Fabricating antibacterial paper towels through the use of selenium nanoparticles

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Statement of Purpose: In this study, for the first time, selenium nanoparticles were coated on normal paper towel surfaces through a quick precipitation method and the anti-bacterial properties of selenium coated paper towels were characterized using *Staphylococcus aureus*. The results showed that the selenium coatings successfully introduced antibacterial properties to regular paper towels, revealing a promising selenium-based method to prevent bacterial infections on paper products that should be further explored.

Methods: For this purpose, selenium nanoparticles were synthesized through a simple reaction between glutathione and sodium selenite (4:1 molar mixture) and were precipitated on the surface of paper towels for 30s. SEM (Scanning Electron Microscope, HITACHI 2700) images of the substrate surfaces were taken to determine the distribution and coverage of selenium nanoparticles. For the bacteria experiments, a bacteria cell line of *Staphylococcus aureus* was obtained in freeze-dried form from the American Type Culture Collection (catalog number 25923). A bacteria solution was prepared at a concentration of 10^6 bacteria/ml, which was assessed by measuring the optical density at 562nm using a SpectraMax M5 plate reader (Molecular Devices, Sunnyvale, CA). Selenium coated samples were put into to a 24-well plate, treated with the prepared bacterial solutions (10^6 bacteria/ml) and cultured for either 24, 48 or 72 hours in an incubator (37°, humidified, 5% CO_2). For those samples that were cultured for 48 and 72 hours, the medium was changed with 1mL of sterile and fresh TSB (0.3mg/mL) every 24 hours. After the treatment, the samples were rinsed with a PBS (phosphate buffered saline) solution twice and placed into 1.5ml microfuge tubes with 1ml of PBS. These tubes were shaken at 3000 rmp for 15 minutes on a vortex mixer to release the bacteria attached on the surface into the solution. Solutions with bacteria were spread on agar plates and bacteria colonies were counted after 18 hours of incubation. All experiments were completed in triplicate and were repeated three separate times.

Results: Figure 1 shows the SEM images of the selenium coated paper towels (image a) and uncoated paper towels (image b). On the selenium coated paper towel samples, the selenium nanoparticles were well distributed and completely covered the surface. The diameters for most of the selenium particles were around 50 nm. For the uncoated paper towel, there were no particles observed. Thus, the selenium nanoparticles were successfully coated on the paper towels and the large surface area of the selenium coated fibrous paper towel surface increased the exposure of selenium. According to AAS results, the concentration of the selenium nanoparticles on the coated paper towel surface was 69.00 g/m^2. The fibrous structure of the paper towel significantly increased surface area to allow for more selenium nanoparticle deposition.

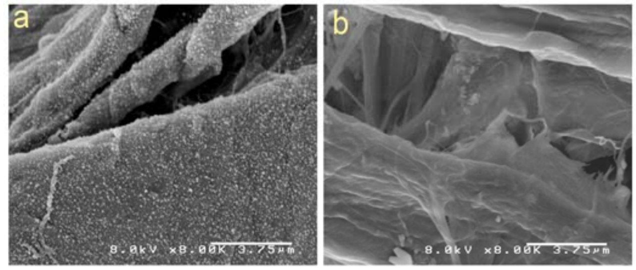

Figure 1. SEM images of selenium coated (image a) and uncoated paper (image b) towel samples. The coating condition for image (a) was 0.5M NaOH for 30 seconds. The concentration of selenium on the paper towel as measured by AAS was 69.00 g/m^2 for the selenium coated paper towels and 0 g/m^2 for the uncoated paper towels.

Experiments with bacteria (specifically, *Staphylococcus aureus*) showed high effectiveness for the selenium coated paper towels at killing bacteria and preventing bacteria from attaching. Bacteria colonization decreased significantly when the paper towels were treated with selenium (Figure 2). The selenium coatings inhibited the growth of bacteria (*S. aureus*) on the surfaces after 24, 48 and 72 hours by 88.6%, 89.1% and 87.3%, respectively, compared to the uncoated samples. Importantly, this was accomplished without using antibiotics.

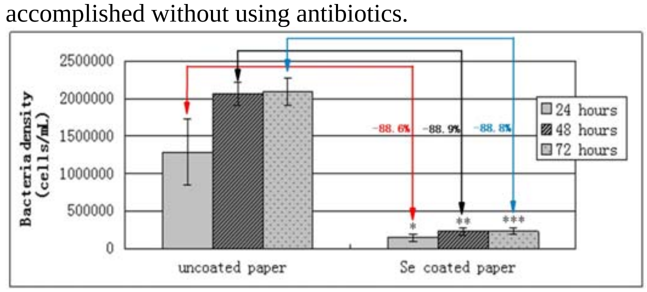

Figure 2. *S. aureus* growth on the surface of uncoated and selenium coated paper towels. The control group is the uncoated paper towels. Data=Mean ± standard deviation, n=3; *p<0.02 compared with the control group (uncoated paper) after 24 hours; **p<0.002 compared with control group after 48 hours; ***p<0.002 compared with the control group after 72 hours.

Conclusions: In conclusion, the selenium precipitation process was used as an easy and quick method to coat selenium nanoparticles on paper towels, and the selenium coatings significantly inhibited the growth of *S. aureus* on the surface of paper towels after 24, 48 or 72 hours. The effectiveness of bacteria inhibition reached about 90% for all three different periods of treatment compared with the uncoated paper towels. This study, thus, suggests that selenium nanoparticles coatings could be used as an effective way to decrease *S. aureus* infections on paper products, which might have potentially important applications in the food packaging industry, medicine, and in clinical environments.

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