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The Green Synthesis and Phytochemical Properties of Silver Nanoparticles Obtained from Eggplant †

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Abstract: Green synthesis is one of the lowest energy processes for constructing nanomaterials because it is clean, safe, and cost-effective. The aim of this research is to prepare green nanoparticles using eggplant extract and then optimize and characterize these particles using different techniques. This research also includes a study of total antioxidants and their ability to scavenge free radicals. The method of green synthesis of silver nanoparticles with eggplant extract was elaborated for the first time. The best conditions for this were 1 mM of argentum nitrate. The obtained green nanoparticles possess high activity against oxidation.

Keywords: synthesis; phytochemical; silver nanoparticles; eggplant; eco-friendly technology

1. Introduction

Green synthesis is one of the lowest energy processes for constructing nanomaterials because it is clean, safe, and cost-effective. Microorganisms such as bacteria, yeast, fungi, algal species, and certain plants act as substrates for the green synthesis of nanomaterials, and one of the most important issues at present concerns human health safety and improving the environment. Phytochemical constituents work with nutrients and fibers to form key parts of the protection system against many diseases and stress conditions.

Phytochemicals are compounds found in plants that are utilized as food and medicine to prevent against illness and to ensure human health. Phytochemicals have antioxidant or hormone-like impacts, which help in fighting against many diseases/conditions, including cancer, heart disease, diabetes, and high blood pressure [1]. Phytochemicals are essentially divided into two groups, primary and secondary constituents, according to their role in plant metabolism. Primary constituents include common sugars, amino acids, proteins, and chlorophyl while secondary constituents consist of alkaloids, terpenoids, saponins, phenolic compounds, flavonoids, tannins, and so on [2]. The plant fresh extract contains various metabolites such as polyphenols, flavonoids, alkaloids and terpenoids, phenolic acids, sugars, and proteins, in which these compounds are mainly responsible for the reduction of ions and the formation of metal nanoparticles [3].

Various wild and cultivated plant species are used in green synthesis processes, through the twelve principles of green chemistry. There is a diverse array of wild and cultivable plants with potential biological activity that can be used efficiently to perform green synthesis, with pharmacological, agricultural, or environmental applications, materials, and methods [4,5]. Silver is often used to produce nanoparticles. Silver nanoparticles exhibit significant antimicrobial activity. Green synthesis makes it possible to obtain silver nanoparticles relatively easily using plant extracts. For example, silver nanoparticles obtained using green synthesis using *Justicia glauca* and *Ocimum gratissimum* showed high

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antimicrobial activity [6]. Eggplants are widely grown as agricultural plants and are produced in many countries around the world. Eggplant contains a large amount of vitamins, including C and B6, folic acid, carotene, and trace elements, such as potassium, calcium, iron, copper, zinc, etc. The high content of potassium salts in eggplants has a positive effect on the functioning of the heart and promotes the excretion of excess fluids from the body. This work is devoted to studying the possibility of obtaining silver nanoparticles using the green synthesis method based on eggplant extract. For the experimental stage, antioxidants were obtained from eggplant skin via extraction. These extracts were analyzed using a DPPH assay to determine their antioxidant capacity, and finally, those samples with the best antioxidant capacity were used as a reducing agent to synthesize silver nanoparticles at room temperature. The obtained nanoparticles were characterized using UV-visible (UV-Vis) spectrophotometry and dynamic light scattering (DLS).

2. Material and Methods

2.1. Preparation of the Aqueous Extract of Eggplant Peels

Twenty grams of eggplant peel (*Solanum melongena* L.), which was brought from a local market in Babylon, Iraq, was used. After being rinsed with tap water, the plants had their peels removed and were diced before being combined with 250 mL of deionized water in a commercial blend to prepare the aqueous extract. The aqueous extract was filtered using filter paper.

2.2. Preparation of Silver Nanoparticles

Silver nanoparticles were prepared by mixing 5 mL of aqueous extract of eggplant peels with 1 mM silver nitrate solution and then heated with stirring at 40 °C for 60 min (Figure 1). The formation of a slight pink color indicated the synthesis of silver nanoparticles [3]. The color started to change after 10 min, and after 30 min, it changed to a slight pink. This change in color indicated the formation of AgNPs. The solution was kept at room temperature for 24 h to complete the development of nanoparticles, after which it was used for analyses [4,7,8]. To achieve optimum conditions for the synthesis of nanoparticles, the experiment was completed under various silver ion concentrations. The influence of the silver ion concentration on the synthesis of silver nanoparticles was determined using a UV-Vis spectrophotometer.

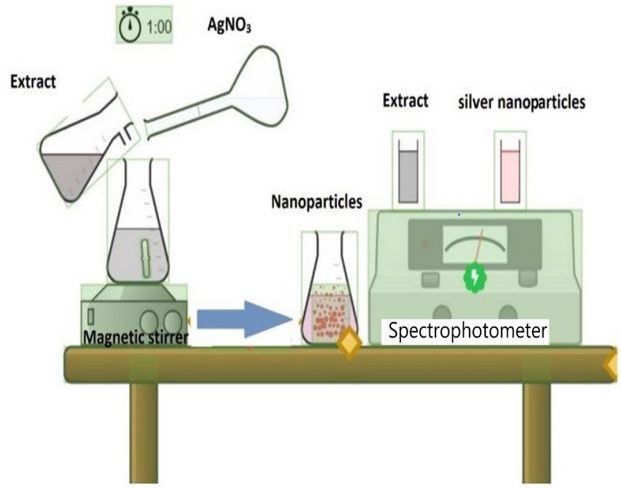

Figure 1. Diagram of the preparation process for the green synthesis of silver nanoparticles.

2.3. Characterization of the Green Synthesis of Silver Nanoparticles

2.3.1. Color Change Method

The change in reaction mixture color was registered through observation. Its change from brown to slight pink indicated that the silver nanoparticles were synthesized.

2.3.2. UV-Visible Spectral Analysis

Silver ions (Ag) were reduced to silver nanoparticles (Ag). They were spectrophotometrically differentiated using a double-beam UV-Vis spectrophotometer (PG-303UV) at different wavelengths (300–700 nm). The graph of wavelength on the X-axis and absorbance on the Y-axis uses deionized water as a reference. The procedure for the preparation of silver nanoparticles was repeated to achieve optimization at different concentrations of silver nitrate (0.25, 0.5, 1, and 2 mM).

2.4. Oxidant—Antioxidant System

Some biochemical measurements were performed using standard methods [9–12].

2.4.1. Total Antioxidant Capacity Assay (TAC)

- **Principle**

Total antioxidant capacity (TAC) is an analyte frequently used to assess the antioxidant status of biological samples and can evaluate the antioxidant response against the free radicals produced in a given disease.

- **Reagents**

1. Copper (I) chloride solution at a concentration of 10^{-2} M;
2. Ammonium acetate (NH_4Ac) buffer, pH = 7.0;
3. Neocuproine (Nc) (2,9-dimethyl-1,1-phenanthroline) solution at a concentration of 7.5×10^{-3} M.
4. Standard uric acid solution (1 mM).

- **Procedure**

According to the particular protocol, the essential additions were calculated in order to perform the total antioxidant capacity assay (Table 1, Figure 2).

- **Calculation**

Total antioxidants levels = A.test/A.STD* Conc. of STD (mM).

Table 1. Details of the CUPRAC method.

Reagents	Test	S.T.D	Blank
$CuCl \times H_2O$ solution	1000 µL	1000 µL	1000 µL
Serum	50 µL		
Uric acid solution		50 µL	
Dist. water	1000 µL	1000 µL	1050 µL
Neocuproine (Nc) solution	1000 µL	1000 µL	1000 µL
Ammonium acetate (NHAc) buffer	1000 µL	1000 µL	1000 µL

Test tubes were mixed using a vortex mixer and incubated at 37 °C for 30 min before being centrifuged at 1000× *g* for two minutes. The absorbance was then measured using a spectrophotometer at 450 nm [6].

2.4.2. Determination of Antioxidant Activity

2,2-Diphenyl-1-picrylhydrazyl

2,2-diphenyl-5-picrylhydrazyl (DPPH) is a dark-colored crystalline powder composed of stable free-radical molecules. The DPPH radical has a deep violet color in solution, and it becomes colorless or pale yellow when neutralized and converted into DPPH-H [8].

Antioxidants react with DPPH and reduce it to DPPH-H, and as a consequence, the absorbance decreases. Lower absorbance indicates higher free radical scavenging activity. Ascorbic acid was utilized as the standard compound. The diminution in the absorbance of the reaction mixture indicated higher free radical scavenging activity (Figure 3).

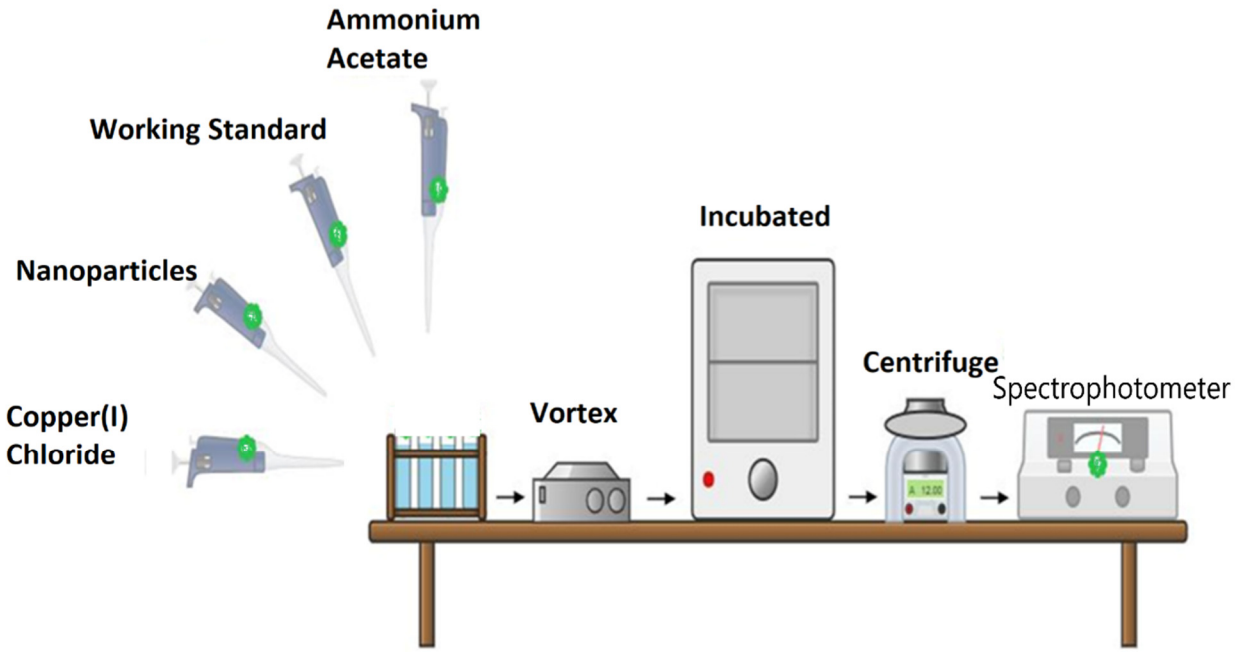

Figure 2. Diagram showing procedures for measuring TAC level.

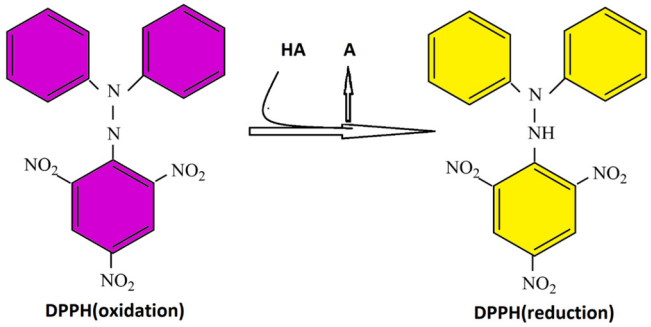

Figure 3. Concept of 2,2-diphenyl-5-picryl hydrazyl radical scavenging capacity.

The results were expressed as μmol of ascorbic acid equivalent (μmol)/100 g of sample. The percentage of inhibition of DPPH oxidation was calculated with the following formula:

$$\text{DPPH_inhibition (\%)} = [(\text{Acontrol-Asample})/\text{Acontrol}] \times 100 \quad (1)$$

3. Results and Discussion

3.1. Green Synthesis of Silver Nanoparticles for Solanum melongena

The characterization absorption spectra are the important properties of AgNPs and the UV-visible spectra; they proved to be very useful for the analysis of the AgNPs, and it is a good method for the characterization of the formation and growth of AgNPs. The variation in spectra may be due to the number of particles and the size distribution in the solution. In the present study, the absorption spectra of the aqueous component of *Solanum melongena* L. extract were measured in the range of 300–700 nm, using a double-beam UV-Vis spectrophotometer. Figure 4 shows a strong surface plasmon resonance centered at approximately 420 nm, suggesting that the nanoparticles were scattered in the aqueous solution, providing proof of accumulation in the UV-Vis absorption spectrum and the presence of silver nanoparticles.

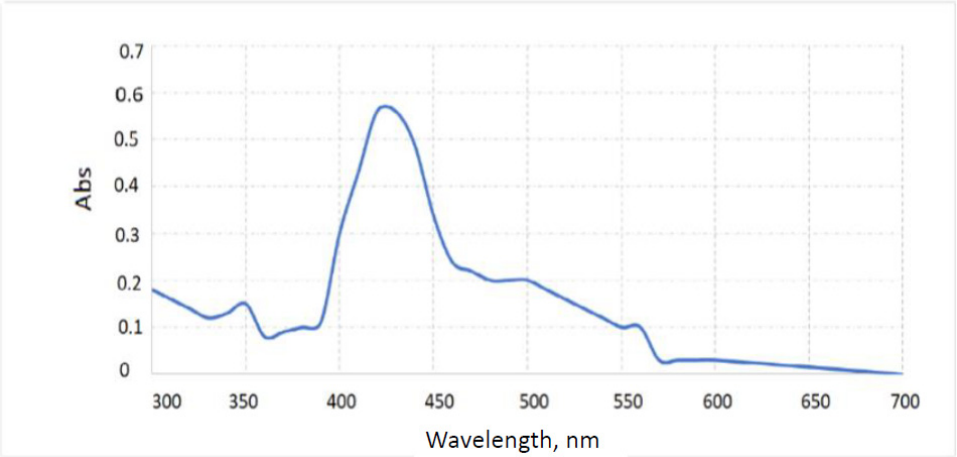

Figure 4. UV-visible spectrum of silver nanoparticles. The maximum absorption was at a wavelength of 420 nm.

3.2. Optimization Conditions for the Synthesis of AgNPs

The absorption increased when increasing the concentration of silver ions from 0.25 mM to 1 mM (Figure 5). This may be attributed to the formation of more AgPs as the reaction progresses since the intensity of the surface plasmon peak is directly proportional to the density of the AgPs in the solution. Over and above 1 mM of silver nitrate concentration, there was a fall in absorbance. The best salt concentration was 1 mM.

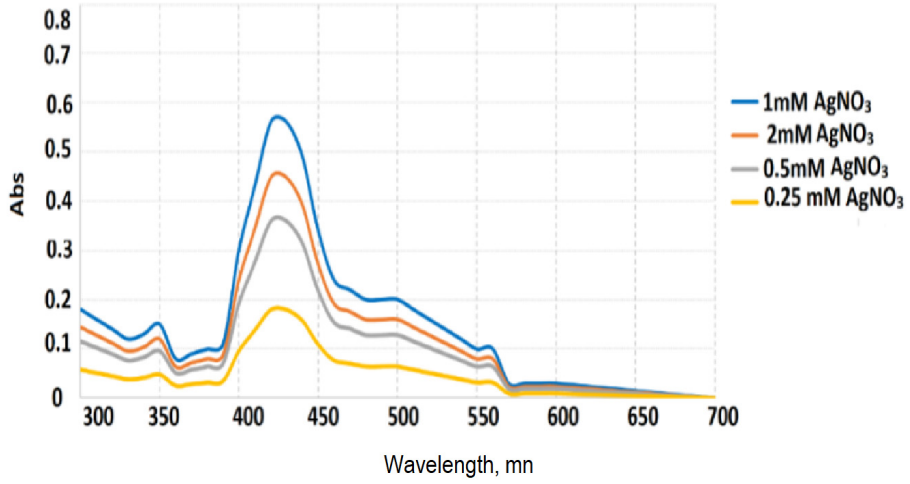

Figure 5. UV-visible spectrum of silver nanoparticles at different concentrations of $AgNO_3$. Note: 1 mM is the best concentration.

3.3. Total Antioxidant Capacity Assay (TAC)

We found that the total antioxidant capacity (TAC) concentration of 200 ppm was better compared to a concentration of 50 ppm and 100 ppm (Figure 6). This result gives a good indication of the antioxidant properties of silver nanoparticles compared to eggplant extract as a control, and the total antioxidant capacity depends on the concentration of silver nanoparticles (AgNPs), as the concentration of antioxidants is directly proportional to the concentration of nanoparticles used. Cömert et al., summarizing the results of determining total antioxidant activity, showed that color is related to antioxidant capacity in some fruits and vegetables [13].

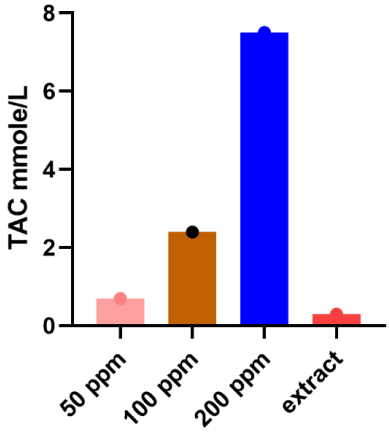

Figure 6. Results of the total antioxidant capacity assay.

3.4. Determination of Antioxidant Activity: The 2,2-Diphenyl-1-picrylhydrazyl (DPPH) Inhibition Method

It was found that, as in the case of the TAC method, the concentration of 200 ppm was the best concentration for inhibiting free radicals in the DPPH inhibition assay. Inhibition of DPPH oxidation by nanoparticles based on a concentration of 200 ppm was almost 2.5 times more active than the plant extract itself and 20 percent greater than the effect of ascorbic acid solution used as a standard antioxidant agent.

4. Conclusions

In this research, the method of green synthesis of silver nanoparticles with eggplant extract was elaborated for the first time. The best conditions for this were 1 mM of argentum nitrate. The obtained green nanoparticles possess high activity against oxidation. Thus, the first evidence of the effectiveness of these silver nanoparticles based on eggplant extract was obtained. We plan to evaluate the effectiveness of the resulting nanoparticles in inhibiting the growth of microflora pathogenic to humans.

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