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Eco-friendly Biosynthesis of Silver Nanoparticles from Aloe vera Leaves Based on Various Parameters.

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Abstract

In the current study, an ecofriendly and economically very effective method for the biosynthesis of silver nanoparticles (AgNPs) using aqueous extract of Aloe vera leaves has been investigated.

The synthesis of AgNPs was checked by the change of color of the solution from yellow to dark blue or black due to a phenomenon known as surface plasmon resonance. The ability of silver nanoparticles to get effected by various process parameters like volume of Aloe vera leaves extract, concentration of silver nitrate solution, and the total incubation time was checked. The analysis and characterization was done using UV-Visible spectroscopy and SEM-EDX.

The SEM-EDX analysis confirmed the size, shape and formation of the silver nanoparticles. The best conditions needed for the synthesis of AgNPs using Aloe vera leaves extract was found to be 5mM concentration of silver nitrate solution using 15% volume of Aloe vera leaves extract and incubated for 10minutes under the sunlight.

Keywords: Green synthesis, silver nitrate, nanoparticles, process parameters, Aloe vera.

1. Introduction

Nanotechnology is an upcoming branch of science which is trending in recent times due to its high rate of applications in many fields of research. The small size of the synthesized nanoparticles which usually ranges from 1nm to 100nm provides a large volume to surface area ratio (Sharma et al., 2009). The synthesis of nanoparticles can be carried out by biological, chemical or physical methods and by following either bottom up or top down approach. Among the three different methods for the synthesis of nanoparticles the biological method is widely used as following physical or chemical methods will involve presence of toxic reductants and also usage of high energy (Chun-hui et al., 2007).

The biological synthesis of nanoparticles is also known as the green synthesis. This type of nanoparticle synthesis is an environment friendly way and also is an energy efficient method. Green synthesis of nanoparticles can be done from various sources like fungi, bacteria, algae and extracts of plants (Anju et al., 2021). Using and selecting of proper solvent medium is one of the major steps during green synthesis of metal nanoparticles. Also selecting of a good reducing agent and also stabilizing agent which are environment and ecological friendly becomes are extremely important and significant step to be taken into consideration while synthesizing nanoparticles biologically (Iravani et al., 2014).

Biosynthesis of silver nanoparticles effectively by using various types of plant extract is the best, economic and very simple method. This method has plant extracts which contains various biomolecules like sugars, proteins, vitamins, enzymes, acids which help in the nanoparticle synthesis. These biomolecules help in acting as reducing agents and also capping agents in the biological synthesis of various nanoparticles (Mohapatra et al., 2015). The synthesized silver nanoparticles from extracts of plants are also known to show catalytic reduction of dyes namely methylene blue in presence of arsenic (Kundu et al., 2002).

Aloe vera is a widely studied and experimented plant species in various fields of science and technology. This plant species is known to have elements which help to cure diseases of the skin, diseases caused by infection, gastrointestinal ailments, wounds and injuries. It is also known to have very good antioxidant, cytotoxic properties and many more (Akaberi et al., 2016). The vast use of Aloe vera plant in various fields of research and its high rate of applications has made the usage of this plant for synthesizing the silver nanoparticles. Since nanoparticles, mainly silver nanoparticles are the very much in study due to their high stability, easy and quick synthesis and vast variety of applications. Nanoparticles also enhance the quality of living in humans (Gupta and Tejavath, 2019).

The main aim and objective of this experimental work is to biologically produce the silver nanoparticles using aqueous plant extract of Aloe vera leaves and silver nitrate solution. Also to study and check the effect of different process parameters like volume of Aloe vera leaves extract, concentration of silver nitrate solution and incubation time. The nanoparticles are then checked and are characterized by UV-Visible spectroscopy and SEM-EDX.

2. Materials and methodology

2.1. Preparation of aqueous plant extract from Aloe vera leaves

Fresh and green Aloe vera Leaves were collected from the household garden. Then the leaves collected are further washed thoroughly with help of distilled water for multiple times to wash off the dirt, any chemical impurities or minute particles. The washed and cleaned leaves are then cut into very small pieces. From the chopped Aloe vera leaves 10g are taken and then added to 100ml distilled water and this is boiled very well at 80ºC for 10 minutes in a big flask to obtain the extract of Aloe vera leaves. The aqueous Aloe vera leaves extract then filtered with whattman filter paper to get a yellow coloured Aloe vera Extract, to be used for the silver nanoparticles synthesis. (Pattanayak et al., 2013)

2.2. Preparation of various concentrations of silver nitrate solution

The silver nitrate aqueous solution acts and is used as a precursor for the synthesis of silver nanoparticles (AgNPs) from Aloe vera leaves extract. Three different concentration solution of silver nitrate in aqueous solution was prepared. Concentrations of 1 mM , 5 mM and 9 mM were prepared using pure silver nitrate.

2.3. Synthesis of silver nanoparticles from Aloe vera leaves extract

The silver nanoparticles were biosynthesized by adding a well-known volume of Aloe vera leaves extract to its corresponding volume of $AgNO_3$ solution at known molarity in 1:9 ratios respectively. The prepared solution is hand mixed and is allowed to react under the sunlight for duration of 10 minutes. The sample is then repeatedly monitored for the production of silver nanoparticles by checking for the change in colour of prepared sample.

3. To synthesize silver nanoparticles based on various process parameters

3.1. Effect of various silver nitrate concentrations on the synthesis of AgNPs

Three 50ml conical flasks are taken to which silver nitrate solution (1 mm, 5 mm and 9 mm concentration separately) and Aloe vera leaves extract is added in 9:1 ratio respectively. The prepared solutions are hand mixed and incubated under sunlight. The color of the prepared sample changes from pale yellow to darkish grey/black representing formation of the nanoparticles. The samples are then analyzed using UV-Visible Spectroscopy at 540nm (Awwad et al., 2013).

3.2. Effect of Aloe vera Leaves Extract concentration on the synthesis of AgNPs

The Aloe vera leaves extract of different volume ratio (5%, 10%, 15%) was added and mixed with the best molarity of $AgNO_3$ aqueous solution. A 1ml, 2ml and 3ml of Aloe vera leaves extract was added to 19ml, 18ml and 17ml of $agno_3$ solution. The prepared solution was incubated under the sunlight, until the color of the mixture changes to dark grey/black. After the color change the mixtures are analyzed individually under UV-Vis Spectroscopy at 540nm.

3.3. Effect of sunlight exposure timings on the synthesis of AgNPs

The observed best volume of the plant leaves extract was mixed with the observed best molarity of $AgNO_3$ solution in a small conical flask. The prepared mixture is hand mixed and was incubated under the sunlight for different time interval (5, 10 and 15 minutes) for each sample, until the color of the mixture changes. After the color change the mixtures are analyzed individually under UV-Vis Spectroscopy at 540nm.

4. Characterization of the synthesized AV-AGNPs

A sample of around 2ml of the synthesized AgNPs produced using best molarity $AgNO_3$, best volume plant leaves extract, and incubated under best sunlight exposure time, was taken under room temperature and the UV-Visible Spectroscopy analysis was conducted on Spectroquant Prove 600. The variation between the metal particles and the leaf separate and their response of AgNPs was observed by UV-Visible Spectroscopy with changing frequency from 200nm to 700nm.

The AV-AgNPs morphology and its elemental composition were analyzed using SEM-EDX (JEOLJSM-7800F0) under various magnifications. (Galatage et al., 2021)

5. Results and Discussion

5.1 Biosynthesis of silver nanoparticles from Aloe vera leaves extract

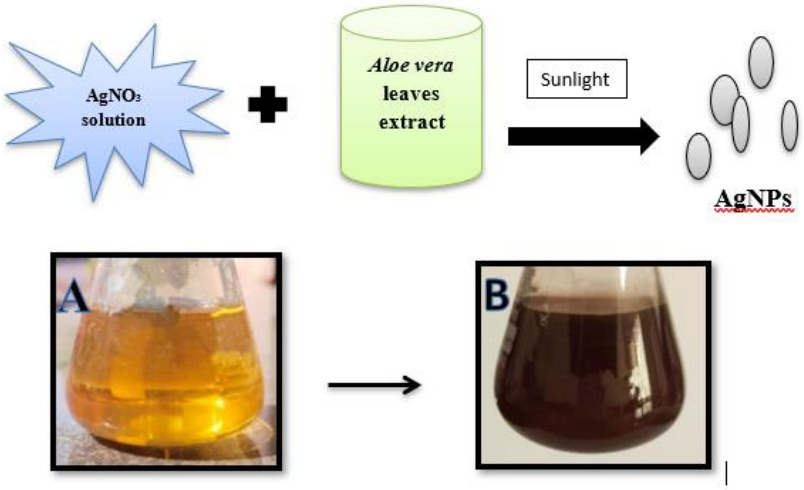

Figure 1: The biosynthesis of silver nanoparticles from Aloe vera Leaves Extract and using Silver Nitrate solution.
A: Initial solution formed (leaf extract + $AgNO_3$ solution) which is yellow in color
B: The change in the color to dark grey/black indicating the formation of silver nanoparticles
Initially, when the Aloe vera Leaves extract is added to the prepared silver nitrate solution and mixed well the color of the sample becomes bright yellow in nature. After the incubation under the sunlight, the color of the sample changes to dark grey/blackish. This change in the color of the solution indicates and confirms that the biological synthesis of the silver nanoparticles ($AgNO_3$) has occurred.

5.2. Effect of various process parameters on AgNPs synthesis

5.2.1. Effect of various silver nitrate ($AgNO_3$) concentration on the synthesis of AgNPs

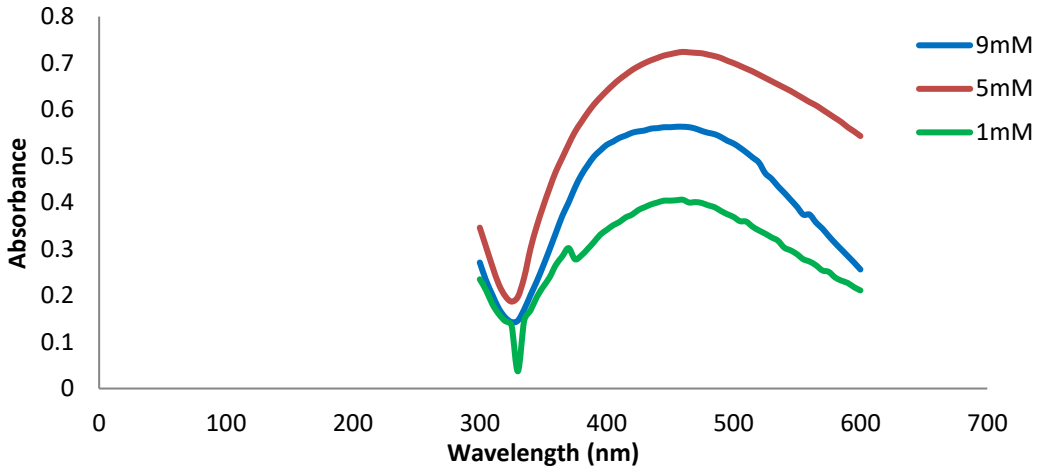

Figure 2: The UV-Visible Spectroscopy of the AV-AgNPs at various silver nitrate concentrations (1mM, 5mM and 9mM)
A gradual increase in the absorbance peak was observed between 350-550 nm for 1 mM, 5mM and 9mM $AgNO_3$ concentrations.
For all the different silver nitrate concentrations 1mM, 5mM and 9mM the highest absorbance peak was seen at 460nm. The 5mM silver nitrate solution displayed higher absorbance of 0.724 and broadening of the band at 460nm due to increase in silver nitrate particle size. At 1mM concentration the rate of AV-AgNPs formation was found to be slow therefore showing weaker absorbance.

5.2.2. Effect of Aloe vera Leaves Extract concentration on the synthesis of AgNPs

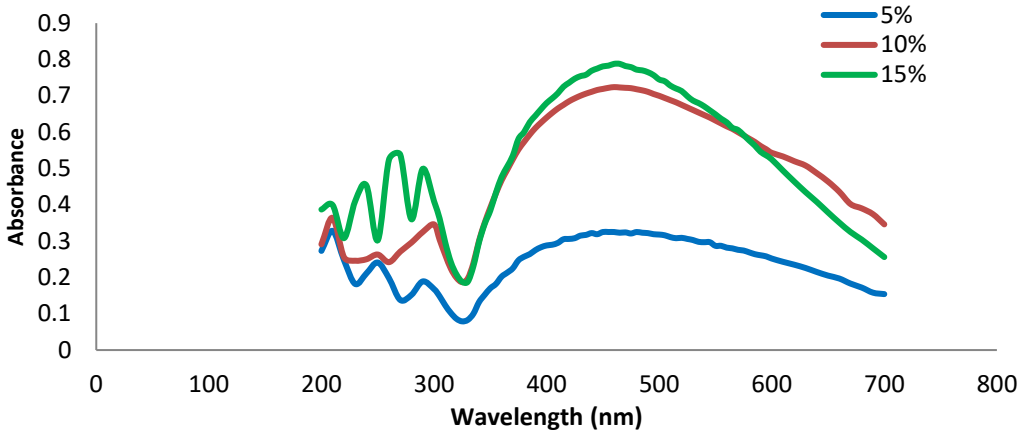

Figure 3: The UV-Visible spectroscopy of AV-AgNPs when Aloe vera leaves extract of different volume ratio (5%, 10%, 15%) was added to known volume and best molarity of $AgNO_3$.

The change in the rate of silver nanoparticles formation and their absorbance with increase in volume of plant extract is due to the availability of various types functional groups present in the aqueous extracts of plants. From the UV-Visible spectroscopic analysis, it is observed that as aqueous Aloe vera extract volume ratio increased the absorbance peak of the synthesized silver nanoparticles also increased. From the plotted graph it was analyzed that 5% Aloe vera extract volume showed the lowest absorbance whereas the 15% Aloe vera Extract volume showed the highest absorbance peak at 460nm due to more formation of silver nanoparticles. The 15% Aloe Vera leaves extract showed an absorbance of 0.788 at 460nm, which is higher than that of 10% (0.724) and 5% (0.325) respectively. This indicates that 15% Aloe vera extract volume when added to the best observed molarity of silver nitrate solution (5mM concentration) synthesized best silver nanoparticles.

5.2.3. Effect of sunlight exposure time on the synthesis of AgNPs

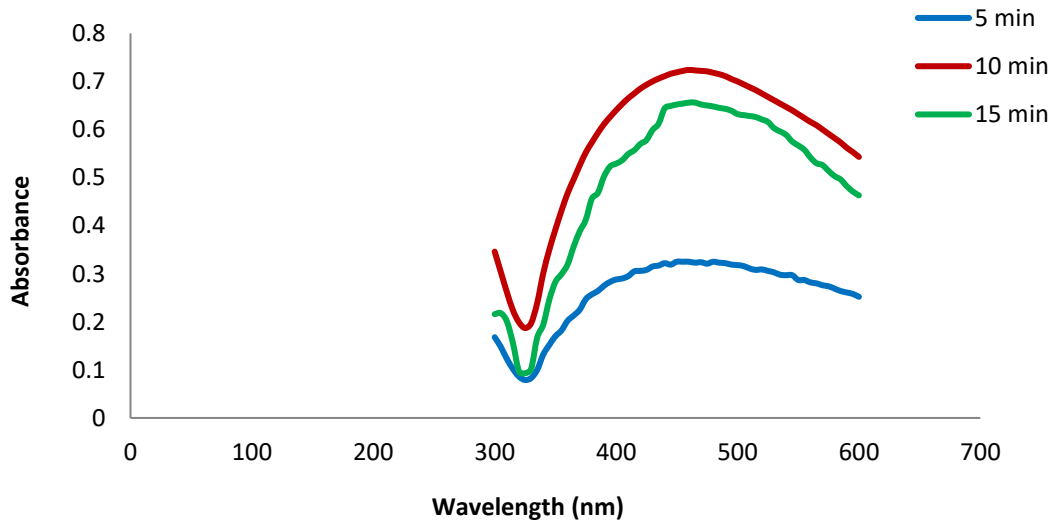

Figure 4: The UV-Vis spectroscopy when best observed volume of plant leaves extract was mixed with the best observed molarity of $AgNO_3$ solution and incubated under the sunlight at different time interval (5, 10 and 15 minutes)

From UV-Vis spectroscopic analysis, at 5 minutes a very small absorbance peak was formed. At 10 minutes of exposure the absorbance peak was the maximum of 0.724 and a sharp peak was observed at 460nm. At 15 minutes of sunlight exposure the surface plasmon resonance band gets broadened and the absorbance peak gets decreased to 0.656. Therefore, the suitable limit of sunlight exposure of 10 minutes will yield best silver nanoparticles.

Reduction mechanism of silver nitrate to produce the silver nanoparticles is possibly due to the presence of these metabolites in the aqueous solution of Aloe vera leaf extract. When 5mM silver nitrate solution was added to 15% volume ratio of Aloe vera leaves extract and incubated under the sunlight for 10 minutes there was a change in the color which was seen from pale yellow to dark grey/ black. This confirms the formation of silver nanoparticles as the silver ions starts get reduced due to the effect of agitation and sunlight and formation of Ag+ complex. This color change shows the formation of Ag nanoparticles.

6.3 Characterization of the synthesized AV-AGNPs

Scanning Electron Microscopy is also known as SEM is an analysis technique used for the characterization and study of nanoparticles and their structures.

The signals received from electron sample interactions give information regarding sample surface texture, chemical composition.

The Ag nanoparticle SEM analysis result is shown in figure 5. The average particle size observed of Ag nanoparticles was found and estimated to be around 30nm at 100nm magnification. EDX analysis was also done to understand and check the elemental composition of the silver nanoparticles. EDX analysis revealed an evident sharp peak at 1.2keV, 1.3keV and 2.5keV for carbon, oxygen and silver respectively confirming the presence of silver nanoparticles (AV-AgNPs)

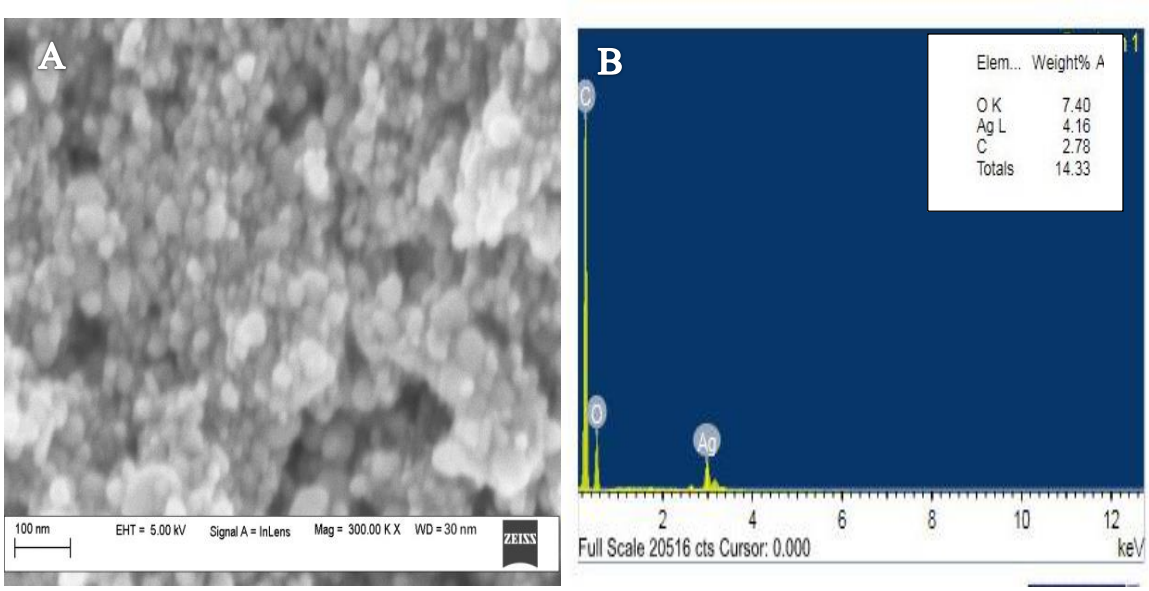

Figure 5: A) SEM image at 100nm magnification.
B) EDX graph displaying the elemental composition

Conclusion

Silver nanoparticles and their applications are increasing tremendously in each and every fields of health, food technology, personal care and multiple other industries due to their very unique and highly applicable physical and chemical properties.

In this study, silver nanoparticles where successfully synthesized under various process parameters from Aloe vera (L.) leaves extract by following green synthesis method. Various parameters and limitations play a major role in efficient biosynthesis of AV-AgNPs. The synthesized silver nanoparticles where analyzed using UV-Visible spectroscopy and SEM-EDX.

With just very minimum uncovered mechanism of the present study, there are still many fields yet to be unfolded. In the coming future years of research there is a wide scope for detailed investigations of AgNPs in the field of agriculture, drug discovery and many more.

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