Bacteria-nanoparticle interaction based on functionalized surfaces

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Abstract

Silica nanoparticles were synthesized and functionalized with different chemical groups (hydroxyl, mercapto, isocyanate, carboxyl and amino) in order to understand how different functional groups favor the interaction between nanoparticles and the envelope of different bacteria. Obtained results showed that bacteria-nanoparticle interaction is driven by the nature of nanoparticles surface and that different types of bacteria envelope do not influence this mechanism.

Nanometric structures, functionalization, bacteria interaction.

Introduction

Nanoparticles are being used as one of the most promising strategies to prevent bacterial growth and development. Due to their unique physicochemical properties, nanomaterials are able to interact intimately with bacteria. Therefore, this mechanism of interaction has been still unknown.¹⁻² It is believed that it depends on the properties of the nanoparticles (such as size, aggregation state and functionalization of its surface) and also on the organization of the constituents of the bacterial cell envelope.³

Results and Discussion

Quantification of chemical groups present on the silica surface was determined by thermogravimetric analysis through distinct weight loss stages (Figure 1A). For SiO₂-OH and SiO₂-NH₂ samples, the weight loss between 180 °C and 700 °C is ~ 4.2% and ~ 5.6%, respectively. The difference ~ 1.4% between these samples is related to the -NH₂ group incorporated on the material surface. This is also valid for SiO₂-NCO and SiO₂-SH samples, which showed ~ 2.1% and ~ 4.2% of -NCO and -SH groups, respectively. For SiO₂-COOH, taking into account that SiO₂NPs-NH₂ were used as precursor for the synthesis, the difference between the weight loss of SiO₂-NH₂ and SiO₂-COOH is ~ 9.5% related to -COOH group. FTIR spectra (Figure 1B) confirms the functionalization success where bands attributed to different chemical groups can be identified. Incubation experiments (Figure 1C and 1D) with *Staphylococcus aureus* and *Escherichia coli* bacterium showed the following bactericidal efficiency trend: SiO₂-OH > SiO₂-COOH > SiO₂-NH₂ > SiO₂-SH > SiO₂-NCO. Bare nanoparticles and aliquots of nanoparticles incubated with bacteria were analyzed by scanning electron microscopy (SEM) and are presented in Figures 1E, 1F and 1G.

Figure 1. Results obtained for silica nanoparticles synthesis.

Conclusions

Bacteria-nanoparticle interaction is extremely dependent on the the nature of nanoparticles surface which can be tailored to obtain structures with high bactericidal efficacy. Similar behaviors were seen when different types of bacteria cell envelopes where compared.

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¹ Gilbert, P.; et al. *Antimicrob Agents and Chemotherapy*. **1990**, 34, 1865-1868.

² Darouiche, R. O.; et al. *J. Med.* **2004**, 350, 1422-1429.

³ Aruguete, D. M.; et al. *Environ Chem*. **2010**, 7, 3-9.