Synthesis and characterization of combined silver nanoparticles/zinc humate preparation for antibacterial and wound healing applications

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Antimicrobial activity of silver nanoparticles (Ag-NP) against antibiotic-resistant bacteria strains led to an active application of Ag-NP in medical practice and festering wound treatment. The long-lasting wounds such as bedsores, burns, purulent wounds are an enabling environment for pathogenic flora. To increase the rate of wound healing of such wounds various Zn compounds are currently used. In this regard, a combination of Ag-NP and Zn in one treating complex could increase the productivity of wound healing and reduce the possibility of its infection. However, in addition to antibiotic activity, Ag-NP may show the cytotoxic effect due to an elevation of oxidative stress in human cells. To avoid this negative effect the utilization of humic substances (HS) both as a reduction agent for the formation of Ag-NP and an antioxidant to reduce the cytotoxicity of synthesized Ag-NPs is a promising technique. Besides the ability to reduce Ag HS is also a natural complexing ligand that could form stable humate complexes with metal ions including Zn. For this reason, the aim of the present study was to optimize the synthesis of the combined preparation of Ag-NP/Zn humate as a promising agent for wound healing with intensive antimicrobial activity.

In the present study, we analyzed influence of pH, initial concentration of AgNO₃ and presence of Zn(NO₃)₂ on degree of Ag⁺ into Ag-NP conversion. The degree of conversion was estimated by UV/Vis-spectroscopy using position of maximum and intensity of Ag surface plasmon resonance (SPR) peak at 400–420 nm. The size of the synthesized nanoparticles was investigated using transmission electron microscopy (TEM).

Figure 1. Size distribution of Ag-NPs.

The maximum degree of conversion was achieved after 3 h at the initial concentration of HS 10 g/L, AgNO₃ 42 mM and pH 11. According to TEM results, fine nanoparticles with an average diameter of 10±4 nm were formed (Figure 1). More than 90% of Ag⁺ was converted into Ag-NP. It was also found that addition of 10 mM Zn(NO₃)₂ solution at the initial stage of the synthesis decreases the conversion rate of Ag-NP.

However, addition of separately synthesized Zn humate with concentration of HS of 10 g/L, and of Zn - 10 mM in the ratio of 1:1 (v:v) did not significantly affect the Ag-NP formation. The concentration of Ag-NPs stabilized at the same level as in the absence of Zn²⁺ in the solution for 3.5 h and remained stable.

As a result, we have shown that the preferable way of synthesis of combined silver nanoparticles/zinc humate preparation is separate synthesis of the components followed by their mixture in 1:1 volume ratio.

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