NanoNEXT

Research Article

Production of AgNPs by Chemical Method in Seaweed Extracted Media

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Abstract: Chemical method approach was utilized to synthesize silver nanoparticles (Ag-NPs) using seaweed extract combined with varying concentrations of $NaBH_4$. The seaweed extract functioned as an environmentally friendly stabilizing agent, while $NaBH_4$ acted as the reducing agent. While the increasing of $NaBH_4$ concentrations, the quantity of Ag-NPS were increased and reaching its highest peak at 0.04 M. UV–visible spectroscopy confirmed the formation of Ag/κ-carrageenan complexes through the appearance of surface plasmon resonance peaks in the range of 390 to 400 nm. Transmission electron microscopy (TEM) revealed that the silver nanoparticles were uniformly distributed, with an average size of about 28 nm. Atomic force microscopy (AFM) showed that the nanoparticles had a spherical shape. Fourier-transform infrared (FT-IR) spectroscopy indicated that compounds present in the seaweed extract played a key role in the nanoparticle synthesis.

Keywords: Chemical Method, $NaBH_4$, Silver- Nanoparticles, Seaweed Extract, Transmission Electron Microscopy

1. Introduction

Particles having nanometer-scale dimensions, usually smaller than 100 nanometers (nm), are called nanoparticles. Materials exhibit diverse chemical, physical, and biological characteristics that distinguish them from their larger, bulk forms. These qualities, which include enhanced reactivity, strength, and distinctive optical properties, make nanoparticles useful in a variety of applications across a wide range of industries, such as electronics, medicine, and environmental science [1] Numerous techniques, including chemical reduction, sol-gel procedures, and green synthesis employing biological agents, can be used to create nanoparticles. The intended uses and characteristics of the nanoparticles determine the synthesis method to be used [1, 2]. A promising green synthesis technique is the creation of silver nanoparticles (AgNPs) from κ-carrageenan, a naturally occurring polysaccharide that is taken from red seaweed. By serving as a stabilizing and reducing agent, κ-carrageenan makes it easier to reduce silver ions (Ag^+) to create AgNPs without the need of dangerous chemicals or significant energy inputs [3, 4]. This environmentally beneficial strategy is consistent with sustainable nanotechnology and green chemistry [3, 4]. Several methods are utilized to characterize the generated AgNPs, such as Uv-vis spectroscopy, which is used to ascertain the nanoparticles' size, shape, and concentration. To determine which functional groups are involved in the stabilization and reduction processes, Fourier-transform infrared spectroscopy (FTIR) is utilized [5]. Surface Plasmon Resonance (SPR) is frequently used to detect and characterize nanoparticles, such as silver nanoparticles (AgNPs), Atomic Force Microscopes (AFM) and Transmission Electron Microscopes (TEM) are accustomed to achieve the higher resolution, allowing scientists to see fine details at the nanometer scale. The resulting AgNPs are appropriate for use in antimicrobial coatings, medical equipment, and water disinfection since they are usually spherical in shape and have good stability and antibacterial qualities.

2. Materials and Method

All chemicals used in this study were of analytical grade and used without further purification. Silver nitrate ($AgNO_3$, 99.98%) was obtained from Merck, Germany, and served as the silver precursor. The κ-carrageenan seaweed powder, used as the support material for silver nanoparticles, was purchased from Sigma (CAS 9000-07-1). Sodium borohydride ($NaBH_4$, 98.5%) from Sigma-Aldrich (St. Louis, MO) acted as the reducing agent. All solutions were prepared using double-distilled water.

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2.1 Synthesis of Silver Nanoparticles

For the synthesis of Ag/seaweed composites, five separate samples labelled a, b, c, d, and e were prepared. Each contained 1.5 M silver nitrate and 1% seaweed extract solution. The mixtures were stirred at room temperature for 24 hours to allow proper mixing of silver nitrate with the extract. Freshly prepared sodium borohydride solutions with concentrations of 0.00, 0.01, 0.02, 0.03, and 0.04 M were then added to samples a to e respectively. After adding the reducing agent, stirring was continued for another hour. The resulting suspensions were centrifuged at 15,000 rpm for 20 minutes. The precipitates were washed four times with double-distilled water to remove any unreacted silver ions, and dried under vacuum at 40°C overnight.

2.2 Characterization Techniques

The surface plasmon resonance (SPR) of the nanoparticles was analyzed using a UV-1650 PC-Shimadzu B UV–visible spectrophotometer (Shimadzu, Osaka, Japan). FT-IR spectra were recorded in the range of 200–4000 cm^{-1} using a Series 100 PerkinElmer FT-IR 1650 spectrophotometer. Transmission electron microscopy (TEM) images were captured using a Hitachi H-7100 electron microscope (Tokyo, Japan), and particle sizes were evaluated using Image Tool software (Version 3.00). The morphology of the synthesized nanoparticles was examined by atomic force microscopy (AFM) using the Q-Scope 350 model.

3. Results and Discussion

For the successful synthesis of stable Ag-NPs via a chemical reduction approach, selecting an appropriate stabilizing and reducing agent is crucial. In this study, seaweed extract was utilized as a stabilizer, while $NaBH_4$ served as a strong reducing agent. The reduction of $AgNO_3$ by $NaBH_4$ in the presence of a seaweed extract component $(\kappa - carrageenan)$ according to the following equation [6].

$$Ag^{+} + seaweed\ extract\ (\kappa - carrageenan) + BH_4^{-} + 3H_2O \rightarrow Ag^{0}/seaweed\ extract\ (\kappa - carrageenan) + B(OH)_3 + 3.5H_2 \quad (1)$$

3.1 UV–Visible Spectroscopy Analysis

Using surface plasmon resonance (SPR), UV-visible spectroscopy offers a quick and easy way to track AgNP production. For AgNPs, the absorption peak typically falls within the 300–450 nm range [7]. As illustrated in Figure 1, the absorbance spectra were recorded at varying $NaBH_4$ concentrations (0.00, 0.01, 0.02, 0.03, 0.04 M) and labeled as (a–e), respectively. Initially, in sample (a), no UV-visible absorption band was observed before $NaBH_4$ was added. However, after its introduction, a plasmon peak appeared at 390 nm in samples (b) and (c), confirming the formation of AgNPs. A further increase in NaBH4 concentration led to higher peak intensities, indicating an increased yield of AgNPs. In samples (d) and (e), the absorption peak exhibited a slight redshift towards 400 nm, signifying a slight increase in particle size [8].

3.2 FT-IR Chemical Analysis

FT-IR spectra verified the interactions between Ag-NPs and κ-carrageenan. The structure of pure seaweed extracts 2 (a) and Ag/seaweed extract (b) is compared using FT-IR spectra in Figure 2. The spectrum of pure seaweed extract revealed key absorption bands, including 3389 cm^{-1} for O–H stretching, 2933 cm^{-1} for C–H stretching, 1619 cm^{-1} for H–O–H bending of polymer-bound water, and peaks at 1424, 1234, 1159, 960, and 844 cm^{-1} corresponding to sulfate, ester sulfate, glycosidic linkage, and other structural features of κ-carrageenan [9]. With the exception of the appearance of a new peak at 430 cm-1, the majority of absorption intensities stayed rather constant following the addition of AgNO3 and 0.04 M NaBH4 (2b). This peak represents the bonding of Ag-NPs with oxygen atoms from hydroxyl groups in the chains of seaweed extract [10].

3.3 Morphology study

The TEM images a of Ag-NPs in seaweed extract at 0.04 M of $NaBH_4$ shown in Figure 3, TEM conducted to measure the size distributions of the AgNPs [11]. TEM image improve the formation of AgNPs in seaweed extract with average size of Ag-NPs were about 28 ±1.74 nm based on size distribution analysis.

AFM analysis further characterized the synthesized AgNPs, revealing amorphous yet predominantly spherical structures (Figure 4). Previous studies have also documented topographical AFM images indicating regular nanoparticle shapes. AFM imaging provided insights into the precise configuration of the nanoparticles and confirmed their uniform size distribution and spherical morphology [12].

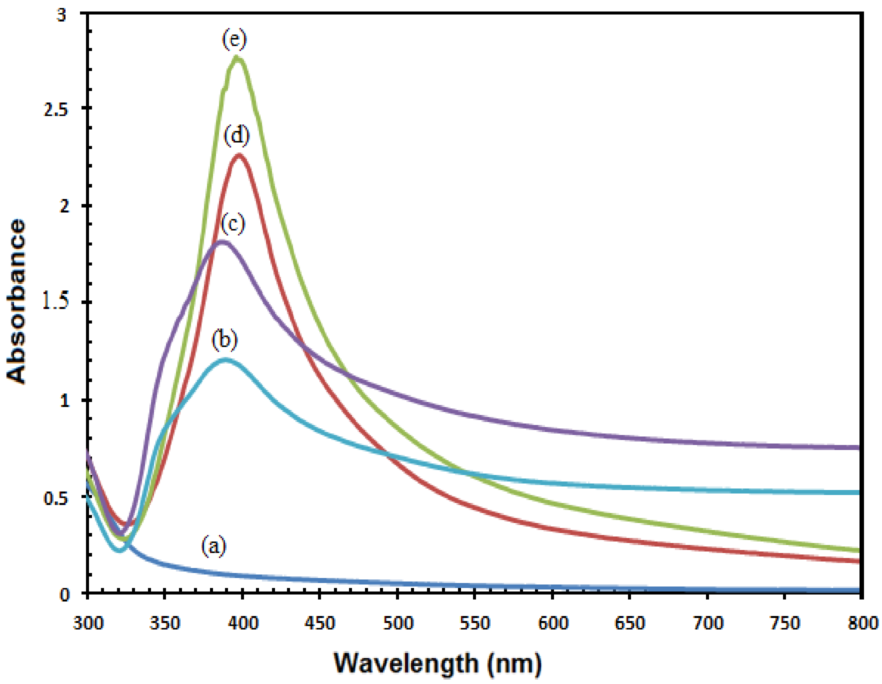

Figure 1. UV-visible absorption spectra for Ag/ seaweed extract at differentconcentration from NaBH4 (0.00, 0.01, 0.02, 0.03, 0.04 M) respectively (a–e).

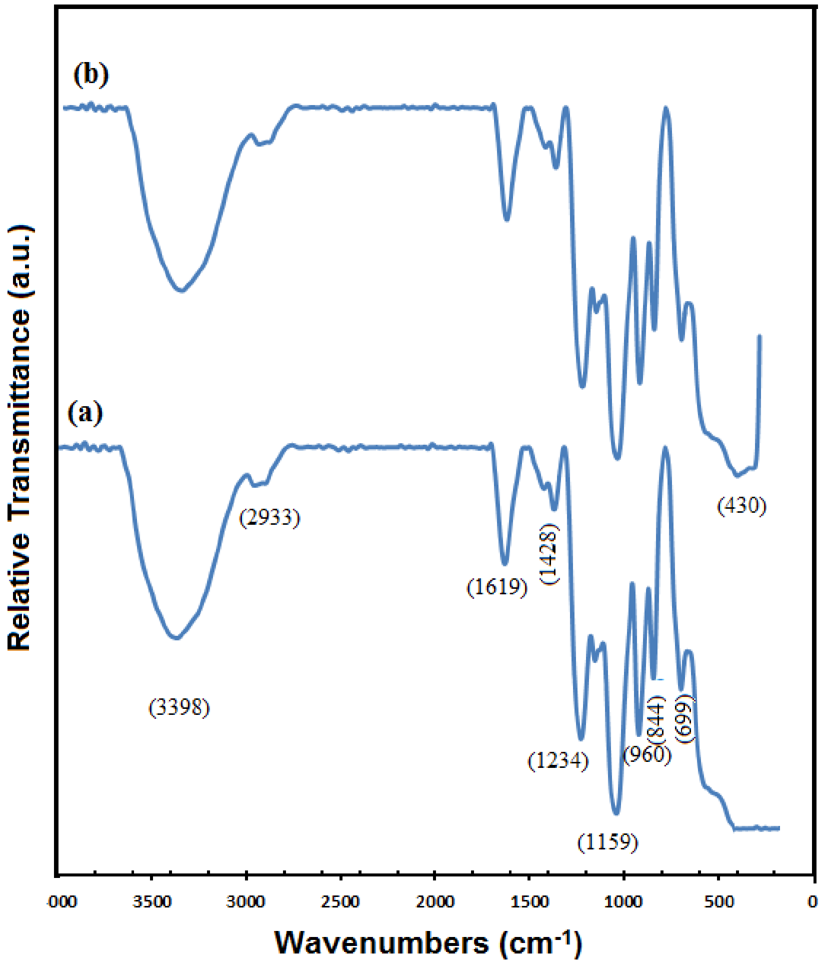

Figure 2. FT-IR spectra of seaweed extract, (a) and Ag/ seaweed extract (b)

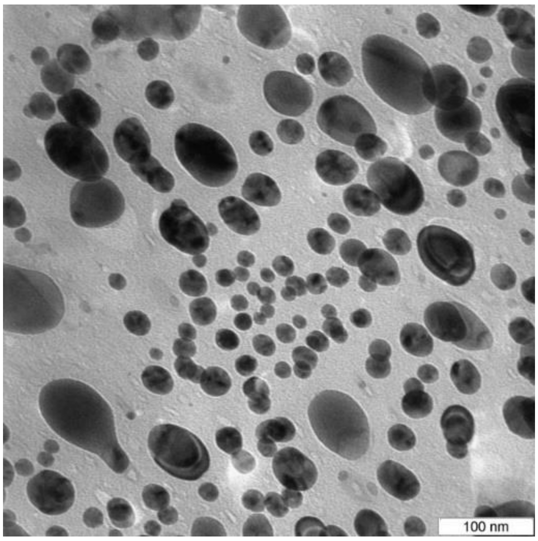

Figure 3. The TEM images a of Ag-NPs in seaweed extract at 0.04 M of NaBH4

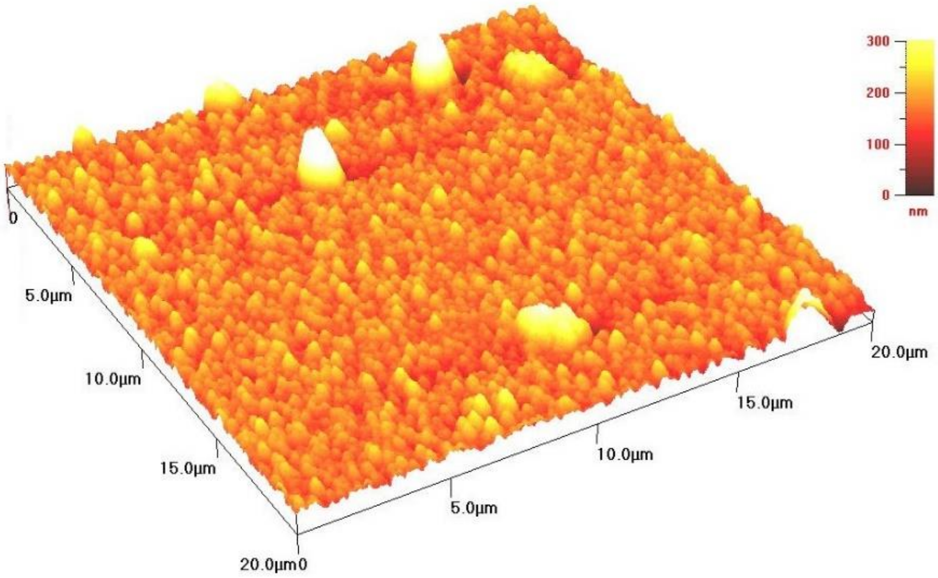

Figure 4. The AFM images a of Ag-NPs in seaweed extract at 0.04 M of NaBH4

4. Conclusion

In summary, Ag-NPs were effectively synthesized using a chemical reduction technique within a seaweed extract medium, utilizing NaBH4 at different concentrations. Their UV-vis SPR peak at 390–400 nm verified the existence of Ag-NPs. TEM analysis determined the average nanoparticle size to be 28 nm, while AFM imaging validated their spherical structure.

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Author Contribution Statement

Randa F. Elsupikhe: Concetualization, Methodology, Investigation, Data Collection, Formal Analysis, Writing Original Draft. Hitham M: Formal Analysis, Writing Review & Editing. Tahani S. Alfazani: Formal Analysis, Writing Review & Editing. Nada F. Elzawi: Formal Analysis, Writing Review & Editing. All the authors read and approved the final version of the manuscript.

Does this article screened for similarity?

Yes

Conflict of interest

The Author's declares that there is no conflict of interest anywhere.

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