when the microorganisms grasp target ions from their environment

and then turn them into the metal elements by the action of the enzymes generated by the cell activities [10]. Studies have revealed that while some bacteria are able to reduce metal ions and retain them as nanoparticles (NPs) inside the cell, others are capable of synthesizing them both intra- and extracellularly [11,12]. Transferring ions into the microbial cell to form nanoparticles in the existence of enzymes constitutes the intracellular method. The extracellular synthesis of nanoparticles consists of binding of the metal ions on the surface of the cells and reducing ions in the center of enzymes [10].

Microorganisms could be regarded as suitable reductants and coating agents for nanotechnology. These syntheses resulted in the production of a restricted number of different nanoparticles (mostly metal nanoparticles, though some metal oxides and salts are also reported) [8-12]. Microorganisms can also be used to yield nanoparticles but the degree of synthesis is slow and only

narrow number of sizes and forms are produced compared to routes involving plant based substances [12]. Microorganisms cope with a definite defense mechanism as a result of the extreme environmental settings which could attribute to change the redox state of the metal ions, therefore, forming the basis for nanoparticle synthesis [8].

Concerning the case of chemical synthesis, silver ions, provided as a silver salt, are decreased by a chemical reducing agent producing a silver nucleus. A capping agent which also prevents aggregation by steric interference or electrostatic repulsion controls the growth of the nucleus to a particle. For the case of biological synthesis, the decreasing and capping agent are both delivered by microorganisms or plants. Functional groups on the cell wall of bacteria are responsible for controlling the growth of the nucleus to a particle [13].

Table 1. Comparison between chemical and biological in nanoparticle production (Adapted from [13]).

Biological synthesis of nanoparticle	Other synthesis of nanoparticle
Advantages	Advantages
Nonuse of expensive and toxic chemicals	Higher yield
Ambient temperature and atmosphere	Short time of synthesis
Modification by genetic engineering	
Nanoparticles with:	Disadvantages
Greater commercial viability	Use of expensive and toxic chemicals
Greater specific surface area	Physical methods need high temperature
Large savings in reductants	Chemical methods need high pressure
Large savings energy costs	Chemical methods need a stabilizer
High production rate	
Higher catalytic reactivity	
Small nanoparticles in large-scale	
Disadvantages	
Time consuming	
Difficult control (size, shape and crystallinity)	

2.1. Bacterial biosynthesis of nanoparticles.

Bacteria make such an attractive category of microorganisms having naturally granted property of decreasing/oxidizing metal ions into metallic/oxide nanoparticles thus functioning as “mini” nanofactories [9]. Some bacteria are characterized by the ability to sorb heavy metals from polluted wastewaters, while others not only have a solid biosorptive capacity but also can diminish and precipitate them in their metallic form [1]. Some of these organisms can endure and grow even at high metal ion concentrations. Neglecting the bacterial species exploited as a reducing agent, the mainstream of the consequential synthesized NPs present polydispersity. The relative ease of manipulation of bacteria is one of the reasons for their employment for nanoparticles synthesis [5]. The capacity of organisms to yield metal nanoparticles with anticipated morphological features and sizes has introduced a new and exciting method to nanoparticle synthesis [11].

There are some pitfalls in culturing of microbes, which is being slow and challenging in providing better control over size distribution, form and crystallinity [3]. In their attempts to improve or control size and form of synthesized NPs, researches have reported strain selection, enhancing the settings such pH, incubation temperature and time, concentration of metal ions, and the extent of biological material, to optimize the large scale manufacture for commercial purposes [3]. Temperature changes

can result in the formation of particles with changing shapes, such as varying proportions of three-sided and hexagonal nanoplates accompanied by spherical NPs, in addition to particles of different sizes. For the sake of optimizing metal nanoparticle production through bacteria, genetically manipulated microorganisms have started being created with the intention of increasing protein secretion and hence clarify the most probable/better decreasing agent. In general, genetically engineered organisms have revealed to be more effective in comparison with wild type strains [11].

Despite consistency and a green method of creation, the nanoparticle synthesis degree is not analogous to non-biological synthesis approaches. Biosynthesis would be more feasible in terms of commercial uses provided that the nanoparticles could be synthesized more quickly and economically on a large scale [14].

This has always been the case that, formation of metal nanoparticles is affected by stability matters in aqueous solutions that have caused particle aggregation as a result of van der Waal's forces of attraction. The ‘biogenic’ method is supported more according to the fact that the mainstream of the bacteria resist ambient circumstances of temperature, pH and pressure. Greater catalytic reactivity and larger specific surface area are the characteristics of particles generated by these processes. Furthermore as a result of the bacterial carrier matrix there is an enhanced contact between the enzyme and the metal salt. In addition, the carrier matrix could play the role of both, a reductive

and stabilizing agent in the enzymatic creation of nanoparticles [15]. Table 1 represents a comparison between chemical and biological approaches for the creation of nanoparticles.

2.2. Nanoparticle Biosynthesis by Probiotics.

Probiotic microorganisms, can be regarded as good contenders for the production of nanoparticles at the laboratory scale and even at industrial scale. This stems from their ability to compromise with the setting and high growth and propagation, creation of several enzymes, and non-pathogenicity [14].

Lactobacillus, a frequently employed bacterium for the treason of curdling of milk, is extremely useful to our system. It is non-pathogenic, prokaryotic, Gram positive Gram positive and anaerobic-mesophilic microbe [16,17].

Probiotics, or good bacteria, are ordinary inhabitant flora of intestinal area, which can be added into numerous diverse types of produces. The most frequently used probiotics are Species of *Lactobacillus* and *Bifidobacterium*, whilst other microorganisms including *Escherichia coli* strain Nissle and *Saccharomyces cerevisiae* have also been made use of as probiotics. I short,

probiotics microorganisms employ their positive effects through two mechanisms; i) Direct effects of live cells, and ii) Indirect effects via producing an extensive range of metabolites or biogenic [9]. Nanoparticles under both oxidizing and decreasing settings are produced as a result of the facultative nature of *Lactobacilli*. [18].

Similar to most bacteria, probiotics possess an undesirable electro-kinetic potential, which freely attracts the cations, and this step possibly acts as a threshold level of the biosynthesis procedure [17]. Buttermilk ,as the most common inhabitant of *Lactobacillus* strains, when was exposed to suitable ions, led to an increase in metals to such an extent that almost 35% of the harvested dry bacterial biomass is metal [19]. Nanocrystals of gold, silver and their alloys have been produced by the aid of lactic acid bacterial cells [20].

Furthermore, numerous studies stated that probiotics can produce many metal nanoparticles/oxide nanoparticles including Ag, Au, TiO₂, Sb₂O₃, Gd₂O₃, CdS, Selenium, and ZnO.

Table 2. The amount of silver associated with the biomass starting with an initial silver concentration of 200 mg/g CDW.

Species	Ag (mg/g CDW)	XRD
<i>Lactobacillus fermentum</i>	166±19	Ag (0)
<i>Lactobacillus farciminis</i>	151±17	Ag (0)
<i>Lactobacillus fructivorans</i>	146±29	Ag (0), Ag ₂ O
<i>Lactococcus garvieae</i>	146±19	Ag (0)
<i>Pediococcus pentosaceus</i>	141±42	Ag (0), Ag ₂ O
<i>Lactobacillus brevis</i>	137±10	Ag (0)
<i>Lactobacillus parabuchneri</i>	137±2	Ag (0)
<i>Lactobacillus parabuchneri</i>	137±2	Ag (0)
<i>Lactobacillus parabuchneri</i>	137±2	Ag (0)
<i>Lactobacillus rhamnosus</i>	130±8	Ag (0)
<i>Lactobacillus plantarum</i>	128±39	Ag (0)
<i>Lactobacillus mucosae</i>	116±16	Ag (0)
<i>Lactobacillus plantarum</i>	110±15	Ag (0)

Presence of Ag (0), determined by XRD, confirmed if the species was able to reduce silver (1).

3. METAL NANOPARTICLE PRODUCED BY PROBIOTICS

3.1. Silver nanoparticle.

A high level of antimicrobial activity against Gram-positive, Gram negative bacteria as well as anti-inflammatory capacity has been demonstrated by silver nanoparticle. Numerous microbes are known to decrease the Ag⁺ ions to form silver nanoparticles, most of which can be categorized as spherical particles [9]. In recent years, intense interest has been arisen in the sphere of manufactured silver nanomaterials due to their unusual augmented physicochemical and biological properties activities in comparison with the bulk parent materials [21, 22].

In the silver nanoparticles synthesis, silver nitrate was made use of as a precursor. 200 mL of bacteria (*Lactobacillus bulgaricus*) filtrate was added to 300 mL of 1mM AgNO₃ aqueous solution for the sake of reducing Ag ions and was kept at room temperature for 24 hours. The main discovery of synthesized silver nanoparticle was done in the reaction mixture by detecting the color alteration of the medium from pale yellow to reddish brown as well as observed optical density. Having been incubated for 24 hours, in order to make powder for optical measurements, the reaction mixture was filtrated and the suspension was hot air

dried in the oven. The filtrate was concentrated by recurring centrifugation at 10,000rpm for a time span of 10 minutes

studies proposes the bottom-up technique was mostly used in the synthesis of silver nanoparticles compared with the top-down technique (<4% of reviewed articles) [21]. Table 2 provides a comparison of different nanosilver productions by several *Lactococcus* strains, starting with an initial silver concentration of 200 mg/g CDW.

3.2. ZnO nanoparticle.

ZnO NPs, for its exceptional antibacterial, antifungal, wound healing and UV filtering possessions have become the subject of interest for the Scientifics. Scientists have made use of ZnO nanoparticles for the restriction of beta galactosidase [24] or towards H₂S adsorption [25].

Lactobacilli spore tablets with Pharmaceutical grade (SporeLac DS, Sanyko Pharmaceuticals, Japan) were obtained and two tablets were dissolved in 50 mL sterile distilled water comprehending standard carbon as well as nitrogen source. In accordance with the specification, each tablet was capable of making 120 million bacteria of the bacterium. Then the incubation of the culture solution was permitted over the course of night on

room temperature. The following day, the occurrence of the culture was confirmed under a light microscope. The pH pertaining to this source culture solution was recorded to be equal to 3.

Then, equal volume of sterile distilled water comprising of nutrients in five different hard glass test tubes were mixed in order to doubling 10 mL of this source. The day after, the pH was taken and established to be between 4 up to 5, for the case of culture solution. Slight quantity of NaHCO_3 was combined with culture solution until it reached pH 6. For making a solution of 0.25 (M) strength analytical reagent grade Zinc Chloride (ZnCl_2) was made use of into at room temperature. Culture solution was heated on the steam bath up to 80°C for period of 5 to 10 minutes. The commencement of the transformation was perceived by an appearance of starch like smokiness in solution and white deposition at the bottom of the tube. The tubes were permitted to incubate in the laboratory environment for another 9 hours, after which noticeably coalescent white clusters dumped at the bottom of all the tubes [25].

In another procedure, pure culture of *Lactobacillus plantarum* VITES07 was inoculated into a flask comprising of sterile de Man, Rogosa and Sharpe (MRS) broth and incubated at 37°C for 24 h at 100 rpm. Then the culture solution was diluted to four times and permitted to grow for further twenty-four hours. After the incubation period, to postpone the process of transformation, pH of the culture broth was attuned to 6 using 0.4 M NaOH. At that point 0.1 M $\text{ZnSO}_4 \cdot \text{H}_2\text{O}$ was added to the flask encompassing culture solution and for 5 to 10 minutes, it was heated on a water bath up to 80°C . A white impulsive appeared at the end of flask representing the transformation process and the flask was detached from water bath, incubated at 37°C for a time length of 12 h with the intention of depositing all the particles at the bottom of the flask. Afterwards deionized water was used for filtering and washing the product this was followed by drying in a hot air oven at 40°C , for the length of 4 h. At this time, UV-Vis spectroscopy revealed optical properties of the ZnO NPs.

The role of reaction time is of importance prime in the morphology of nanoparticles. For a reaction time of 5-10 min, the synthesized nanoparticles revealed an average size of 7 nm. Spherical clusters of the nanoparticles is represented by the SEM images of the ZnO NPs from *Lactobacillus plantarum*. It is mighty that, the synthesis of ZnO NPs have been resulted because of pH-sensitive membrane bound oxidoreductases and carbon source dependent rH_2 in the culture solution.

Furthermore, the ability of Lactobacilli to cultivate even in the existence of oxygen makes it more capable in terms of metabolic features. Similarly, the existence of glucose in the MRS media used for the synthesis of ZnO nanoparticles makes the oxidation-reduction potential value less probable.

Energy yielding material—glucose (which controls the value of rH_2), the ionic status of the medium pH and overall oxidation–reduction potential (rH_2) which is moderately controlled by the sodium hydroxide, all these elements aggregately negotiate the synthesis of ZnO nanoparticles in the existence of *Lactobacillus plantarum* [24].

3.3. Titanium nanoparticles.

TiO_2 NPs has been explored in several biomedical applications including targeted drug delivery agents, biosensing,

antimicrobial contrast agents, antiwrinkle, wound dressing, and antiparasitic agents due to their non-toxic and biocompatible features. As a result of these properties, TiO_2 can possibly be regarded as a more attractive one than the other oxidative nanoparticles [8]. In medical equipment sphere, titanium pins and many surgical tools, Ti^{IV} drugs well to transferrin in human serum, which could bring it to the cancer cells. This more highlights their future role in cancer chemotherapy and gene transfer.

Nanoparticles of Ti can be prepared by adopting the technique employed by Nair and Pradeep [11] with some minor modifications. The filtrate encompassing *Lactobacillus* was 5 times diluted and pH of the culture solution was noted in the range of 2-4 based on the strength of the solution. At that point, 10% appropriate sugar solution was introduced to the culture solution and this was permitted to incubate overnight. Next day, around 20 mL 0.025 (M) titanium dioxide solution was added to each of the culture. A magnetic stirrer was used to stir comprehensively the culture solution for 0.5 h and then permitted to incubate in laboratory environment on a laminar flow. Noticeably makeable deposits at the bottom of the conical flask was observed after 3–4 days. Nanoparticles encompassing culture solution were filtered under the laminar flow over Whatman filter paper, permitted to dry under blow of hot air after which they were used for X-ray and TEM classifications [20].

Jha and colleagues [16] provided TiO_2 nanoparticles by media supplements of *Lactobacillus* strain (acquired from the butter milk) and yeast (Ascomycetes).

In a different method, 75 mL of sterile distilled water containing nutrients was used in order to diluting about 25 mL of the re-suspended culture of the isolate (*Propionibacterium jensenii* KC545833) for four times. This diluted culture was permitted to grow for another 24 h. The culture solution then combined with 20 mL of 0.025 M $\text{TiO}(\text{OH})_2$ solution and heated on a steam bath up to 60°C for 10- 20 ,minutes until white deposition was appeared at the bottom of the flask. This reveals the commencement of transformation. The culture solution then was chilled and permitted to incubate at room heat in laboratory environment. After 12-48 h, the culture solution was seen to have separate white precipitate set down at the bottom of the flask. Then the precipitate was annealed at 300°C for 1 h so that amorphous transformed into anatase phase and the impurities were detached . This synthesis process led into a well discrete uniform sized anatase form of nanoparticles that are extremely biocompatible, cost effective and stable thus offering numerous advantages over conventional procedures [8].

In the sterile distilled water containing suitable carbon and nitrogen sources, *Lactobacillus* cells or yeast cells were grown as a suspension culture for 36 h, next, a small portion of it was taken and by adding water containing nutrients for *Lactobacillus* and in 30 % ethanol for yeast was diluted four times. This diluted culture solution was again permitted to cultivate for another 24 h. Next, $\text{TiO}(\text{OH})_2$ solution was supplied to the culture solution, and it was heated to 60°C , on a steam bath for 10–20 minutes and then rested for 12–48 h. *Lactobacillus* sp. (20–30 nm) and yeast (10–15 nm) with very few aggregates are made use of forming TiO_2 nanoparticles. The scholars advise that the particle size acquired in the case of yeast was lower primarily due to the fact that yeast is a

eukaryote having superior level of organization at the cellular stage [26].

3.4. Sb₂O₃ nanoparticle.

Antimony trioxide (Sb₂O₃) can be regarded as a decent semiconducting material and an outstanding catalyst for the production of PET plastic used in the packing of mineral water as well as soft drinks. Also the material used for the mixture of antimony gluconate, is regarded to be an active medicine compared to Kala azar. Antimony mixtures are evaded in cases of dysentery, jaundice, nephritis and pulmonary tuberculosis [17, 26]. Jha and colleagues used Sb₂O₃ nanoparticle based on preceding methods which they formed other nanoparticles [17].

3.5. Gd₂O₃ Nanoparticles

Gadolinium oxide is likewise used as phosphors for color television tubes, absorption supplies in atomic responses, and microwave requests. The culture solution was supplied with twenty milliliters of 0.25 M gadolinium acetate solution and for 10–20 minutes was heated in a steam bath up to 60°C so that the culture solution reached a starchy haziness and white deposition appeared at the lowermost of the tube, representing the beginning of transformation. Then the culture solution was cooled and permitted to incubate at room heat in laboratory atmosphere for letting precipitation of lighter particles. The culture solution was perceived to have discrete coalescent white clusters accumulated at the bottom of the tube after 9 h [18].

3.6. CdS nanoparticles.

CdS nanoparticles are significant in biological sensors, solar cells, photovoltaic, field effect transistors, photocatalysis, infrared photodetector photoluminescence, light emitting diodes and environmental sensors.

For providing the source culture, lactobacillus cells obtained from butter milk were permitted to cultivate as a suspension culture in sterile distilled water holding suitable carbon and nitrogen source for 36 h. A small share of it (25 mL) was taken and by adding 75 mL of sterile distilled water containing nutrients were diluted four times. This diluted culture solution was yet again permitted to propagate for another 24 h. Now, 5 mL aqueous solution of Hydrogen Sulfide was added (in two equal portions) to 20 mL of 0.25 M cadmium chloride (CdCl₂) of the solution until it reaches orange-yellow color signifying formation of cadmium sulfide. The culture solution was provided by the solution and it was heated on steam bath for 10–20 minutes up to 60° C until cottony orange-yellow deposition initiates to appear at the lowermost of the flask, representing the beginning of transformation. Now the culture solution was cooled and permitted to incubate at room heat in the laboratory environment over the course of night. Next day, it was observed that the culture solution have definitely markable coalescent orange-yellow clusters accumulated at the bottom of the flask having the colloidal supernatant at the top. This, then was filtered for further studies [27].

3.7. Selenium Nanoparticles.

Lactobacillus sp is stated to yield selenium nanoparticle. The analysis presented that the distribution differs with the pH, due to the fact that the cohesion of the spheres is a function of the pH of the liquid medium. The nanoparticles stick to each other, at pH 4 up to 10 but pH above 10, breaks the consistency of the particles. The used up elemental nano-Se in an organic structure constantly alters to selenite [SeO₃²⁻]. An analyses and a graphical

illustration was made from the selenite concentration transformation in the supernatant for a few days [4]. Purified elemental selenium nano-spheres by electron microscopic picture of 250 nm sized selenium nanospheres were synthesized. Selenium created this manner is remarkably worthy raw material for making Nano surfaces due to its homogeneous particle size distribution and consistent, spherical form [28]. Milk (4480 mL) comprising of 5% fat content, for 15 minutes was sterilized at 120° C. The sodium hydrogen selenite (NaHSeO₃) in a 10.000 mg/L stock solution was used as a selenium source. 10 mL of this stock solution to 490 mL of the sterilized milk, (i.e. around 200mg/L concentration) was added to it. From the fresh bacterium culture (formerly stored at 4°C for maximum 3-4 days) 10 to 500 mL of selenite containing milk was added. *Lactobacillus casei* was made use of for the inoculation strains of *Lactobacillus acidophilus* and *Lactobacillus*. Adjusting the pH of the culture medium, is not a vital issue as it usually, remains around 7-8 in the beginning and decreases to around 3-4 at the end of the fermentation process.

This happens due to the production of lactic acid by the *Lactobacillus* sp. next, the culture was placed into the shaking incubator at 37° C (optimum temperature for lactic acid bacteria full reproduction cycle) for 36-48 h. At the end of the fermentation procedure, the culture medium color turned into red, due to the made elemental selenium. The color of elemental selenium is normally red and the creation of red color approves the decrease of the sodium hydrogen selenite to elemental selenium. Following phase was to centrifuge the medium for 10-15 minutes, at 10.000 rpm and the supernatant was thrown away. The pellets were suspended in purified water.

The creation mechanism of elemental selenium is primarily intracellular in lactic acid bacterium that is the reason of the cells digestion importance due to their very resistant cell wall. The most operational and feasible method is to make use of high concentration of hydrochloric acid (37% HCl). Enzyme hydrolysis is regarded too costly to be used as a unit process. Next step is to adding around 1.5x acid to the nanoselenium sample in 1.5:1. The process of acidic hydrolysis takes about five days at room temperature. Next phase is about eliminating the acid; to do so, and for returning the sample's pH to the normal, it was centrifuged at 10,000 rpm for 15 minutes and washed several times with purified water. Then, for disintegrating the cohesive selenium spheres, the samples were ultrasonicated for 10-15 minutes. In the final step vacuum filter was used to exclude the rest of the bacteria cell wall. The separation was conducted by the aid of two paper layers and one plastic filter layer. Finally, the quality was tested by visual or laser controlling to see if they meet the requirements [28].

Incorporation of probiotics in numerous foods are stated e.g. cornflakes [29], pomegranate juice [30], Doogh [31], cheese [32], fermented drink [33], yogurt [34-40], fermented juice [41], etc. Probiotics can be used to produce numerous valuable metabolites throughout their growth and metabolism for instance, production of bioactive compounds [42], conjugated linolenic acid [43, 44], propionic acid [45, 46] etc. Lately, decrease of oxidative stress and inflammatory elements (47, 48) exclusion of toxins and heavy metals (49-50) are described for these amazing microorganisms. Prebiotics are controlled for stimulating probiotic growth (23-25). Growing data on human colonic microbiota and

microbiota growth supports the design of new more detailed and until now unidentified probiotics and prebiotics (51-54). This study, provided an approach towards introducing a very different

4. CONCLUSIONS

The use of microorganisms in the synthesis of nanoparticles can be viewed as an eco-friendly and exciting approach in the production of nanoparticles. This stems from low energy consumption, environmental compatibility, low production costs, scalability, and nanoparticle stabilization in comparison with the chemical synthesis. Because of their intense diversity,

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and novel capabilities of probiotics it seems that this feature could be extensively used for controlling antibiotic resistant infections.

microbes have the inherent potential for the synthesis of nanoparticles and they could be considered as potential biofactories for the synthesis of nanoparticles. For commercial uses, having a nonpathogenic biological system that produces the metallic nanoparticles such as the probiotic bacteria will be regarded as a competitive advantage.

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6. ACKNOWLEDGEMENTS

Research reported in this publication was supported by Shahid Beheshti University of Medical Sciences under award number....., Tehran, Iran.



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