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Synthesis and antimicrobial properties of nanosilver

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Abstract

Nanosilver (nAg) was prepared via Tollens method using dextrin as stabilizer. The morphology, size distribution and average size of the obtained nAg were characterized using Transmission electron microscope (TEM) and Dynamic light scattering (DLS) technique. A kinetic study of toxicity of nAg on *Escherichia coli* (*E. coli*) was determined. The obtained results showed that nAg exhibits spheric shape with an average particle size of 14 nm. The average particle size of nAg increased with increasing concentration of the salt in the solutions. The toxicity of nAg in DI water increased with increasing nAg concentration. A dose-response relation between E. coli and different concentrations of nAg was found. Solutions containing divalent cations solutions could promote the aggregation of nAg. In addition, the toxicity assay indicates that small nAg were more toxic than larger nAg aggregates (nAg concentration: 0.1 mM).

Keywords: Nanosilver; Tollens' method; DLS

1. Introduction

Nanosilver has been widely applied in many industries as an antimicrobial reagent [1-8] and as catalysts [9-10]. Currently, nanosilver can be synthesis and prepared using different approaches such as physical, chemical and biological approaches. Among all the approaches, Tollens' method within the chemical approaches provides a simple and environmental-friendly way to synthesize nanosilver by reducing the silver ion to its elementary state using reducing agents such as polysaccharides [1-4].

The antimicrobial ability of nanosilver has been well studied. However, to the author's knowledge, antimicrobial properties of nanosilver in different salt solutions were not reported. This study applied Tollens' method for nanosilver preparation. The obtained nanosilver was characterized using UV-Vis spectroscopy, TEM and dynamic light scattering (DLS). Its antimicrobial ability was evaluated using plate count method.

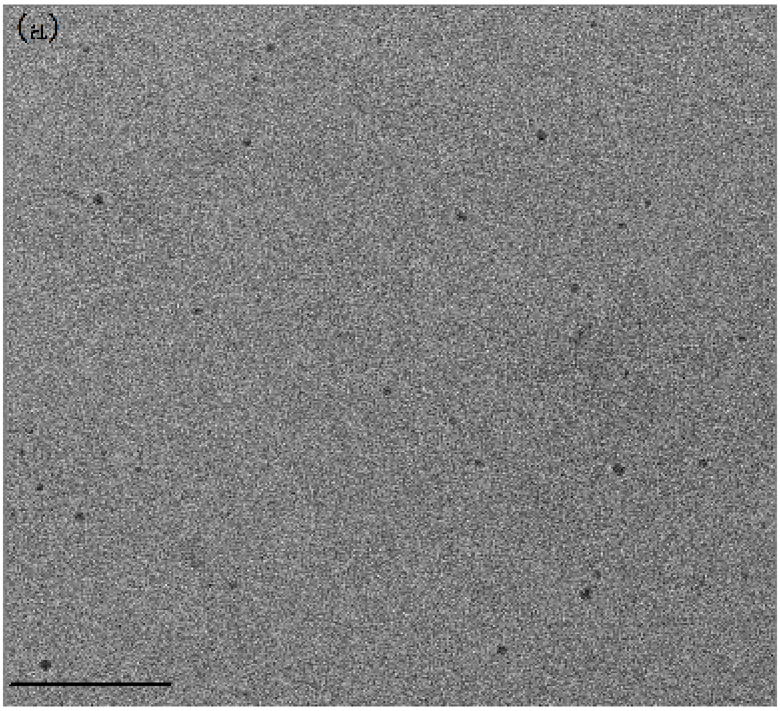
2. Materials and methods

nAg was synthesized using Tollens method. The concentrations of the reactants were 1×10^{-3} mol·L^{-1}, 1×10^{-2} mol·L^{-1} and 5×10^{-3} for $AgNO_3$, maltose and ammonia, respectively [2]. pH value of the reaction system was adjusted to 11.5 using NaOH. Then, the obtained nanosilver was ultrafiltrated using a 3000 ultrafiltration membrane and passed through DI water for cleaning and pH neutralization. Concentration of the cleaned nanosilver was measured using ICP-OES.

Electrolyte solution of NaCl and $CaCl_2$ were prepared using the concentration range from 0.01-10 mM. Particle sizes of nanosilver in these salt solutions were measured by DLS. *Escherichia coli (E. coli)* (ATCC 15597) was used as a surrogate. The microbial culture procedure and the antimicrobial properties determination procedure follows the previous published literatures [2].

3. Results and discussion

As can be observed in Figure 1 (a), nanosilver exhibits spherical shape and no aggregation was observed. Figure 1 (b) presents the the UV-Vis spectrum of nanosilver, which shows that the characteristic peak of the spectrum is around 400 nm. This observation is in agreement with other published data [1-4].



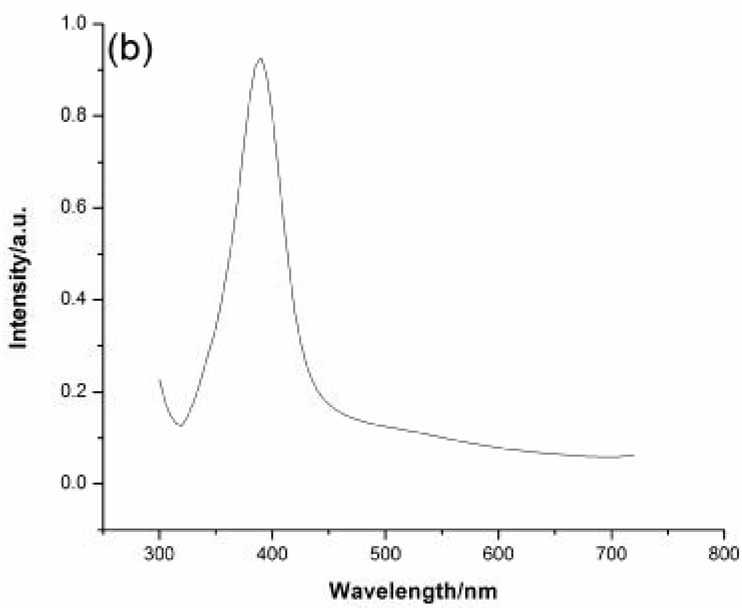


Figure 1: TEM (a) and UV-Vis spectrum (b) of synthesized nanosilver using Tollens' method (Black line=200 nm).

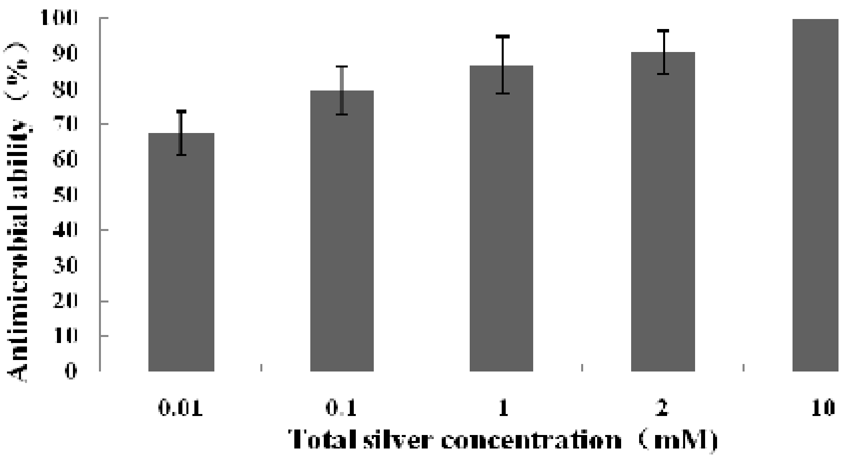


Figure 2: Antimicrobial ability of nanosilver against *E. coli* in DI water.

Figure 2 shows the antimicrobial properties of nanosilver in DI water condition. The result shows that the antimicrobial ability of nanosilver increases with increasing nanosilver concentration. The mechanisms of the antimicrobial properties of nanosilver are suggested in different investigations. One mechanism indicates that nanosilver could adsorb or penetrate through the cell membrane, which could damage the cell membrane and cause cell death; another mechanism suggest that silver ion released from nanosilver could interact with the cell membrane and the intracellular component, which could cause lysis and cell death; the third mechanism shows that nanosilver could form reactive oxygen species and could cause cell death by oxidation [2]. The observation from Fig. 2 agrees with most of the previously published works indicating that there is a dose-response relation between nanosilver and bacteria [6-8].

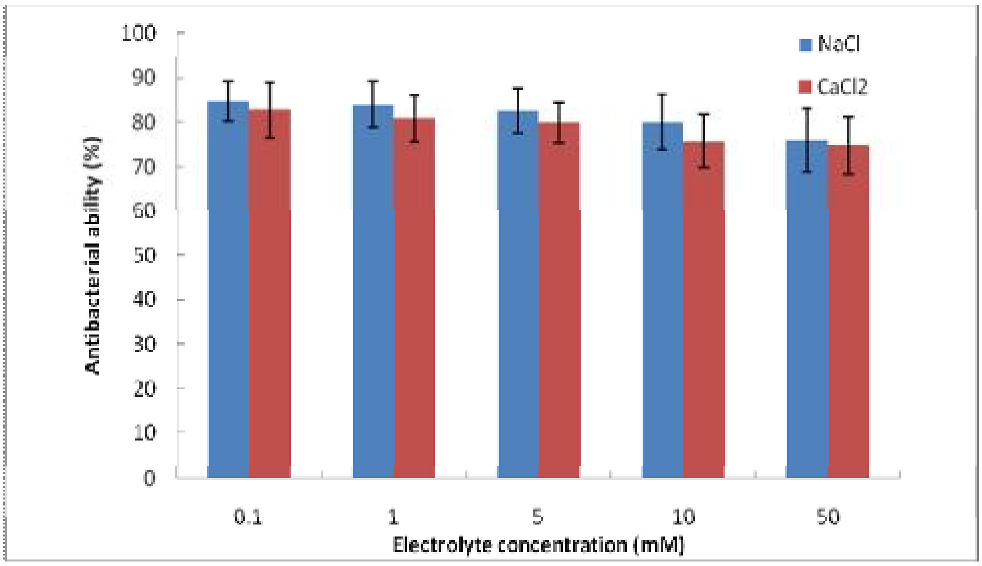


Figure 3: Antimicrobial properties of nanosilver in different electrolyte solutions.

Figure 3 shows that the antimicrobial properties of nanosilver decreases with increasing electrolyte concentration. After adding nanosilver into NaCl and $CaCl_2$ solutions, the Cl^- ion presents could react with the Ag^+ released from nanosilver and form precipitation. Additionally, cations (Na^+ and Ca^{2+}) present in the electrolyte solution could adsorb onto the surface of the nanoparticles and neutralize the surface charge of the nanosilver which could lower the energy barrier of the aggregation process between nanoparticles. Increased particles size indicated a lower chance of interaction with bacteria in comparison with well dispersed nanosuspension in DI water.

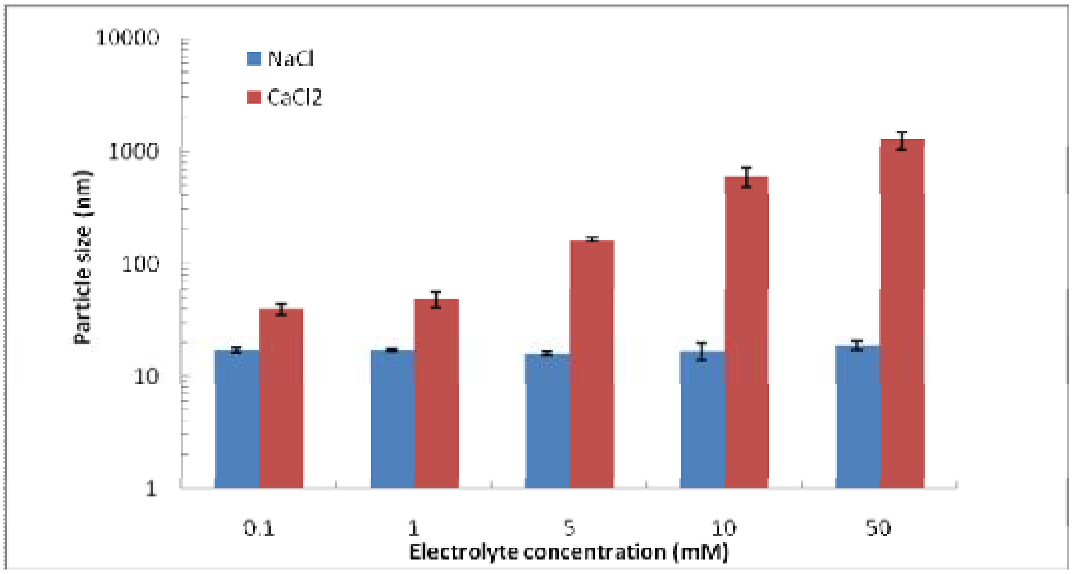


Figure 4: Particle size of nanosilver in different electrolyte solutions.

In Figure 4, we also observed a more intense aggregation in $CaCl_2$ solution than in NaCl solution, which is due to the Schulze-Hardy rule indicating that the stability of one colloidal system depends on the surface charge of the counter ions of the nanoparticles. Our observation is also in agreement with other prior data. Zhang et al., (2012) and Zhang and Oyanedel-Craver (2012) have also found the same trend in toxicity evaluations of nanosilver coated with different polymers. Their studies have indicated a decreasing toxicity of nanosilver with increasing concentrations of electrolyte.

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