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Extracellular synthesis of silver and gold nanoparticles by *Sporosarcina koreensis* DC4 and their biological applications

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ABSTRACT

The present study highlights the microbial synthesis of silver and gold nanoparticles by *Sporosarcina koreensis* DC4 strain, in an efficient way. The synthesized nanoparticles were characterized by ultraviolet-visible spectrophotometry, which displayed maximum absorbance at 424 nm and 531 nm for silver and gold nanoparticles, respectively. The spherical shape of nanoparticles was characterized by field emission transmission electron microscopy. The energy dispersive X-ray spectroscopy and elemental mapping were displayed the purity and maximum elemental distribution of silver and gold elements in the respective nanoproducts. The X-ray diffraction spectroscopy results demonstrate the crystalline nature of synthesized nanoparticles. The particle size analysis demonstrate the nanoparticles distribution with respect to intensity, volume and number of nanoparticles. For biological applications, the silver nanoparticles have been explored in terms of MIC and MBC against pathogenic microorganisms such as *Vibrio parahaemolyticus*, *Escherichia coli*, *Salmonella enterica*, *Bacillus anthracis*, *Bacillus cereus* and *Staphylococcus aureus*. Moreover, the silver nanoparticles in combination with commercial antibiotics, such as vancomycin, rifampicin, oleandomycin, penicillin G, novobiocin, and lincomycin have been explored for the enhancement of antibacterial activity and the obtained results showed that 3 μg concentration of silver nanoparticles sufficiently enhance the antimicrobial efficacy of commercial antibiotics against pathogenic microorganism. Furthermore, the silver nanoparticles potential has been reconnoitered for the biofilm inhibition by *S. aureus, Pseudomonas aeruginosa* and *E. coli* and the results revealed sufficient activity at 6 μg concentration. In addition, gold nanoparticles have been applied for catalytic activity, for the reduction of 4-nitrophenol to 4-aminophenol using sodium borohydride and positive results were attained.

1. Introduction

Nanobiotechnology deals with the development of biogenic and eco-friendly technology for the synthesis of nanoparticles and their biomedical applications. Nanoparticles, especially silver and gold are of great significance interest because of unique size and shape dependent tunable properties and potential applications in the fields of medical nano-engineering and pharmaceutical science for the development of several therapeutic agents, chronic disease diagnostics and treatment, biosensors etc. [1]. Silver owing to its antimicrobial properties has been applied for the treatment of bacterial infections associated with burns and wounds, for instance, in the form of silver nitrate or silver sulfadiazine. Silver at the nanostructure level have gained considerable attention due to their enhance antimicrobial, anticoagulant, biofilm inhibition, anticancer and anti-inflammatory efficacy as compared to bulk silver, which make them an ideal candidate in medical and biological platform. Further, silver nanoparticles are applied in electronics, bio-sensing, clothing, food industry, paints, sunscreens, cosmetics and medical devices [2].

Gold nanoparticles are also emerging as promising agents for cancer diagnosis, therapy and drug carriers [3]. Gold nanoparticles exhibit unique physicochemical properties including surface plasmon resonance, optical property and the ability to allowing surface modification further applied in biomedical applications for photo-thermal therapy, contrast agents, radiosensitisers etc. [3,4].

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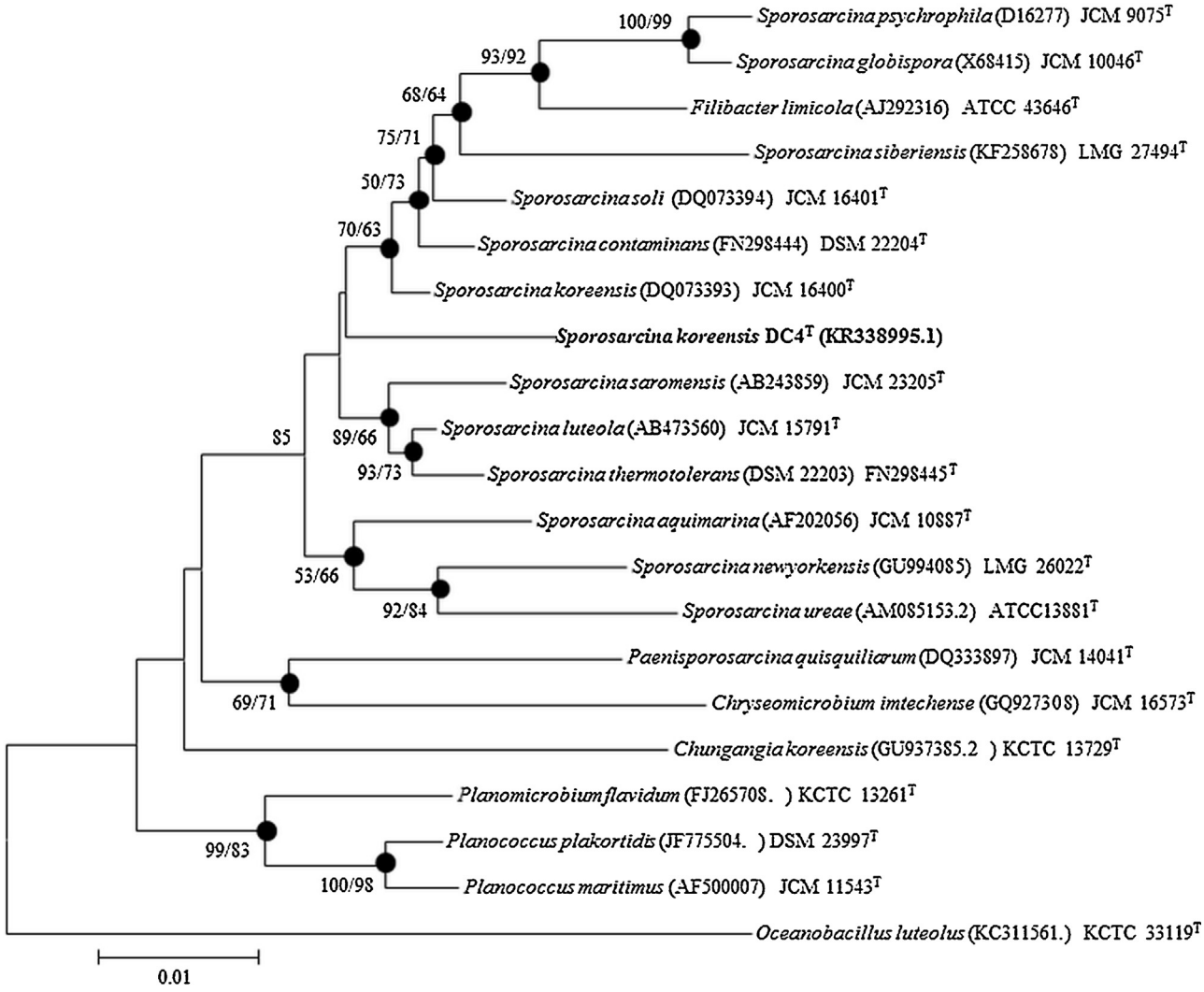

Fig. 1. Neighbour-joining tree based on 16S rRNA gene sequence analysis showing phylogenetic relationships of strain *Sporosarcina koreensis* DC4 and members of the genus *Sporosarcina*. Filled circles indicate that the corresponding nodes were also recovered in the tree generated with the maximum-parsimony algorithm. Bootstrap values greater than 50% based on 1000 replications are shown at branching points. *Oceanobacillius luteolus* KCTC 33119^T (KC311561) was used as an outgroup. Scale bar, 0.01 substitutions per nucleotide position.

Considering the importance of silver and gold nanoparticles, the study focuses on the synthesis these nanoparticles in a green way. Even though, various physiochemical methods have been extensively applied for the reduction of silver and gold metal, but the methodologies have numerous drawbacks including high energy consumption, utilization of toxic and highly reactive chemicals, which possess potential environmental and biological risks [5]. To overcome the disadvantage of physiochemical methodologies, the scientific community has turned to biological systems which utilize ecofriendly technique for the synthesis of nanoparticles [6]. Recently, various microorganisms and plant extracts has been reported for the green synthesis of silver and gold nanoparticles in an efficient way [7–13]. Following the green route, the present study shows the green synthesis of silver and gold nanoparticles by *S. koreensis* DC4 strain, isolated from soil sample.

In medical field, increasing infections and diseases due to the multidrug-resistant pathogens for which current antibiotic therapies are not effective is a major risk to our society [14]. The etiology of multidrug-resistant depends on the individual, the causing microorganisms and developed resistance mechanisms. Thus, the developing multidrug resistance in microorganisms are major threats to human health, which strongly needs the rapid reduction in the misuse of drugs, diagnosis, monitoring of antibiotic consumption and most importantly innovation of novel effective antibiotics or drug conjugates with optimized pharmacokinetics and pharmacodynamics in order to improve treatment outcomes [14,15]. To address this problem, it's necessary to find the alternatives for the production and application of antimicrobial agents against pathogenic microorganisms. Silver nanoparticles have been considered as a viable alternative to antibiotics and seem to have a high potential to solve the problem of the emergence of multidrug resistance microorganisms [15]. Considering this, the present study highlights the activity of synthesized silver nanoparticles against pathogenic microorganisms including *V. parahaemolyticus*, *E. coli*, *S. enterica*, *B. anthracis*, *B. cereus* and *S. aureus* in terms of MIC and MBC. In addition, the silver nanoparticles were additionally evaluated for the combined effect with commercial antibiotics, comprising vancomycin, rifampicin, oleandomycin, penicillin G, novobiocin, and lincomycin against these pathogenic microorganisms. Moreover, the silver nanoparticles efficacy has been evaluated against biofilm inhibition, as is it a major worry, in different field where especially films or membranes are developed to apply in various devices such as medical field (catheter) and chemical field (water membrane filtration system) [16,17].