

Research Article

Synthesis and Evaluation of *Helianthus annuus* Silver Nanoparticles

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Abstract

The increasing prevalence of antibiotic-resistant bacteria necessitates the exploration of novel antimicrobial agents. Silver nanoparticles (AgNPs) have emerged as promising candidates due to their broad-spectrum antimicrobial properties. This study aimed to synthesize and characterize silver nanoparticles using a green synthesis approach employing *Helianthus annuus* (sunflower) extract and to evaluate their antibacterial activity against selected bacterial strains. The formation of AgNPs was initially indicated by a visible color change from light yellow to brown in the reaction medium. The nanoparticles obtained were evaluated using UV, FTIR, Zeta Sizer and SEM analysis. The UV-Vis spectrum of reaction medium for all concentrations displayed an emission peak at 347.5 nm, which corresponded to the absorbance of silver nanoparticles (300 to 500 nm) and showed well dispersed nanoparticles in the aqueous solution without aggregation in UV-Vis absorption spectrum. The zeta sizer showed a particle size of 70.37 nm with a polydispersity index of 0.382. The greatest antibacterial activity of Synthesized Silver nanoparticles was observed against the *Pseudomonas aeruginosa* with an inhibition zone diameter (IZD) of 20 ± 0.12 mm followed by *Escherichia coli* (IZD of 19 ± 0.12 mm), *Bacillus subtilis* (IZD of 14 ± 0.06 mm and lastly *Staphylococcus aureus* with inhibition zone diameter of 12 ± 0.06 mm. The results of the antimicrobial studies conducted on the synthesized *H. annuus* nanoparticle showed promising activity against both gram-positive and gram-negative bacteria, suggesting their potential application in the biomedical field as an antimicrobial agent.

Keywords

Helianthus annuus, Green Synthesis, Antimicrobial, Nanoparticles

1. Introduction

Nanotechnology is a field of science concerned with the manipulation and creation of nanoparticles, which have at least one or two dimensions within 100 nm or less. [1, 2]

These nano-scaled particles have unique properties that distinguish them from their larger counterparts, including a large surface area to volume ratio that results in significant bio-

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chemical and catalytic activity. [3] Nanoparticles have a wide range of applications in areas such as drug delivery, biomedical science, gene delivery, chemical industries, optics, mechanics, and catalysis, with silver nanoparticles being particularly noteworthy for their antibacterial and anti-inflammatory effects. [4, 5] Despite their widespread use, the exact mechanisms behind the formation of silver nanoparticles are not fully understood. [6] While traditional methods rely on physical and chemical approaches involving toxic substances and high energy, there is increasing interest in biological methods that produce more biologically compatible nanoparticles. [7] Recent studies have focused on the synthesis of silver nanoparticles through biological means. The biological method offers nanoparticles with high yield and stability compared to the conventional physical and chemical approach. [8]

Synthesis of silver nanoparticles (AgNPs) has been an active research field in recent years due to their unique physicochemical properties and potential applications in various fields such as medicine, catalysis, and electronics. The development of green and sustainable methods for the synthesis of AgNPs has also gained attention in the research community.

Several methods have been reported for the synthesis of AgNPs, including chemical reduction, photochemical reduction, and biological methods. Chemical reduction involves the use of chemical reducing agents such as sodium borohydride, hydrazine, and citrate to reduce silver ions to form AgNPs. Photochemical reduction utilizes light as the reducing agent to convert silver ions to AgNPs. Biological methods involve the use of microorganisms such as bacteria and fungi or plant extracts to synthesize AgNPs.

Recent studies have focused on the development of green and sustainable methods for the synthesis of AgNPs, using plant extracts as reducing and stabilizing agents. These methods have been shown to be efficient, eco-friendly, and cost-effective.

Among the various metallic nanoparticles, silver nanoparticles (AgNPs) have been widely explored for their unique physical and chemical properties and their potential applications in various fields such as catalysis, electronics, and medicine. In addition, the antibacterial properties of AgNPs have been extensively studied due to their potential use in developing antimicrobial agents against drug-resistant bacteria.

Several studies have reported the green synthesis of AgNPs using various plant extracts such as neem, aloe vera, and green tea, among others. These plant extracts contain bioactive compounds such as phenols, flavonoids, and alkaloids that can reduce silver ions to AgNPs and stabilize them. Moreover, the use of plant extracts in green synthesis can enhance the antibacterial activity of AgNPs due to the presence of these bioactive compounds. [9]

Researchers also have investigated the antibacterial properties of green-synthesized AgNPs against various pathogenic

bacteria, including *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*, among others. The antibacterial activity of AgNPs is attributed to their ability to interact with bacterial cell membranes and disrupt their structural integrity, leading to cell death. [10]

The increasing incidence of antibiotic resistance in pathogenic bacteria has spurred research into alternative approaches to combat bacterial infections. One such approach is the use of silver nanoparticles (AgNPs) due to their broad-spectrum antimicrobial properties. [11] Plant-mediated synthesis of AgNPs has gained popularity in recent years as an eco-friendly and cost-effective approach. [12] In this study, we aimed to synthesize AgNPs using leaf extract of *Helianthus annuus* and evaluate their antibacterial activity against four strains of bacteria.

1.1. Nanoparticles

Nanoparticles (NPs) are tiny particles with sizes ranging from 1 to 100 nm in diameter. They have unique physicochemical properties, such as high surface area to volume ratio, that make them useful in various applications such as catalysis, drug delivery, and electronic devices. [13]

Physical methods involve the breaking down of larger particles into smaller ones, such as milling, lithography, and laser ablation. [13] Among the physical methods, milling is a widely used technique for producing nanoparticles. It involves the use of mechanical force to break down larger particles into smaller ones. [14] Laser ablation, on the other hand, involves the use of a laser to vaporize a target material, which then condenses to form nanoparticles. [15]

1.1.1. Chemical Method

Chemical methods, on the other hand, involve the use of chemical reactions to form nanoparticles, including sol-gel, co-precipitation, and hydrothermal synthesis. [16] Chemical methods, such as the sol-gel method, involve the hydrolysis and condensation of metal alkoxides to form nanoparticles. [16] Co-precipitation is another chemical method used to synthesize nanoparticles, which involves the simultaneous precipitation of metal ions by the addition of a precipitating agent. [16] Hydrothermal synthesis is a method that involves the use of high-pressure and high-temperature conditions to synthesize nanoparticles. [17]

1.1.2. Biological Method (Green Synthesis)

Biological methods also called green synthesis utilize living organisms, such as bacteria, fungi, and plants, to synthesize nanoparticles through the reduction of metal ions. [13] Biological methods, such as the use of bacteria to synthesize nanoparticles, involve the use of specific bacterial strains to reduce metal ions into nanoparticles. [13] Similarly, fungi and plants can also be used to synthesize nanoparticles through the reduction of metal ions. [13]

Green chemistry also known as biological synthesis has

been developed as an alternative to the use of environmentally harmful processes and products due to the serious consequences that the world is facing and the limited available time to find effective solutions. [18]

1.2. Green Synthesis of Silver Nanoparticles (AgNP) Using Plant Extract

The primary requirement of green synthesis of AgNPs is silver metal ion solution and a reducing biological agent. In most of the cases reducing agents or other constituents present in the cells acts as stabilizing and capping agents, so there is no need of adding capping and stabilizing agents from outside.

Several studies have reported the synthesis of AgNPs using various plant extracts. Gardea-Torresdey et al. illustrated that the first approach of using plants for the synthesis of metallic NPs was done by using Alfalfa sprouts, which was the first description about the synthesis of Ag-NPs using living plant system. [19] Alfalfa roots have the ability to absorb Ag from agar medium and voyage them into shoots of plant in same oxidation state. In shoots, these Ag atoms arranged themselves to produce Ag-NPs.

Singh et al. used leaf extract of *Azadirachta indica* to synthesize AgNPs. The extract was mixed with silver nitrate solution, and the formation of AgNPs was confirmed by UV-Vis spectroscopy. [10]

The spherical Ag-NPs have been synthesized using the extract of *Abutilon indicum* and also studied their high antimicrobial activity against *S. typhi*, *E. coli*, *S. aureus*, and *B. subtilis* microorganism by Ashokkumar et al. [20]

According to a study by Nakkala et al., green-synthesized AgNPs using the leaf extract of *Plectranthus amboinicus* showed potent antibacterial activity against *S. aureus*, *E. coli*, and *P. aeruginosa*, with minimum inhibitory concentrations ranging from 5 to 15 µg/mL. The authors attributed the antibacterial activity to the presence of phenolic and flavonoid compounds in the extract. [21]

Another study by Patel et al. reported the green synthesis of AgNPs using the fruit extract of *Emblica officinalis* and their antibacterial activity against *Escherichia coli* and *Staphylococcus aureus*. The authors found that the green-synthesized AgNPs showed higher antibacterial activity than the chemically synthesized AgNPs, with minimum inhibitory concentrations ranging from 10 to 30 µg/mL. The authors suggested that the higher antibacterial activity of green-synthesized AgNPs could be attributed to the presence of bioactive compounds such as tannins and flavonoids in the extract. [22]

There are no much studies that have accounted for the synthesis of AgNP from leaf extract of *Helianthus annuus*. This research work aims to synthesize AgNPs using leaf extract of *Helianthus annuus* and evaluate their antibacterial activity.

Overall, the green synthesis of AgNPs using plant extracts is a promising approach to develop eco-friendly and sustain-

able antimicrobial agents. Further research is needed to explore the potential applications of green-synthesized AgNPs in various fields and their mechanism of action against pathogenic bacteria.

1.3. *Helianthus annuus*: (Common Name: Sunflower)

The Sunflower is a native of North America. [23] The sunflower is the core of medicinal values which is used as food and medicine worldwide. *H. annuus* is cultivated basically for its seeds, which give the world's second most important source of edible oil. The seed oil, shoots, and herb tincture are employing for anti-inflammatory, anti-oxidant, antitumor, antiasthmatic, antigen, antipyretic, astringent, antihypoglycemic effect, cathartic, diuretic, stimulant, vermifuge, antimicrobial activities and vulnerary purposes, other parts of the plant, the petioles and young flowers are use as savory delicacies. The use of yellow petals as coloring agents gives its new eventual in cosmetic industry. [24]

1.4. Medicinal Uses of Sunflower Plant

Several recent studies have investigated the antibacterial properties of *Helianthus annuus* leaf extract. For example, a study by Gul et al. found that *Helianthus annuus* leaf extract exhibited significant antibacterial activity against various Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*. [25] Other medicinal uses of *Helianthus annuus* are briefly discussed as follows:

Anti-inflammatory and analgesic activity: A study by Daburkar et al. reported that *Helianthus annuus* leaf extract showed significant anti-inflammatory and analgesic activities in animal models. The study suggested that the plant's flavonoids and phenolic compounds were responsible for these effects. [26]

1. **Antidiabetic activity:** *Helianthus annuus* has also been shown to have antidiabetic properties. A study by Singh et al. reported that the methanolic extract of *Helianthus annuus* seeds significantly lowered blood glucose levels in diabetic rats. The study attributed this effect to the presence of flavonoids, alkaloids, and saponins in the extract. [27]
2. **Anticancer activity:** Several studies have investigated the anticancer properties of *Helianthus annuus*. A study by Sehrawat et al. reported that the methanolic extract of *Helianthus annuus* seeds showed anticancer activity against human breast cancer cells. The study attributed this effect to the presence of phenolic compounds and flavonoids in the extract. [28]
3. **Wound healing activity:** *Helianthus annuus* has also been reported to have wound healing properties. A study by Pashaei-Asl et al. reported that the topical application of *Helianthus annuus* oil on skin wounds in rats signif-

icantly increased the rate of wound closure. The study suggested that the oil's antioxidant and anti-inflammatory properties were responsible for the effect. [29]

2. Materials and Method

2.1. Chemicals and Reagents

The chemicals used were as follows: Silver nitrate (AgNO_3) (Blulx laboratories; 99.9%, MW = 169.87 g/mol). Other chemicals used in this study were of analytical grade.

2.2. Methods

2.2.1. Plant Collection and Preparation

Fresh leaves of *Helianthus annuus* were used for the biosynthesis and the stabilization of AgNPs. Fresh plant leaves of *Helianthus annuus* were collected from wild plants growing freely in Faculty of Pharmacy, University of Uyo medicinal plant farm in Uyo, Akwa Ibom State. The plant was identified and authenticated in the Department of Pharmacognosy and Natural Medicine, University of Uyo. The plant leaves were thoroughly washed with tap water to rinse off dusts and other unwanted materials accumulated on the leaves from their natural environment. The dust free leaves were size reduced using a knife, then allowed to dry under shade in the Pharmacognosy and Natural Medicine Laboratory for 24 hours.

2.2.2. Extraction Procedure

20 g of the dried size-reduced plant material was kept in 500 extraction bottle and 250 mL of distilled water was added. The bottle was covered and kept under laboratory temperature for 72 hours to macerate. Then, the extract was filtered using cotton wool followed by Whatman no 1 filter paper. The extract obtained was kept for the nanoparticle synthesis.

2.2.3. Preparations of AgNO_3 Solution

Three (3) concentrations of Silver Nitrate (AgNO_3) (0.1%w/v, 0.25%w/v, and 0.5%w/v) were prepared by dissolving 0.1 g, 0.25 g and 0.5 g of silver nitrate powder in distilled water in 3 separate 100 mL beaker and making the volume up to 100 mL respectively.

2.2.4. Synthesis of Silver Nanoparticles using Aqueous Extract of *Helianthus annuus*

This was carried out according to method of Jackson *et al*, 2019 with few modifications. [30] 5 ml of each concentrated AgNO_3 solution was measure into separate 25 ml measuring cylinder respectively. 10 ml syringe was use to collect 10 ml of the plant extract.

To each of the concentrations, the plant extract in the 10

ml syringe was added in a dropwismanner while stirring with a magnetic stirrer until a colour change (from colourless to reddish brown) of the reaction mixture is observed. The colour change indicates the formation of Ag-NP. The volume of extract that reacts with each concentration of AgNO_3 to form Ag-NP was noted. The Ag-NP formed was freeze dried (Gallenkamp, England) and subjected to further analysis.

2.2.5. UV - vis Spectroscopy to Determine Surface Plasmon Resonance for Silver Nanoparticles

The synthesis of the AgNPs was confirmed by measuring the absorbance of the colloidal mixture by using a UV-Visible spectrophotometer (UNICO 2100, China) in the range of 200 to 500 nm of the light wavelength.

2.2.6. Antimicrobial Studies of Silver nitrate (AgNO_3), *Helianthus annuus* leaf extracts and Plant Extract-Silver Nanoparticle (AgNP)

The antibacterial activity of optimized batch plant extract nanoparticles, leaf extract of *Helianthus annuus* and AgNO_3 was determined by measuring their respective inhibition zone diameter at different concentration against four test bacteria.

(i). Microorganisms Used

Four test microorganisms (two-gram negative and two gram positive) were used in this study; obtained from Pharmaceutical Microbiology laboratory in the Department of Pharmaceutical Microbiology, University of Uyo, Nigeria. Gram-positive species used were *Staphylococcus aureus* and *Bacillus subtilis* while *Escherichia coli* and *Psuedomonas aeruginosa*, were the Gram-negative species. There were identified by their characteristics size and shape on specific media, followed by biochemical tests.

(ii). Plate Preparation

The Disc method was used for the antibacterial testing. Four plates were inoculated with respective bacteria and 20 ml of molten nutrient agar was aseptically poured over the bacterial suspension in the petri dish, which was made to rotate on the table for proper mixing then, plates were allow to solidify under the laboratory temperature. Thereafter, four holes were bored on each plate using a 4 mm sterile cork borer.

Three (3) holes were then respectively filled with different concentrations (0.1%, 0.2% and 5%) of the synthesized silver nanoparticles while the fourth hole was filled with 0.1 ml of 25 mg/ml of Moxifloxacin which served as a control for the test. The plates were allowed on the laboratory bench for 1 hour at room temperature to ensure effective diffusion after which incubation was done at 37 °C for 24 hours. Observations for each plate was done, and the inhibition zone diameter was recorded.

The same procedure as above was performed for the different concentrations of AgNO_3 and the leaf extract of *Helianthus annuus*.

(iii). Preparation of Leaf Extract concentration

A two-fold serial dilution of *Helianthus annuus* extract was done. 50 mg of the extract was used to obtain a stock solution of 50 mg/ml. Thereafter, concentrations of 25 mg/ml and 12.5 mg/ml were obtained; these three concentrations (50 mg/ml, 25 mg/ml and 12.5 mg/ml) were used for testing the antibacterial activity of the extract.

2.3. Data Analysis

IBM SPSS Statistics version 25 software was used to analyze the zones of inhibition data of silver nanoparticles against test organisms. Level of significance among means was compared at $p \leq 0.05$ and data was investigated using one-way ANOV Analysis.

3. Results and Discussion

3.1. Colour Change and UV - Vis Spectroscopy

The aqueous solution of silver nitrate changed from colourless to pale yellow on reaction with the *Helianthus annuus* leaf extract within 30 seconds and to reddish brown colour within 1 mins to 10 mins indicating the presence of silver nanoparticles which was further confirmed by UV vis spectroscopy. The silver nanoparticles exhibited dark brown colour due to excitation of plasmon resonance on particle surface. This colour change to dark black is as a result of increased strength and multiplication of silver nanoparticles. The UV-Vis spectrum of reaction medium for all concentrations displayed an emission peak at 347.5 nm, which corresponded to the absorbance of silver nanoparticles (300 to 500 nm) (ref) and showed well dispersed nanoparticles in the aqueous solution without aggregation in UV-Vis absorption spectrum.

Table 1. Formation of Nanoparticles.

S/N	Conc. of AgNO_3 (%W/V)	Extract Volume Used (ml)	Time of AgNP Formation (Sec)	Maximum Wavelength of Absorption (nm)
1	0.10	2.0	3	316.5
2	0.25	2.5	5	347.5
3	0.50	3.0	10	347.5
4	1.00	0.60	5	347.5
5	2.5	0.40	5	347.5

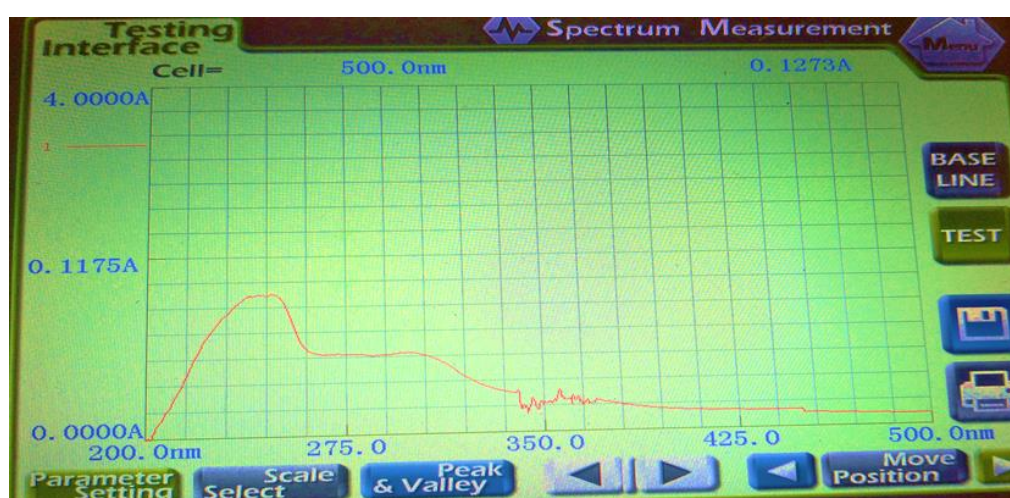


Figure 1. Asorption band of silver nanoparticles of *Helianthus annus*.

Size Distribution Report by Volume

v2.2



Sample Details

Sample Name: 22ma 0.5% AgNO₃

SOP Name: (Zetasizer).sop

General Notes: Average result created from record number(s): 33 34 35

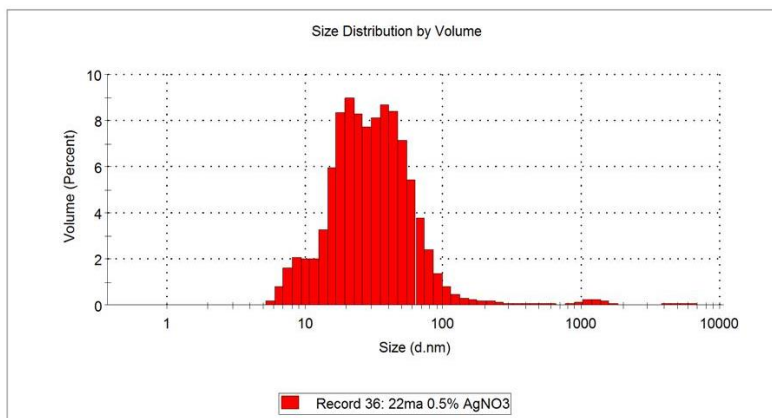
File Name: Analysis.dts	Dispersant Name: Water
Record Number: 36	Dispersant RI: 1.330
Material RI: 1.59	Viscosity (cP): 0.5476
Material Absorbance: 0.010	Measurement Date and Time: 26 May 2023 12:46:27

System

Temperature (°C): 25.0	Duration Used (s): 60
Count Rate (kcps): 395.6	Measurement Position (mm): 4.65
Cell Description: Disposable sizing cuvette	Attenuator: 7

Results

	Size (d.n...)	% Volume:	St Dev (d.n...
Z-Average (d.nm): 70.37	Peak 1: 9.231	7.9	1.774
Pdl: 0.382	Peak 2: 20.68	40.5	4.927
Intercept: 0.944	Peak 3: 52.06	50.6	41.37
Result quality Good			



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Zetasizer Ver. 7.01
Serial Number: N/A

File name: Analysis
Record Number: 36
26 May 2023 12:49:04

Figure 2. Particle Size of Nanoparticle.

3.2. Particle Size and Polydispersity of Nanoparticles

The particle size of the synthesized nanoparticles was 70.37 nm, while the polydispersity index was 0.386, indicating the formation of an ideal silver nanoparticles with uniform dispersion.

3.3. Antibacterial Properties

Silver nanoparticles prepared by the reduction of silver ions using Sunflower (*Helianthus annuus*) leaf extracts as reductants as well as stabilizing agent was tested for their antibacterial activities against four (4) pathogenic bacteria; two Gram negative bacteria (*Escherichia coli* and *Pseudomonas*

aeruginosa) and two Gram positive bacteria (*Staphylococcus aureus* and *Bacillus subtilis*) using the Disk diffusion method. The antibacterial activities of the synthesized AgNP, Silver Nitrate (AgNO_3) and the *Helianthus annuus* leaf extract was observed at different concentrations, using Mofloxacin (25 mg/ml) as the control for the test. 0.1 ml of different concen-

trations (0.1 mg/ml, 0.25 mg/ml and 0.5 mg/ml) of test samples was added to appropriately labelled wells of agar plates which was inoculated with the test bacteria and incubated for 24 hours. The table below shows the Inhibition Zone diameter of samples at different concentrations.

Table 2. Zone of inhibition (mm) of sun-flower (*Helianthus annuus*) nanoparticles, Concentrations of Silver Nitrate and Leaf extract of Sun-flower.

Sample	Test Organisms	Mean $\pm$ Standard Deviation of Inhibition Zone Diameter (mm) at Different Concentrations		
		0.1% W/V	0.25% W/V	0.5% W/V
SFNP	<i>E. coli</i>	14	15	19 $\pm$ 0.12
	<i>P. aeruginosa</i>	12	15	20 $\pm$ 0.12
	<i>S. aureus</i>	10	10	12 $\pm$ 0.06
	<i>B. subtilis</i>	8	10	14 $\pm$ 0.06
AgNO_3	<i>E. coli</i>	14	11	16 $\pm$ 0.29
	<i>P. aeruginosa</i>	10	16	16 $\pm$ 0.23
	<i>S. aureus</i>	15	15	16 $\pm$ 0.12
	<i>B. subtilis</i>	8	10	12 $\pm$ 0.06

Sample	Test Organisms	Mean $\pm$ Standard Deviation of Inhibition Zone Diameter (mm) at Different Concentrations		
		12.5 mg/ml	25 mg/ml	50 mg/ml
SF	<i>E. coli</i>	7	10	12 $\pm$ 0.06
	<i>P. aeruginosa</i>	12	12	14 $\pm$ 0.06
	<i>S. aureus</i>	15	16	20 $\pm$ 0.06
	<i>B. subtilis</i>	9	12	14 $\pm$ 0.12

Note: Values are mean of three replicates $\pm$ standard deviation. Values are statistically significant ($p < 0.05$) at 95% confidence interval. SF = sun-flower (*Helianthus annuus*); SFNP = Sunflower leaf extract nanoparticle; AgNO_3 = Silver Nitrate Solution.

There was a significant difference at $p < 0.05$ among the antibacterial activities of the *Helianthus annuus* leaf extract nanoparticles, silver nitrate and the *Helianthus annuus* extract.

The highest antibacterial activity of Synthesized Silver nanoparticles was observed against the *P. aeruginosa* with an inhibition zone diameter of 20 ± 0.12 mm followed by *E. coli* with inhibition zone diameter of 19 ± 0.12 mm, *B. subtilis* with inhibition diameter of 14 ± 0.06 mm and *S. aureus* with inhibition zone diameter of 12 ± 0.06 mm.

The synthesized silver nanoparticles of *Helianthus annuus* exhibited good antibacterial activity against gram negative bacteria *Escherichia coli* and *Pseudomonas aeruginosa* as well as gram positive bacteria *Staphylococcus aureus* and

Bacillus subtilis. The inhibition of bacterial growth at various applied concentrations of the test solutions are significant indicating that silver nanoparticles exhibit good biocidal activity against gram-positive and gram-negative bacteria.

The result shows that silver nanoparticles synthesized via green route are promising antimicrobial agent against pathogens and have a great potential in biomedical applications. [31]

The antibacterial activity of *Helianthus annuus* plant extract was also studied, as 50 mg/ml of the plant extract had a significant different ($p < 0.05$) greatest activity against *Staphylococcus aureus* with inhibition diameter of 20 ± 0.06 mm. There was no significant different ($p < 0.05$) between the activity of the leaf extract of *Helianthus annuus* against *P. ae-*

ruginosa and *B. subtilis* with inhibition zone diameter of 14 ± 0.06 mm and 14 ± 0.12 mm respectively. The extract was observed to have the least antibacterial activity against *E. coli* with inhibition zone diameter of 12 ± 0.06 mm.

In accordance with the above studies, Özkaya et al. had examined the effect of sunflower leaf extract on *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*) using the agar well diffusion method. The results showed that the extract had a significant inhibitory effect on both bacterial strains, with *E. coli* showing the highest sensitivity. [32]

Another study by Zengin et al. (2021) evaluated the antibacterial activity of sunflower leaf extract against *Bacillus subtilis* (*B. subtilis*) and *Pseudomonas aeruginosa* (*P. aeruginosa*) using the disc diffusion method. The findings indicated that the extract had a notable inhibitory effect on both bacterial strains, with *B. subtilis* being more sensitive than *P. aeruginosa*. [33]

Pure plant extract was seen to have greater antibacterial activity against *Staphylococcus aureus* with a significant ($p < 0.05$) inhibition diameter of 20 ± 0.06 mm than with the Plant Nanoparticle and Silver Nitrate (AgNO_3).

Overall, these studies suggest that sunflower leaf extract has potential antibacterial properties against a range of bacterial strains, although further research is needed to determine the mechanisms behind its antibacterial activity and to explore its potential applications in medicine and industry.

4. Conclusion and Recommendation

4.1. Conclusion

The synthesis and evaluation of *Helianthus annuus* silver nanoparticles have been successfully carried out in this research work. The green synthesis approach utilized in this study is a promising and eco-friendly method for synthesizing silver nanoparticles. The synthesized nanoparticle was characterized using UV-Vis spectroscopy analytical technique, which confirmed the nature by its absorption at 374.5 nm. The results of the antimicrobial studies conducted on the synthesized *H. annuus* leaf extract nanoparticle showed promising activity against both gram-positive and gram-negative bacteria, suggesting their potential application in the biomedical field as an antimicrobial agent. Also, the leaf extract of *Helianthus annuus* showed a good antibacterial activity against both gram-positive and gram-negative bacteria. The gives room for its application as herbal medicine in the treatment of bacterial infection. Moreover, Silver Nanoparticles are biologically compatible as confirmed by other research studies; they are non-toxic to human cells, which indicates their safety for use in biomedical applications. In summary, this research work provides a valuable contribution to the field of nanotechnology and opens up avenues for further research in the development of green and biocompatible nanoparticles for various applications.

4.2. Recommendation

1. In the course of the research, it was observed that *H. annuus* leaf extract possesses a broad-spectrum antibacterial activity at a concentration of 50 mg/ml. As such, further studies should be carried out to ascertain the standard of using *Helianthus annuus* leaf extract for the treatment of bacterial infection.
2. The Plant nanoparticle demonstrated effective activity against test bacteria, which was attributed to a combination of the leaf extract constituents and the silver metal. In order to combat the growing issue of Antibiotic resistance in the management of bacterial diseases, it is recommended to formulate antibiotics using the plant nanoparticle.
3. The synthesis of nanoparticles should be accomplished through the biological method, specifically using plant extracts. This method is preferable due to its lower cost, non-toxicity, and time efficiency, as the required materials are readily available and easily accessible, allowing for easy scale-up productions.

Abbreviations

AgNPs	Silver Nanoparticles
NPs	Nanoparticles
AgNO_3	Silver Nitrate

Conflicts of Interest

The authors declare no conflicts of interest.

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