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Surface Plasmon Resonance of Silver Nanoparticles: Synthesis, Characterization, and Applications

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Abstract

In this study, the silver nanoparticles (AgNPs) were chemically fabricated from gallic acid and characterized by utilizing UV–Vis absorption spectroscopy and TEM. Then, the influence of surface plasmon resonance (SPR) of AgNPs against MCF-7 cell line was investigated. The synthesized silver colloidal solution was described by using. UV–Vis absorption spectroscopy revealed the particles present a narrow band with absorbance maxima at 396 nm. Based on the results of TEM, the AgNPs were spherical-shaped (the average diameter was 11.6-15.2 nm). Besides, the cytotoxicity influence of AgNPs against MCF-7 enhanced with increasing concentration. The IC_{80} value was assessed at 50 µg/mL of AgNPs in 72 hr.

Key words: Surface plasmon resonance (SPR), Silver nanoparticles, Gallic acid, MCF-7 cell line, Cytotoxicity

Introduction

Nanotechnology is the science of production and utilization of biological, chemical, and physical systems of not more than 100 nm, (Al-Bishri, 2018) and the application of these nanostructures in larger systems. (Nourmohammadi *et al.*, 2018) Nanotechnology is rapidly progressing by generating nanoproducts and nanoparticles (NPs). These NPs can have new and size-related physicochemical characteristics varying significantly from larger materials.(Rai *et al.*, 2009; Kim *et al.*, 2007; Powers *et al.*, 2007) It is now considered as a future domain to treat and diagnose many diseases.(Ayaz, 2018) The new NPs are widely used in various fields including environmental remediation, renewable energies, medicine, cosmetics, and biomedical devices. Among them, silver nanoparticles (nanosilver or AgNPs) have gained growing interest because of their exclusive biological, chemical, and physical features compared to their macroscale counterparts. It has therapeutic potential against numerous diseases. (Hamza and AlSolami, 2018) The silver has been used even before the Neolithic revolution. For instance, the Greeks used to apply it for cooking and water safety. The first reported medicinal utilization of silver was during the 8th century. Previously, it was only known as a metal. However, by the emergence of the nano-era, people began to realize that silver could even be produced at the nanoscale. AgNPs are nanoparticles of silver with a diameter of 1-100nm. They have distinctive optical, thermal, and electrical characteristics and are utilized in various products such as photovoltaics, as well as biological and chemical sensors. Nowadays, nano silver-based materials are extensively used in commercial products ranging from disinfecting medical devices and home appliances to water treatments.(Rai *et al.*, 2009; Kim *et al.*, 2007; Powers *et al.*, 2007) AgNPs have improved features such as plasmon resonance features according to their size and morphologies. (Scholl *et al.*, 2012) An interesting thing about some metallic NPs, especially silver and gold NPs, is that these particles reveal strong plasmonic features. When light photons interact with the AgNPs surface, the outer free electrons of the particles form localized plasmons. (Zeng *et al.*, 2011) Plasmons are density waves of the free outer electrons. Specific wavelengths of light cause the outer electrons to oscillate. This event is called surface plasmon resonance (SPR). When these resonances happen, the intensities of absorption and scattering are much higher than those of the same particles without plasmonic features. SPRs highly depend on particle characteristics. (Rycenga *et al.*, 2011) Here we mainly consider the applications of AgNPs against the MCF-7 cell line.

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Materials and Synthesis

Materials

Silver nitrate, gallic acid, and Sodium hydroxide were purchased from BDH-Chemical Ltd. (England), May & Baker Ltd. (England), and Avonchem (United Kingdom), respectively.

Synthesis of silver nanoparticles

100ml of 0.001 M $AgNO_3$ was placed in a 250 mL reaction vessel. 10ml of deionized water containing 0.02 g gallic acid was admixed with the solution under magnetic stirring. The pH was adjusted to 11 by dropwise adding of 1 M NaOH.

Results and Discussions

UV-Vis absorption spectroscopy is very suitable for the detection of wavelength and absorption where the SPR peak exists. Figure 1 indicates the maximum peak of AgNPs as a narrow band with

absorbance maxima at 396 nm. Due to the SPR in the interaction of electrons and electromagnetic radiation in the conduction band around the nanoparticles, an optical absorption band of λ max value is a typical characteristic of the absorption of metallic AgNPs because of the SPR, revealing the presence of AgNP's in the solutions. TEM technique has high accuracy and reliability for determining the shape, distribution, and size of NPs. Based on the results of TEM analysis, AgNPs were spherical-shaped (the average diameter was 11.6-15.2 nm) (Figure 2).

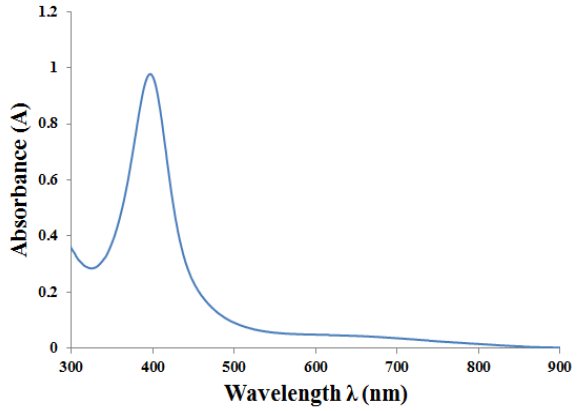

Figure 1: UV–Vis spectra of the synthesized silver nanoparticles.

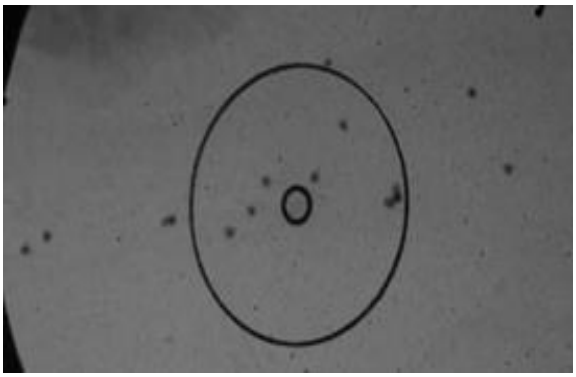

Figure 2: TEM image of the synthesized silver nanoparticles.

In vitro cytotoxicity of synthesized AgNPs

The human breast cancer cell line (MCF-7) was bought from Iraqi Center for Cancer and Medical Genetic Researches (ICCMGR), Iraq. The Eagle's minimum essential medium (EMEM) containing 100 ml FBS was utilized to grow cancer cells. Then, they were kept at 37 ℃, 5% CO_2, 100% relative humidity, and 95% air. Approximately 1×10^5 cells/wells were cultured into 96-well plates and incubated for 24 hr. (Abdul-Majeed 2000; Freshney 2001) MCF-7 cell line was treated with different concentrations of fabricated AgNPs (12.5, 25, and 50 µg/ml). The cytotoxicity of treated cells was analyzed after 72 hr. The media was discarded from the plate and washed three times with PBS. 0.1 ml of crystal violate working solution was added to each well and the plate was kept at 37 ˚C for 20 min and then the dye was removed from the plate and the wells were washed with tap water until the plate became clean. Eventually, the plate was dried and read using an ELISA reader at 492nm.

The Inhibitory Concentration (IC) was described as the drug concentration that is needed to decrease absorption to half of the control. The equation was:

$$\text{The percentage\%} = \frac{\text{mean of test}}{\text{mean of control}} * 100$$

The AgNPs cytotoxicity depends on their concentration, size, and shape. Figure 3 depicts the influence of AgNPs with varying concentrations (12.5, 25, and 50 µg/ml) against the MCF-7 cell line. The cytotoxicity of AgNPs against MCF-7 cell line improved with the enhancement of concentration. Therefore, AgNPs have high cytotoxicity because of ideal features (small dimensions and spherical shape). This demonstrates the cytotoxic effect of AgNPs against the MCF-7 cell line. This is in line with numerous *in vitro* investigations revealed that the AgNPs are toxic mammalian cells. Figure 4 demonstrates microscopic images indicating the percentage of killed MCF-7 cell line by AgNPs.

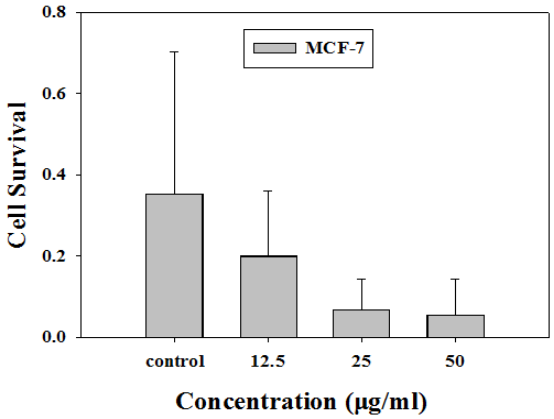

Figure 3: The influence of various concentrations of silver nanoparticles on the MCF-7 cell line.

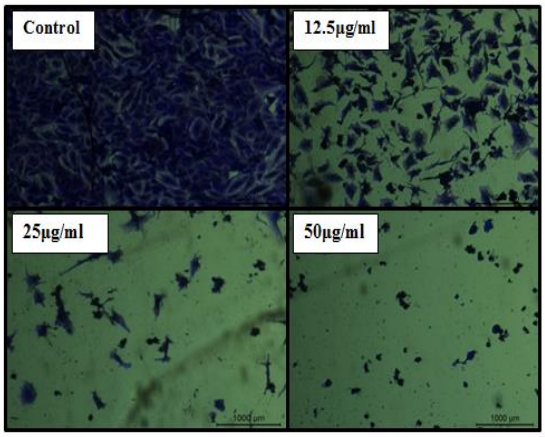

Figure 4: Microscopic images depicting the percentage of killed MCF-7 cells by various concentrations of silver nanoparticles.

Conclusion

AgNPs were fabricated by gallic acid in an aqueous chemical reduction technique and described utilizing UV–Vis absorption spectroscopy and TEM. The synthesized AgNPs had a cytotoxic impact on human breast cancer (MCF-7) cells. The cytotoxicity influence of AgNPs against MCF-7 improved with the enhancement of concentration due to the small dimensions and spherical shape of AgNPs. Thus, synthesized AgNPs can be employed to deliver drugs and also they can be utilized to treat cancer.

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