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Abstract

Silver–Chitosan Nanocomposites for Biomedical Application: Design, Synthesis and Antimicrobial Efficiency †

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Hospital-acquired infections are serious medical problems worldwide. Therefore, novel antimicrobials for the treatment of infections, especially those caused by antibiotic-resistant microbes, are urgently needed. We have previously shown that Ag, CuO and ZnO nanoparticles are also toxic against pathogenic microbes and relatively safe to animal cells [1], thus being promising for medical use, e.g., in wound treatment. Moreover, combining these NPs with biologically active polymers may enhance their efficacy and specificity. Chitosan (CS) is a biocompatible, antimicrobial and immuno-modulating polymer and is already used for wound treatments. Therefore, crosslinking chitosan with antimicrobial nanoparticles can yield novel antimicrobials with both biocidal and immune-modulating effects. The study aimed (i) to design and synthesize silver–chitosan nanocomposites (nAgCSs) with different silver–chitosan (Ag/CS) weight ratios (1:0.3, 1:1 and 1:3), (ii) to evaluate their efficacy against bacteria and fungi that can cause wound infections and (iii) to elucidate the mode of antimicrobial action of nAgCSs. nAgCSs were synthesized through the reduction of $AgNO_3$ with trisodium citrate and stabilized/coated with low-molecular-weight chitosan. The antimicrobial activity of nAgCSs against bacteria *Pseudomonas aeruginosa*, *Escherichia coli* and *Staphylococcus aureus* and fungi *Candida albicans* and *C. glabrata* was studied using a Spot test [2]. In this test, microbes are exposed to toxicants in deionized water for 1, 4 and 24 h and then plated on an agar medium for the quantification of the minimum biocidal concentration (MBC). The synthesized nAgCSs' primary and hydrodynamic sizes were ~50 and ~100 nm, respectively, and the surface charge was ~+25 mV. The shedding of Ag ions was in the range of 2–4%. The synthesized nAgCSs were efficient antimicrobials acting already at sub-mg-per-litre concentrations. In general, the nAgCSs were more toxic towards bacteria than fungi (24-h MBC 0.07–0.56 and 9.3–44 mg Ag/L, respectively), and nAgCSs with an Ag/CS mass ratio of 1:3 were the most efficient. The high antimicrobial efficiency was most likely due to the absorption of nAgCSs onto the surface of the microbes, as shown via confocal laser scanning microscopy and flow cytometry. Interestingly, the shed Ag ions (the most reported toxicity mechanism of AgNPs) did not explain the biocidal effect of nAgCSs, indicating a synergy between chitosan and silver.

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References

1. Suppi, S.; Kasemets, K.; Ivask, A.; Künnis-Beres, K.; Sihtmäe, M.; Kurvet, I.; Aruoja, V.; Kahru, A. A novel method for comparison of biocidal properties of nanomaterials to bacteria, yeasts and algae. *J. Hazard. Mater.* **2015**, *286*, 75–84. [CrossRef] [PubMed]
2. Bondarenko, O.; Juganson, K.; Ivask, A.; Kasemets, K.; Mortimer, M.; Kahru, A. Toxicity of Ag, CuO and ZnO nanoparticles to selected environmentally relevant test organisms and mammalian cells in vitro: A critical review. *Arch. Toxicol.* **2013**, *84*, 1181–1200. [CrossRef] [PubMed]