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(RESEARCH ARTICLE)

Biosynthesis, characterization and photocatalytic activity of silver nanoparticles produced from $AgNO_3$ solution using aqueous extract of *Ocimum bacilicum* L. leaf as the reducing agent

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Abstract

The paper presents a simple and eco-friendly, green synthesis method of silver nanoparticles (AgNPs) from $AgNO_3$ solution using aqueous extract of *Ocimum basilicum* L. leaf as the reducing agent. The influence of some factors such as the volume ratio of *Ocimum basilicum* L. leaf extract/ $AgNO_3$ solution, pH, temperature to the synthesis of silver nanoparticles was investigated. The formation of AgNPs was confirmed by UV-Vis spectroscopy. The morphology and crystalline phase of AgNPs were determined from transmission electron microscopy (TEM), energy dispersive X-ray (EDX) and X-ray diffraction (XRD) spectra. The results showed that the reaction process was rapid for the formation of stable AgNPs, colorless $AgNO_3$ solution changes to brown-yellow after adding aqueous extract of *Ocimum basilicum* L. leaf. The obtained AgNPs were spherical with different average sizes of 6.5 nm - 12.9 nm and have lattice planes of silver. The photocatalytic activity of the synthesized silver nanoparticles was examined by degradation of methylene blue under sunlight irradiation

Keywords: Silver nanoparticles; *Ocimum basilicum* L. leaf; Biosynthesis; Plant extract

1. Introduction

Nanotechnology is emerging as a rapidly growing field with its application in Science and Technology for the purpose of manufacturing new materials at the nanoscale level. The synthesis of metal nanoparticles has attracted considerable attention in physical, chemical, biological, medical, optical, mechanical and engineering sciences [1], [2]. The properties of nanoparticles depend on size, shape, composition, morphology and crystalline phase. Among the various metal nanoparticles, silver nanoparticles have wide applications as antibacterial and antifungal agents in a diverse range of consumer products: air sanitizer sprays, detergents, soaps, shampoos, toothpastes and washing machine [3], [4], [5]. Many techniques of silver nanoparticles synthesis are extremely expensive and also involve the use of toxic, hazardous chemicals, which may pose potential environmental and biological risks [6]. Hence developing of reliable biosynthesis, an environment friendly approach for the synthesis of silver nanoparticles has added much importance because of its ecofriendly products. In recent years, green synthesis of silver nanoparticles was achieved by using microorganisms and plant extract [7], [8], [9]. The plant contains a variety of phytochemical compounds such as polyphenols, flavones, saponins, sterols, triterpenoids,… and these molecules are expected to self assemble and cap the metal nanoparticles formed in their presence and thereby induce some shape control during metal ion reduction [10], [11], [12]. In this study, the silver nanoparticles were synthesized from $AgNO_3$ solution using aqueous extract of *Ocimum basilicum* L. leaf as reducing agent.

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2. Experimental

2.1. Preparation of leaf extract

Fresh leaves of *Ocimum basilicum* L. were collected from local places of Da Nang City, Vietnam. The leaves were washed thoroughly with distilled water and air-dried. A definite amount of leaves were cut into fine pieces and boiled with 100 mL of double distilled water at 80 ^{o}C for t minutes.

After boiling process the extract was filtered through Whatmann No.1 filter paper to obtain aqueous extract and either directly used in the synthesis of silver nanoparticles or stored at 4 ^{o}C for further experiments.

2.2. Synthesis of silver nanoparticles

For synthesis of silver nanoparticles, a definite volume of leaf extract was interacted with 30 mL of 1mM $AgNO_3$ in 100 mL Erlenmeyer flasks. The flasks were incubated for 24 hours at desired temperature.

2.3. UV-Visible spectroscopy

The reduction of the Ag^+ ions by the supernatant of the aqueous extract of *Ocimum basilicum* L. leaf and the formation of silver nanoparticles were characterized by UV-Visible spectroscopy monitored by sampling the aqueous component (2.0 mL) and measuring the UV-Vis spectrum of solutions. The UV-Vis spectra of these samples were measured between 300 nm – 700 nm on a UV-2450 (Shimadzu) spectrophotometer operated at a resolution of 1 nm.

2.4. Transmission electron microscopy (TEM), energy dispersive X-ray spectra (EDX) analysis and XRD measurement

Samples for transmission electron microscopy (TEM) analysis were prepared by drop coating biologically synthesized silver nanoparticles solution on to carbon-coated copper TEM grids. TEM measurements and the EDX analysis were carried out using HRTEM Tecnai G2 F20.

Crystal phase identification of silver nanoparticles was characterized by powder X-ray diffraction using a Panlytical X Pert PRO Diffractometer. The diffracted intensities were recorded from 20^{o} - 80^{o} 2θ angles.

2.5. Photocatalytic degradation of dye

Photocatalytic degradation of methylene blue was carried out by using green synthesized silver nanoparticles under solar light. About 5 mg of biosynthesized silver nanoparticles was added to 100 mL of 10 ppm methylene blue dye solution.

3. Results and discussion

3.1. The optimal conditions for the extraction of *Ocimum basilicum* L. leaf

3.1.1. Effect of extraction time

The effect of extraction time of *Ocimum basilicum* L. leaf to the formation of silver nanoparticles was conducted with the parameters as follows: The ratio of solid/liquid 15 gram *Ocimum basilicum* L. leaf / 200 mL of distilled water; 2 mL aqueous extract of *Ocimum basilicum* L. leaf / 30 mL of 1 mM $AgNO_3$ solution; pH of the solution: pH = 6.2. The time for extraction t = 5, 10, 15, 20, 25 minutes. The UV-Vis spectrum (Fig. 1) shows effect of extraction time of *Ocimum basilicum* L. leaf in nanoparticles synthesized from 1 mM $AgNO_3$. Characteristic surface plasmon absoption was observed at 420 - 460 nm for the brown coloured silver.

The results of Fig. 1 shows the absorption was increased while increasing the extraction time of *Ocimum basilicum* L. leaf from 5 minutes to 25 minutes, and reached the highest absorption at extraction time 15 minutes.

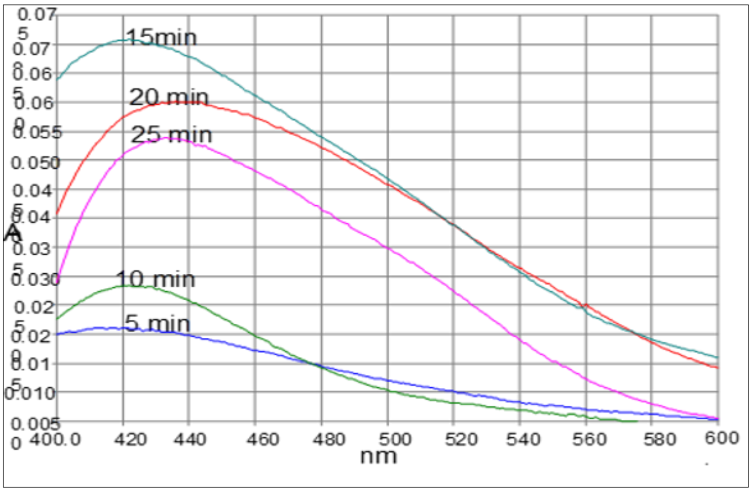

Figure 1 UV spectrum shows effect of extraction time of *Ocimum basilicum* L. leaf in the silver nanoparticles synthesis.

3.1.2. Effect of solid / liquid ratio

The effect of the ratio of *Ocimum basilicum* L. leaf weight/distilled water volume to the formation of silver nanoparticles was conducted with experimental parameters as 3.1.1. The time of extraction was 15 min and the weight of *Ocimum basilicum* L. leaf varies m = 5 g, 10 g, 15 g, 20 g, 25 g.

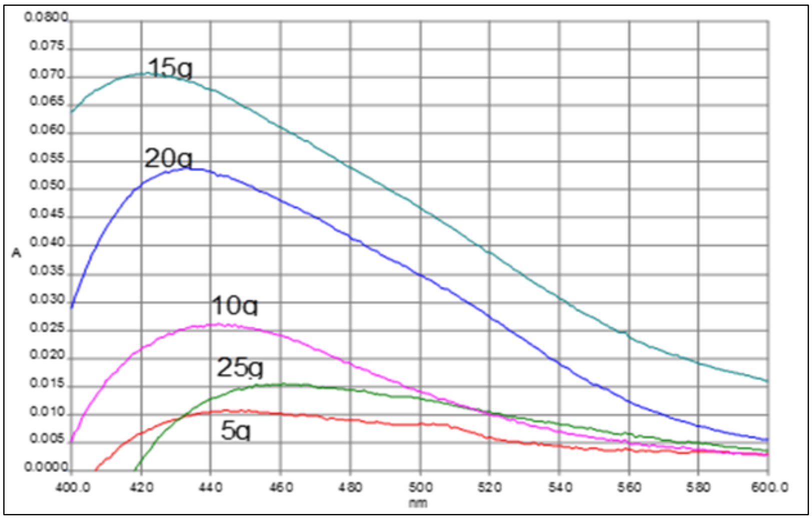

Figure 2 UV spectrum shows effect of the ratio of *Ocimum basilicum* L. leaf weight/distilled water volume in the silver nanoparticles synthesis.

The results of Fig. 2 shows the absorption was increased while increasing the weight of *Ocimum basilicum* L. leaf from 5 g to 15 g/200 mL of distilled water, and reached the highest absorption at 15 g of *Ocimum basilicum* L. leaf / 200 mL distilled water.

3.2. The factors affecting the synthesis of silver nanoparticles

3.2.1. The effect of mixing ratio on the formation of silver nanoparticles

In order to study mixing ratio, five situations were tested (from mixing ratio 1 mL, 2 mL, 3 mL, 4 mL, 5 mL of extract volume / 30 mL of 1 mM $AgNO_3$ solution volume). The samples after color change measured by Spectroscopy within wave length 400 – 600 nm (Fig. 3).

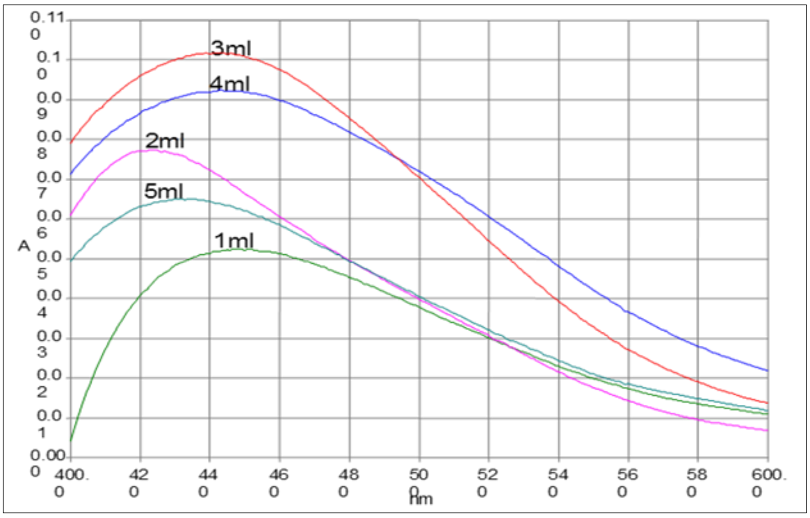

Figure 3 UV spectrum shows effect of mixing ratio of extract volume/ 1 mM $AgNO_3$ solution volume in the silver nanoparticles synthesis.

By change of mixing ratio in similar environmental conditions, the observed wave length of maximum peak (λmax) does not change much and it is between wave lengths of 415 - 425 nm. However, by increase of extract volume, the peak intensity has increased and highest at 3 mL of extract/30 mL of 1 mM $AgNO_3$.

3.2.2. The effect of temperature on the formation of silver nanoparticles

To study temperature effect, six containers containing 30 mL of 1 mM $AgNO_3$ together with 3 mL extract were put at six different temperatures of 20 °C, 30 °C, 40 °C, 50 °C, 60 °C, and 70 °C. The UV-vis spectrum (Fig. 4) shows effect of temperature in the silver nanoparticles synthesis.

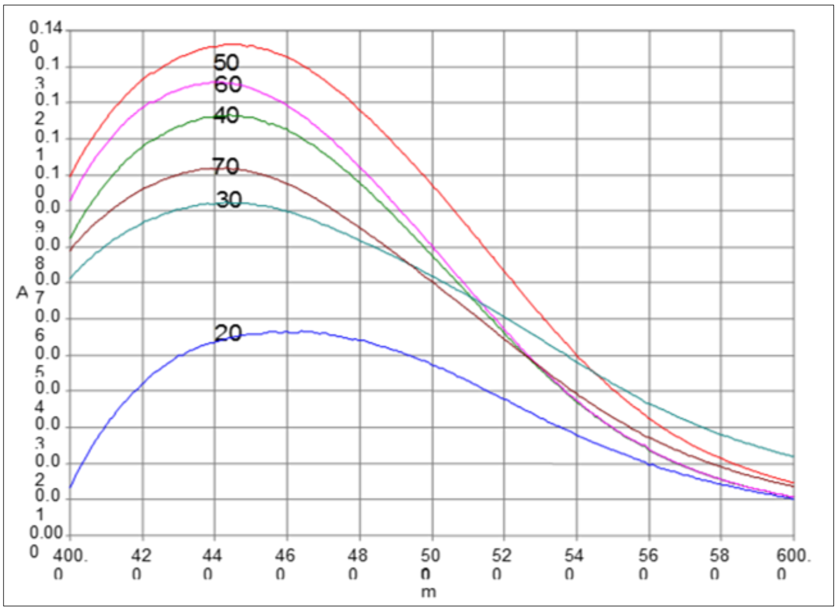

Figure 4 UV spectrum shows effect of temperature in the silver nanoparticles synthesis

The obtained results of Fig. 4 shows that when the temperature increases from 20 °C to 50 °C, the absorption intensity values has increased and reached at temperature of 50 °C. If temperatures continue to rise , the absorption amount decreases .

3.2.3. The effect of pH on the formation of silver nanoparticles

For study of pH effect four containers containing 30 mL silver nitrate of 1 mM at six different pH of 4, 5, 6, 7, 8, and 9. Then, 3 mL *Ocimum basilicum* L. leaf extract was added to each container.

The UV-vis spectrum (Fig. 5) shows effect of pH in the silver nanoparticles synthesis.

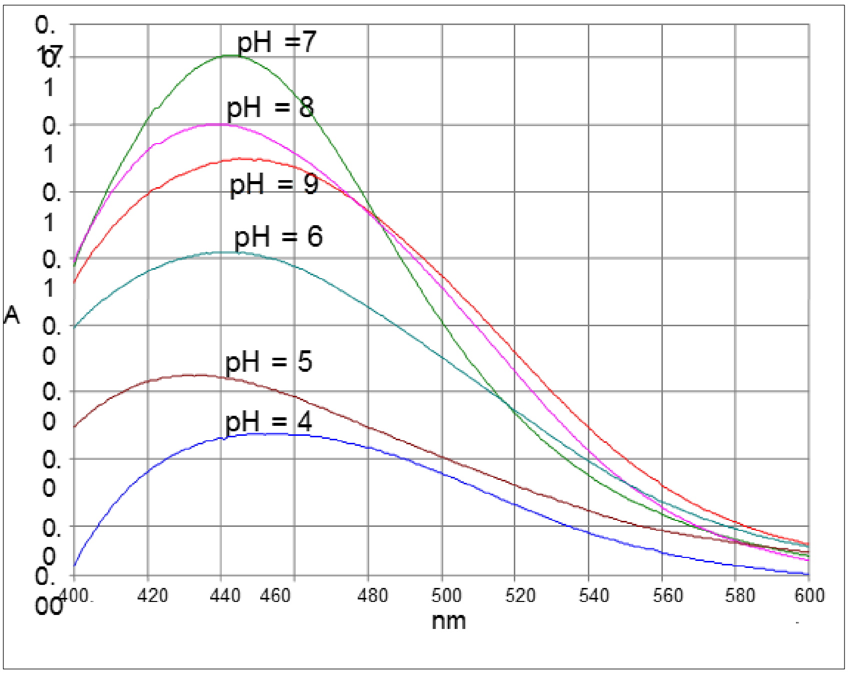

Figure 5 UV spectrum shows effect of pH on the formation of silver nanoparticles

The results of Fig. 5 shows the pH increases from 4 to 7, the absorption intensity values has increased and reached the highest value at pH = 7, meaning that the amount of synthesized silver nanoparticles were well most. However, at pH 8 and 9, the amount of silver nanoparticles was formed too fast, leading to coagulation; silver nanoparticles have large size, which reduces the peak intensity values.

3.3. TEM, EDX, and XRD analysis of silver nanoparticles

TEM image of the produced silver nanoparticles are shown in Fig. 6. The formation of silver nanoparticles as well as their morphological dimensions in the TEM study demonstrated that the average size was from 6.5 nm - 12.9 nm. The shapes of the silver nanoparticles proved to be spherical.

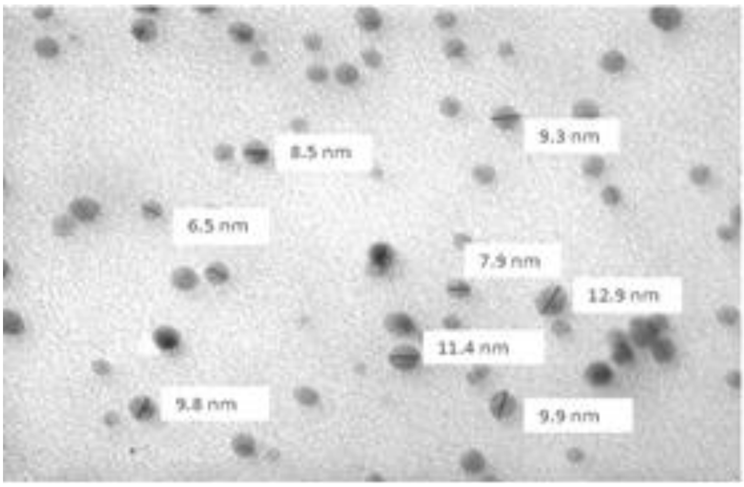

Figure 6 TEM micrograph of silver nanoparticles synthesized by aqueous extract of *Ocimum basilicum* L. leaf.

EDX spectra recorded from the silver nanoparticles were shown in Fig. 7.

From EDX spectra, it is clear that the presence of elemental silver signal of the silver nanoparticles.

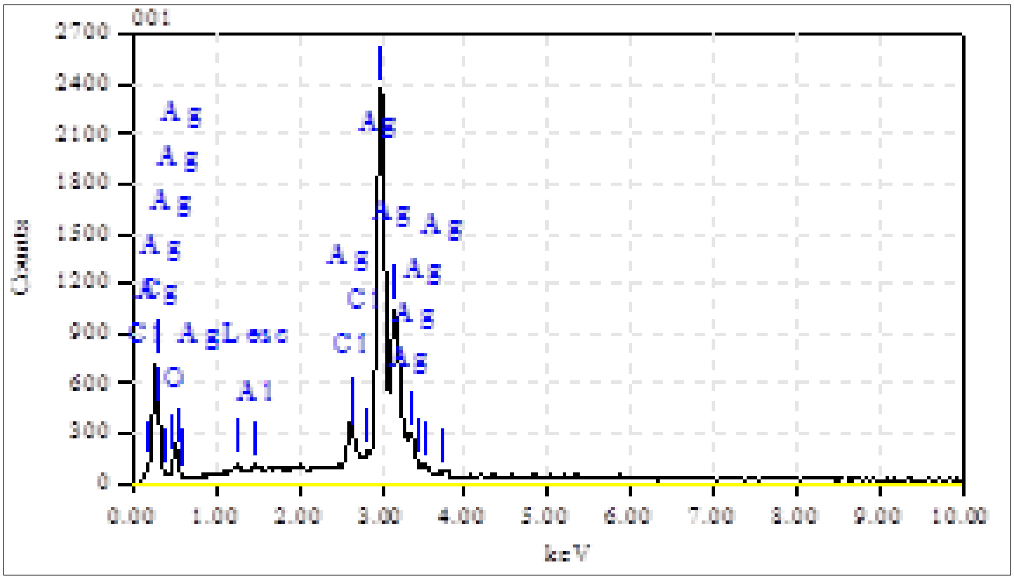

Figure 7 EDX micrograph of silver nanoparticles synthesized by aqueous extract of *Ocimum basilicum* L. leaf**.**

Figure 8 shows the XRD pattern obtained for silver nanoparticles synthesized by *Ocimum basilicum* L. leaf extract. The diffraction peaks at 2θ = 38,13°; 44,49°; 64,56°; 77,6° and 81,6° correspond to the {111}, {200}, {220},{311} and {222} faces of the fcc crystal structure, respectively.

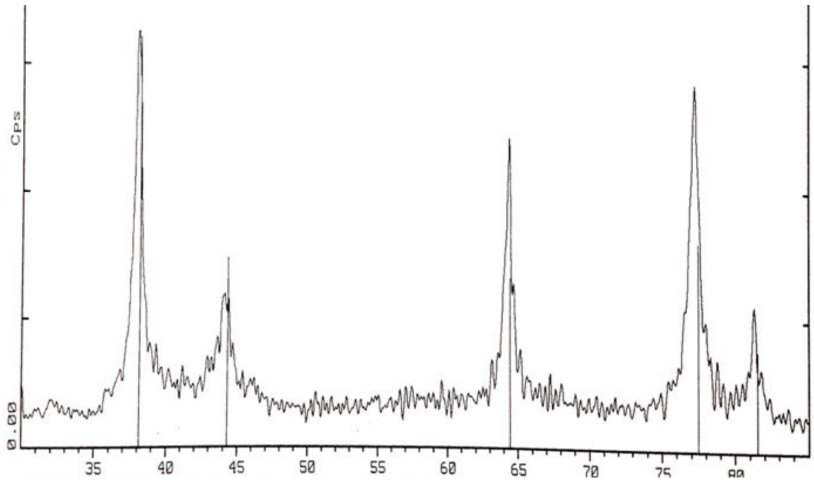

Figure 8 XRD pattern of silver nanoparticles synthesized by aqueous extract of *Ocimum basilicum* L. leaf.

3.4. The photocatalytic activity of the synthesied silver nanoparticles

The photocatalytic activity of the synthesized silver nanoparticles was examined by degradation of methylene blue under sunlight irradiation. Green synthesized silver nanoparticles were effectively degrading the dye nearly 87.65% at 5 h of exposure time.

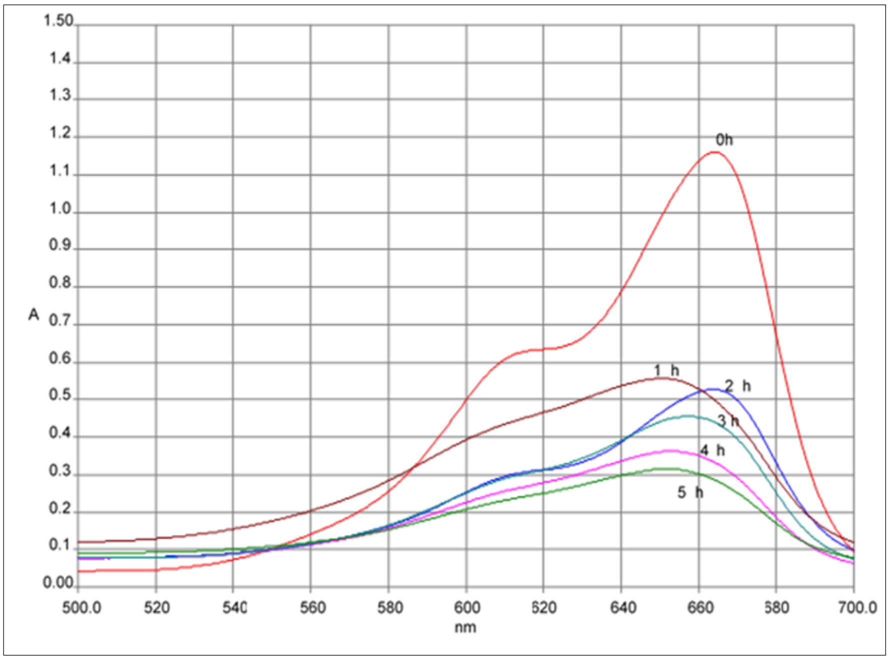

Figure 9 Degradation of MB in presence of Ag –NPs

The obtained results showed that nanosilver had photocatalytic activity for the decomposition of methylene blue, the decomposition process increased with increasing lighting time and achieved an efficiency of 87.65 % after 5 hours of exposure.

The photocatalytic mechanism of silver nanoparticles can be attributed to the fact that under sunlight, photons impact on the surface of silver nanoparticles in colloidal solution, radiating electrons and photogenerated holes. These photogenerated electrons and holes will react with H_2O and O_2 molecules dissolved in the solution to produce OH radicals and oxygen radical anions. These radicals will break down the methylene blue molecules to form simple organics thereby leading to discolouration [13, 14].

$$Ag + h\nu \rightarrow h^+ + e-$$

$$h^+ + H_2O \rightarrow H^+ + OH^{\cdot}$$

$$h^+ + OH- \rightarrow OH^{\cdot}$$

$$e- + O_2 \rightarrow O_2^{\cdot -}$$

$$O_2^{\cdot -} + MB \rightarrow Products$$

$$OH^{\cdot} + MB \rightarrow Products$$

Thus, nano silver synthesized from $AgNO_3$ solution by reducing agent of *Ocimum basilicum* L. leaf extract can act as a stable and effective photocatalyst for the decomposition of methylene blue in the visible light region.

4. Conclusion

The bio-reduction of aqueous Ag^+ ion by the extract of *Ocimum basilicum* L. leaf has been demonstrated. The reduction of Ag^+ ions through *Ocimum basilicum* L. leaf extract leading to the formation of silver nanoparticles of fairly well-defined dimensions. XRD study showed the face-centered cubic lattice of silver nanoparticles. The average crystal size of silver nanoparticles was found to be 6.5 nm - 12.9 nm and an almost spherical shape. Synthesis of silver nanoparticles using green resources like *Ocimum basilicum* L. leaf extract is a better alternative to chemical synthesis, since this green synthesis is pollutant free and eco-friendly. Green synthesized silver nanoparticles were effectively degrading the dye nearly 87.65% at 5 h of exposure time.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

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