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(RESEARCH ARTICLE)

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Green synthesis and characterization of silver nanoparticles using banana peel extract and their biological activity against representative microorganism

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Abstract

In recent science Nanotechnology is a burning field for the researchers. Nanotechnology Deals with the Nanoparticles having a size of 1-100 nm in one dimension used significantly concerning medical chemistry, atomic physics, and all other known fields. The present study reports an eco-friendly, cost efficient, rapid and easy method for synthesis of silver nanoparticles using banana peel extract (BPE) as a reducing and capping agent. The different factor affecting silver reduction was investigated. The conditions were silver nitrate (1.75 mM), BPE (20.4 mg dry weight), pH (4.5) and incubation time (72 h). BPE can reduces silver ions into silver nanoparticles within 5 min after heating the reaction mixture (40-100C) as indicated by the developed reddish brown color. The biosynthetical NPs were characterized using UV, FTIR. The UV-Vis spectrum of silver nanoparticles revealed a characteristic surface plasmon resonance (SPR) peak at 420,345,545 nm. Silver nanoparticles were characterized. . Fourier transform infrared spectroscopy affirmed the role of BPE as a reducing and capping agent of silver ions. Silver nanoparticles showed effective antimicrobial activity against representative pathogens of bacteria and used as antifungal agents. The synthesized nanoparticles showed synergistic effect with levofloxacin antibiotic, the antimicrobial activity and show plant growth promoting activity.

Keywords: Agricultural waste; Silver nanoparticles; Characterization; Antimicrobial activity; Antifungal activity; Plant growth promoting activity

1. Introduction

Nanotechnology is emerging as a rapidly growing field with its application in science and technology (Albrecht et al. 2006). Nanobiotechnology is a field that interrelates both biological sciences and nanotechnology. It provides a platform for the development of ecofriendly and the green synthesis of nanoparticles with the help of biological sources like plants and microorganisms (Guangquan et al. 2012). Nanoparticles exhibit completely new or improved properties based on specific characteristics, such as size, distribution and morphology. A number of approaches are available for the synthesis of silver nanoparticles: Facile method (Nidhi et al. 2009), thermal decomposition of silver compounds (Navaladian et al. 2007), electrochemical (Starowicz et al. 2006), sonochemical (Easu et al. 2010), microwave- assisted process (Sreeram et al. 2008) and recently via green chemistry route (Begum et al. 2009). Unfortunately, many of the nanoparticle synthesis or production methods involve the use of hazardous chemicals, low material conversions, high energy requirements, difficult and wasteful purifications. Therefore, there is a growing need to develop environmentally friendly processes for nanoparticle synthesis without using toxic chemicals. Biosynthetic methods employing either microorganisms or plant extracts have emerged as a simple and viable alternative to chemical synthetic procedures and physical methods (Shanmugavadivu et al. 2014). Synthesis of silver nanoparticles was extensively studied employing chemical and physical methods, but the development of reliable technology to produce nanoparticles is an important aspect of nanotechnology (Natarajan et al., 2010). Synthesis of nanoparticles by physical and chemical methods may have considerable environmental defect, technically laborious and economically expensive (Gopinath et al., 2012). The

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biological methods, using microorganisms and enzymes, have been suggested as possible eco-friendly alternatives (Mohanpuria, Rana, & Yadav, 2008). The plants or peel extract, which act as reducing and capping agents for nanoparticles synthesis, are more advantageous over other biological processes (Valli & Vaseeharan, 2012), because they eliminate the elaborated process of culturing and maintaining of the cell, and can also be scaled up for large-scale nanoparticle synthesis (Saxena, Tripathi, Zafar, & Singh, 2012). Moreover, plant-mediated nanoparticles synthesis is preferred because it is cost-effective, environmentally friendly, a single-step method for biosynthesis process and safe for human therapeutic use (Kumar & Yadav, 2009). Different parts of plant materials such as extracts (MubarakAli, Thajuddin, Jeganathan, & Gunasekaran, 2011), fruit (Prathna, Chandrasekaran, Raichur, & Mukherjee, 2011), bark (Satishkumar et al., 2009), fruit peels (Bankar, Joshi, Kumar, & Zinjarde, 2010), root (Ahmad et al., 2010) and callus (Nabikhan, Kandasamy, Raj, & Alikunhi, 2010) have been studied so far for the synthesis of silver, gold, platinum and titanium nanoparticles in different sizes and shapes (Gopinath et al., 2012). Bananas are consumed all over the world, after consumption of the pulp, the peels are generally discarded (Bankar et al., 2010). A few applications of banana peels discussed in the literature include (i) exploitation for their medicinal properties (Parmar & Kar, 2008); (ii) in ethanol fermentation (Tewari, Marwaha, & Rupal, 1986); (iii) application as a substrate for generating fungal biomass (Essien, Akpan, & Essien, 2005); (iv) use in the production of laccase (Osma, Toca, Rodriguez Couto, 2007); and (v) utilization as a biosorbent for heavy metal removal (Annadurai, Juang, & Lee, 2003). In addition, banana peels that are inherently rich in polymers such as lignin, cellulose, hemicellulose and pectins (Emaga, Andrianaivo, Wathelet, Tchango, & Paquot, 2007) could be used in the synthesis of silver nanoparticles. The present study aims to synthesize silver nanoparticles by a green biological route, using an extract derived from banana peel waste, and characterization of the synthesized nanoparticles utilizing UV-visible spectroscopy and Fourier transform infrared spectroscopy (FT-IR) analysis. Besides, their antimicrobial activity against representatives of human pathogenic microorganisms and antifungal as well as plant growth promoting activity was investigated.

2. Material and methods

2.1. Collection of sample and material used

Banana fruits were purchased from local market (ale, pune, India) at yellow stage. Silver nitrate (Molecular weight 169.87) was taken form (Samarth institute pharmacy, pune, india).

2.2. Microorganism

Representative microorganisms of Gram-positive bacteria (Bacillus subtilis; local isolate, Staphylococcus aureus; ATCC 6538) and Gram-negative bacteria (Pseudomonas aeruginosa; ATCC 9027, P. aeruginosa; local isolate, Escherichia coli; ATCC 8739) as well as the mould *Aspergillus nigar* were used to evaluate the antimicrobial activity, antifungal activity of prepared silver nanoparticles. Bacterial strains were maintained on nutrient agar slants and the mould was maintained on potato-dextrose agar slants at 40 ^{0}C

2.3. Banana peel extract (BPE) preparation

Banana peels were washed and boiled in distilled water for 30 min at 90 ^{0}C. The peels (100 g) were crushed in 100 ml distilled water and the extract was filtered through a cheese cloth to remove insoluble fractions and macromolecules. This filtrate was treated with equal volume of chilled acetone and the resultant precipitate was centrifuged at 1000 rpm for 5 min. This precipitate was resuspended in distilled water and stored in refrigerator 400 C for further studies. This extract was used as reducing as well as stabilizing agent. Haytham, (2015).

2.4. Synthesis of silver nanoparticles using BPE

1mM Silver nitrate solutions were prepared by using a standard formula. Solution of1mM Ag ions was prepared by dissolving 0.017 g of AgNo3 in 100 ml of deionized water. The effect of the silver was determined by different AgNo3 concentration. In this study 3 different type of synthesizing were done i.e.

- 5ml of banana peel extract and 2.5 ml of 1mMAgNo3 solution (Half volume)
- 5ml of banana peel extract and 5ml of 1mM AgNo3 solution (equal volume),
- 5ml of banana peel extract and 10ml of 1mM AgNo3 solution (double volume). Banana peel extract (BPE) were used as a control (AgNo3 free sample).The prepared all samples were incubated at dark room temperature for 24-48 hrs.

2.5. Characterization of silver nanoparticles Visual Identification and UV–Visible analysis

The preliminary detection of AgNPs was carried out by visual observation of the color changes of the reaction solutions. These changes were attributed to the excitation of surface plasmon resonance (SPR) in the metal nanoparticles. Typically, UV–visible absorption is used to investigate SPR. The UV-vis spectroscopy measurements (300nm-600nm) were recorded on a UV visible LAB JUNCTION spectrophotometer (Susan k Thomas).

2.6. FTIR

To determine the functional groups of banana peel extract and predict their role in the synthesis of silver nanoparticles, Fourier Transform Infrared spectroscopy analysis was performed. A Perkin–Elmer Frontier FT-IR spectrometer with Universal Single bounce Diamond ATR attachment was used to analyse samples over a range starting at 400cm-1 up to a maximum of 4000 cm-1 in steps of 4 cm-1. FTIR analysis For FTIR measurements, the air- dried powder samples were grinded with KBr pellets and analyzed in the diffuse reflectance mode operating at a resolution of 4 cm−1

2.7. Antimicrobial activity of synthesized silver nanoparticles by well diffusion method

The antimicrobial activity of silver nanoparticles was investigated utilizing agar well diffusion assay Nanda and Saravanan (2009). The tested microorganisms were swabbed uniformly on nutrient agar- or sabouraud dextrose agar plates using sterile cotton swab, then wells of 6- mm diameter were made using sterile well borer. Twenty microliter of silver nanoparticles solutions with various concentration (2.5, 5, 10) poured into the corresponding well. Control sample (BPE) was used to assess the antimicrobial activity of BPE. The plates were incubated at 37 C for 24 or 48 h for the bacterial and yeast cultures, respectively. The diameter of inhibition zone was measured. To determine the combined effect of silver nanoparticles and the standard antibiotic(levofloxacin), 15 ml of 0.5 mM antibiotic solution was mixed with 15 ml of silver nanoparticles solution (2.5 ,5,10), and placed into the corresponding well of agar plate, inoculated with the tested microorganisms. The plates were incubated at 37 0C for24

h. Zone of inhibition was observed and compared with that of levofloxacin, AgNO3 solution and silver nanoparticles individually.

2.8. Anti-fungal activity

2.8.1. Test organism

Aspergillus nigar

2.9. Fungal growth and experimental conditions

The fungal culture was obtained from Samarth institute of pharmacy, India. The fungus, *Aspergillus nigar* grown in sterile Potato Dextrose Broth and incubated under optimum growth condition at 37 ^{0}C for 24hr. The anti-microbial activity of AgNP was tested on Sterile Potato Dextrose agar plates, using agar Well Diffusion method. The growth inhibition zones formed around wells on culture plates at different temperatures viz room temperature and 37 ^{0}C keeping same concentration of AgNP were measured after 2-days incubation period and expressed in millimeter.

2.10. Well diffusion method

The pure culture of Aspergillus flavus were subcultured on nutrient agar medium in petri dishes.

0.1ml fungal culture was poured homogeneously onto the individual plates and was spread plated.

Wells of 0.5 mm diameter were bored on Potato Dextrose agar plate using gel puncture.

Using micropipette, 10µl AgNP was added to each well.

Three replicates of experiments were carried out.

2.11. Studying plant growth promoting activity

2.11.1. Seeds used

Triticum aestivum (wheat) I was selected from local market.

2.12. Three variations with control were selected for Tray Assay as follows:

- Seeds soaked in water
- Seeds soaked in infectious *Aspergillus nigar* solution
- pouring synthesized nanopartical solution at 70 ^{0}C

2.13. Tray Assay

- Some Seeds were soaked in water for 30min.
- Soaked seeds were the infectious *Aspergillus niger* solution.
- Placed both seed in tray in two portion half contain normal seed, other infectious.
- Plants were watered regularly.
- Plants were then observed for the length of root and shoot and their ramification after 2 week.

3. Results and discussion

3.1. Banana peel extract (BPE) preparation

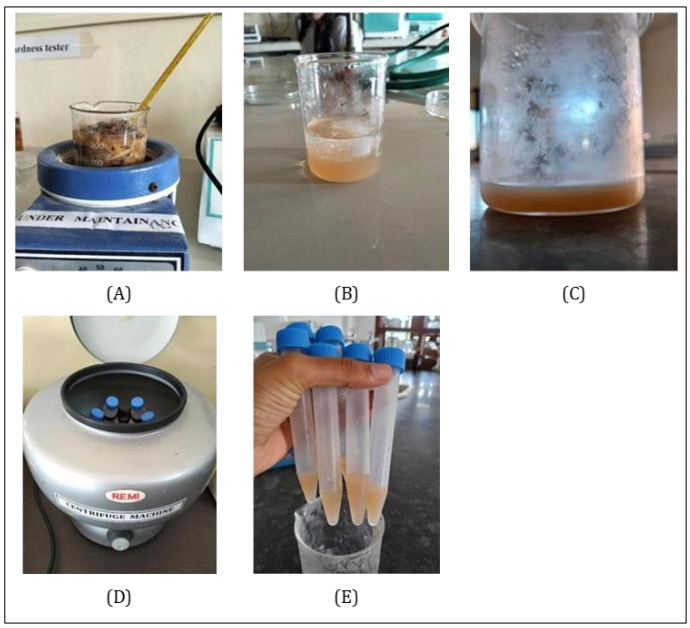

Figure 1 Preparation of BPE (A) Boil banana peel at 90°c (B) Addition of equal amounts of acetone (D)Centrifugation of filtrate (E) Centrifuged filtrate(C) BPE Extract

3.2. Synthesis of silver nanoparticles using BPE

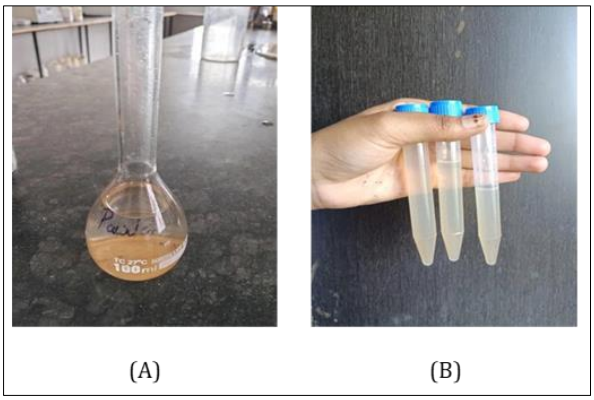

Figure 2 Synthesis of silver nanoparticles using BPE (A) Silver nitrate stock solution (B) Addition BPE & AgNO3

3.3. Characterization of silver nanoparticles Visual Identification and UV–Visible analysis

Nanocomposites were synthesized from BPE in various concentrations when comparatively with different variations were shown in fig no 4, fig no 5, fig no 6 This study revealed that, the composites turned reddish dark brown in colour, after the incubation of 48hrs it indicates that the nanoparticles were formed. This was confirmed by characterization study. Alvakonda (2016), reported, natural synthesis of silver nanoparticles by banana peel extract shows formation of silver nanoparticles was predicted by the color change from yellowish brown to reddish brown. Kokila et al., (2015) also reported, biosynthesis of silver nanoparticles from banana peel extract shows the reduction of silver ions takes place 70 0 c at 24hr the color change of the solution brownish-orange color was observed after incubation, this indicating the formation of silver nanoparticles. In UV-Visible study it has been found that the synthesized AgNPs is equal volume of sample and AgNO3extract Plasmon peak an observed at nearly 345,340,335,330,325,315,310,305,300 nm in size respectively for the synthesized sample. Synthesized AgNPs is half volume of sample and AgNO3 extract Plasmon peak an observed at nearly 410,415,420 It was clearly indicate the presence of silver nanocomposites. The synthesized AgNPs is double volume of sample and AgNO3 extract Plasmon peak an observed at nearly 545,540,535,530,525,515,510,505,500 There is small increase in the intensity of SPR band from 2.5 ml to 10ml. However, when the concentration is increased further, there is a decrease in the intensity of SPR band.

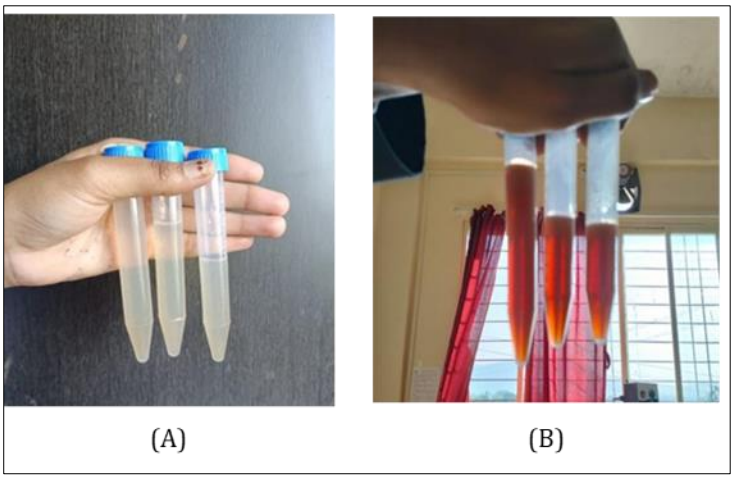

Figure 3 Peel Extract (A) before bioreduction and (B) after synthesis to AgNP, 24-h at 700c after addingAgNO3 solution (1 Mm)

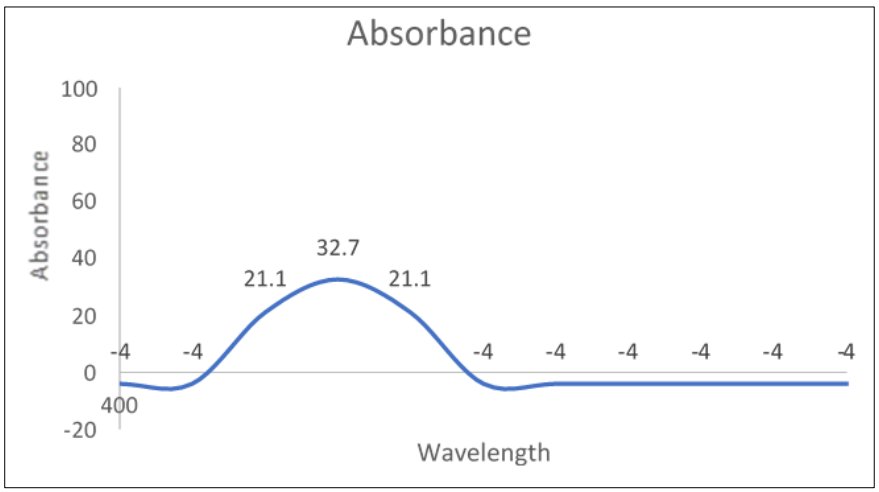

Figure 4 UV-Vis absorption spectra of – The mixture of BPE with Half volume of AgNO3 and were kept for 24 hr at 70 ^{0}C.

The synthesis of AgNPs was detected by the colour change from pale yellow to dark brown (shown in fig 3). After 24 hr reaction mixtures were scanned using UV-Vis spectrophotometer.

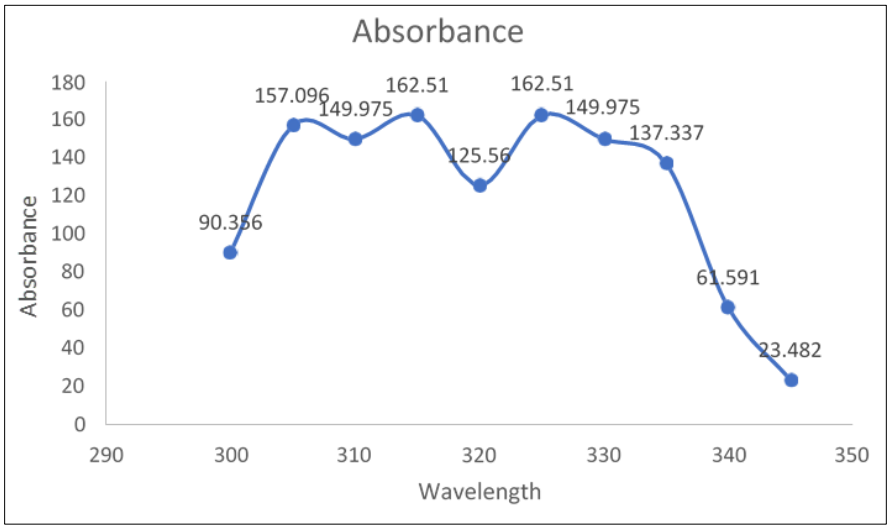

Figure 5 UV-Vis absorption spectra of – The mixture of BPE with equal volume of AgNO3 and were kept for 24 hr at 70 ^{0}C

The synthesis of AgNPs was detected by the colour change from pale yellow to dark brown (shown in fig 3). After 24 hr reaction mixtures were scanned using UV-Vis spectrophotometer.

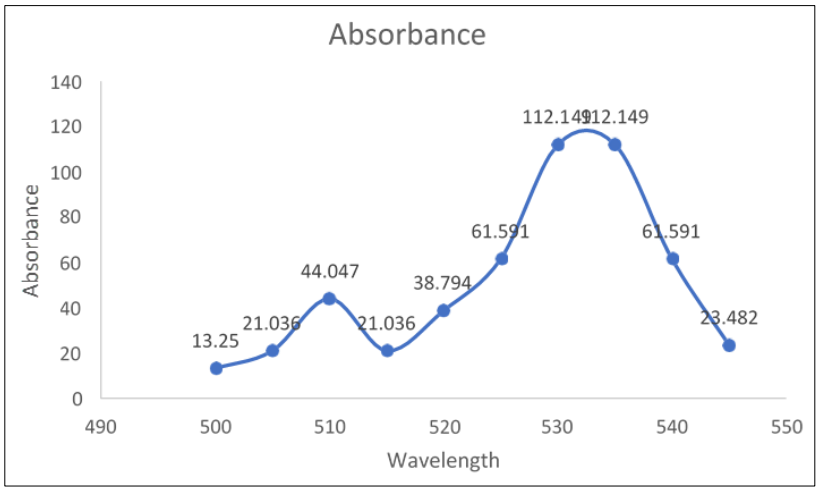

Figure 6 UV-Vis absorption spectra of – The mixture of BPE with Double volume of AgNO3 and were kept for 24 hr at 70 ^{0}C

The synthesis of AgNPs was detected by the colour change from pale yellow to dark brown (shown in fig 3). After 24 hr reaction mixtures were scanned using UV-Vis spectrophotometer

3.3.1. Effect of incubation period

The intensity of the reddish brown color was directly proportional to the incubation time of reaction mixture. The rate of silver ions reduction was going slowly during the first 45 min, as indicated by the low absorbance values at wavelength 420 nm and color intensity .Tangible increase in the absorbance together with color intensity was revealed after longer time periods up to 96 h as shown in Fig No. 8 The maximum reduction of silver ions was obtained after 72 h. This increase in absorbance along with color intensity could be ascribed to an increase in the number of silver nanoparticles with time Bhainsa & D'Souza, 2006). It has been reported that the time required for complete reduction of the metal ions during biosynthesis of metal nanoparticles from 24 to 124 h (Korbekandi, Iravani, & Abbasi, 2009).

The rapid generation of nanoparticles was owing to the excellent reducing potential of the active components of banana peel extract and their polymeric stabilization within a narrow size spectrum.

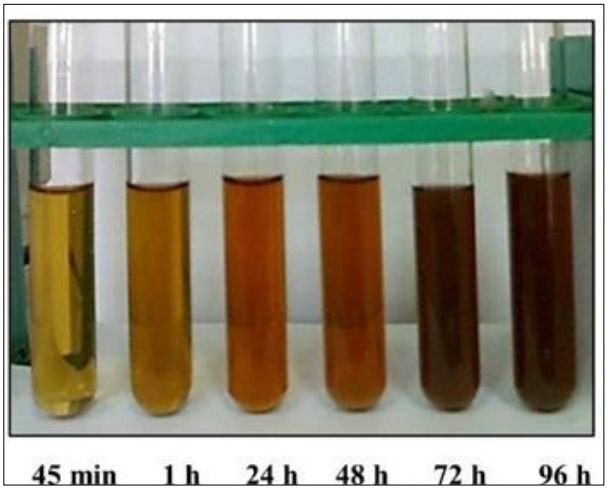

Figure 7 Effect of reaction time on absorbance intensity of synthesized silver nanoparticle and colour intensity of the reaction mixture

3.3.2. Effect of Temperature

The temperature also affected the process of silver reduction. Reaction mixtures incubated at 30, and 50 °C showed light reddish brown color and less pronounced SPR peaks. At higher incubation temperature (70, 80 and 100 °C) dark reddish brown color and more intense SPR peaks were revealed. At room temperature (30 °C) the color change took 10 min to develop, while by heating the reaction mixtures at 40-100 °Cthe reduction process was faster and the reddish brown color was developed within 5 min. The maximum SPR peak intensity was detected at 70 °C. The increase in reaction temperature, UV spectra show sharp narrow peaks at lower wavelength region (300,410,500 nm at 70 °C), which indicate the formation of smaller nanoparticles, whereas, at lower reaction temperature, the peaks observed at higher wavelength regions (434,440,485, nm at 30 °C) which clearly indicates increase in silver nanoparticles size. It is a well-known fact that when the temperature is increased, the reactants are consumed rapidly leading to the formation of smaller nanoparticles (Park, Joo,Kwon, Jang, & Hyeon, 2007). . Similarly, the size of silver nanoparticles was decreased with an increase in incubation temperature

3.3.3. FTIR

To determine the functional groups on banana peel extract and predict their role in the synthesis of silver nanoparticles, FTIR analysis was performed. The band intensities in different regions of the spectrum for the CBPE and AgNPs(before and after reaction with silver nitrate, respectively) were analyzed and are shown in Fig. 4. There was a shift in the following peaks: 3,500-3,200,3,400- 3,200, 3,300- 3,030, 3,300- 3,030, 2,935-2,915, 1,680- 1,620 , 1,680- 1,630, 1,640-1,620, 1,650- 1590, 1,650 – 1550, 1,650 – 1,590, 1,650- 1,550, 1,385-1,380 1,650-1,550,1,615-1,580, 1,385- 1,380, The peak above 1500 is fingerprint region .(Asep Bayu Dani Nandiyanto,2019).

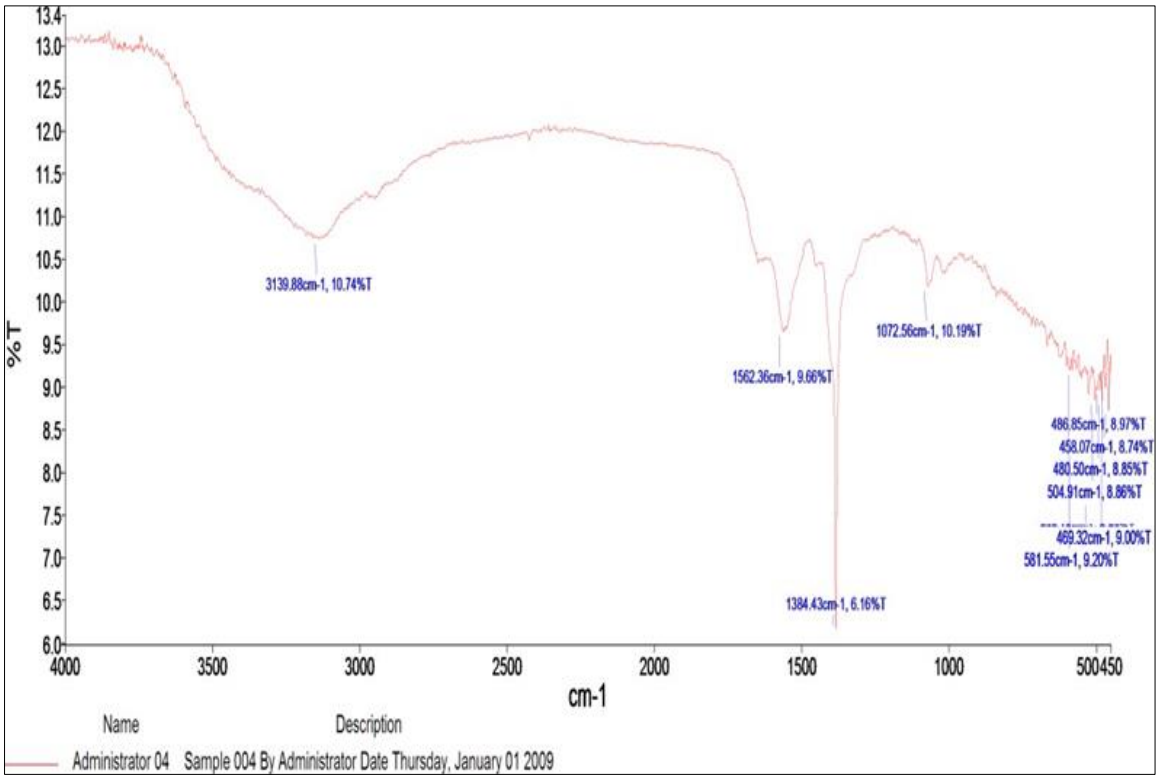

Figure 8 FTIR absorption spectra of – The mixture of BPE with half volume of AgNO3 and were kept for 24 hr at 70 ^{0}C

The synthesis of AgNPs functional group was detected After drying the particle were scanned using Fourier transform infrared spectroscopy

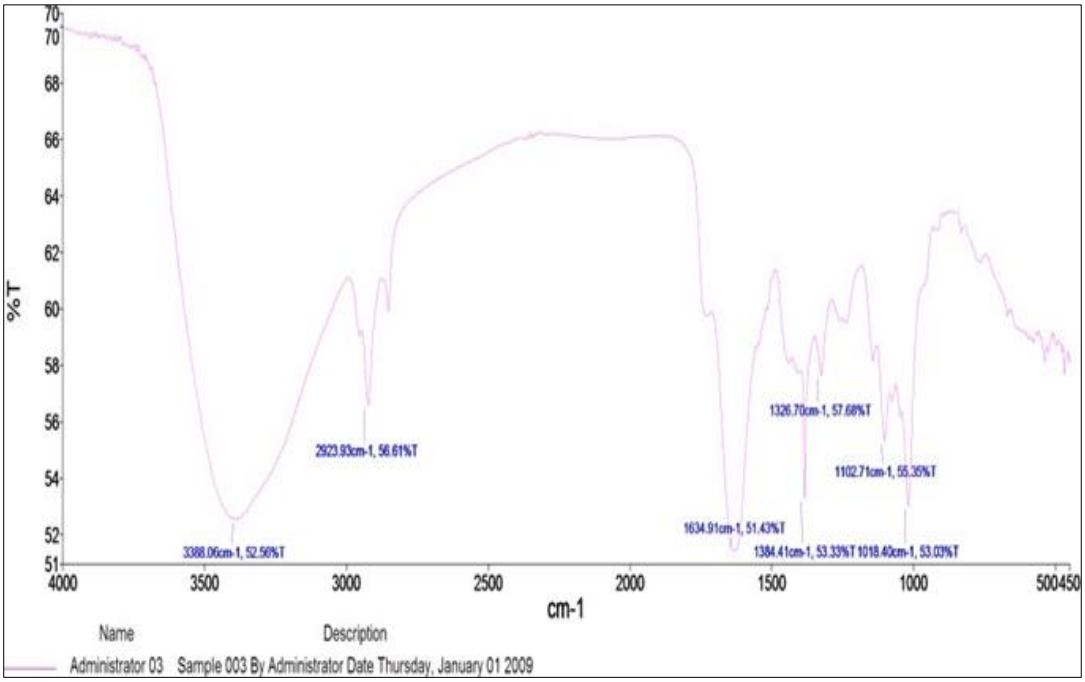

Figure 9 FTIR absorption spectra of – The mixture of BPE with Equal volume of AgNO3 and were kept for 24 hr at 70 ^{0}C

The synthesis of AgNPs functional group was detected .After drying the particle were scanned using Fourier transform infrared spectroscopy

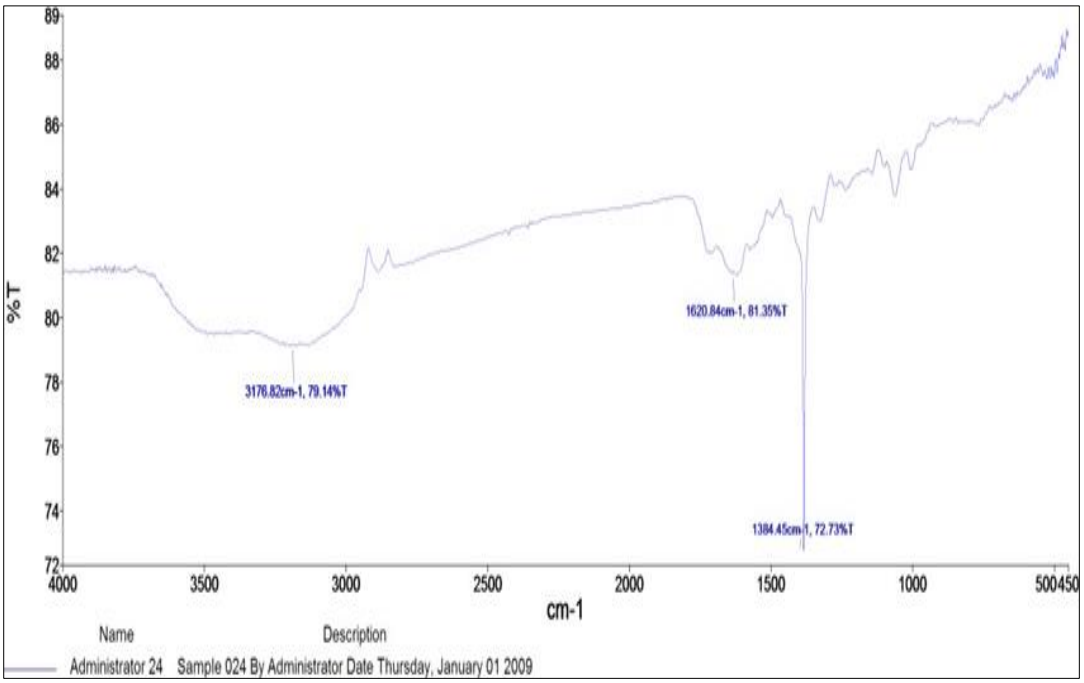

Figure 10 FTIR absorption spectra of – The mixture of BPE with Double volume of AgNO3 and were kept for 24 hr at 70 ^{0}C

The synthesis of AgNPs functional group was detected .After drying the particle were scanned using Fourier transform infrared spectroscopy.

Table 1 FTIR Absorption spectra of AgNP

Sr. No.	Reading Peaks	Functional Groups Presents
1	3388.06cm-1,52.56%T	Hydroxy group, H-bonded OH stretch, Normal ‘‘polymeric’’ OH stretch
2	2923.93cm-1,56.61%T	Methylene C-H asym
3	1634.91 cm-1,51.43%T	Alkenyl C=C stretch, Amide, Organic nitrates, Primary amine, NH bend
4	3141.30 cm-1, 12.51%T	Ammonium ion
5	1558.9 cm-1, 11.35% T	Aliphatic nitro compounds
6	1384.46 cm-1 , 7.86 %T	gem-Dimethyl or ‘‘iso’’- (doublet)
7	3143.11cm-1, 80.60%T	Ammonium ion
8	1616.27cm-1,80.83%T	Primary amine, NH bend
9	1384.46cm-1,65.10%T	gem-Dimethyl or ‘‘iso’’- (doublet), Organic sulfates

3.4. Antimicrobial activity of silver nanoparticle

Silver nanoparticles displayed antimicrobial activity against studied pathogenic microorganisms, with varying degrees, as suggested by the diameter of inhibition zone, while BPE didn't show any antimicrobial activity (Fig. 11). The Gram negative bacteria (E. coli and P. aeruginosa) showed larger zones of inhibition, compared with the Gram positive bacteria (S. aureus) (Fig. 11b), which may due to the variation in cell wall composition. The cell wall of Gram positive bacteria composed of a thick peptidoglycan layer, consisting of linear polysaccharide chains cross linked by short peptides, thus forming more rigid structure leading to difficult penetration of the silver nanoparticles, while in Gram negative bacteria the cell wall possesses thinner peptidoglycan layer (Shrivastava et al., 2007). Several main mechanisms underlie the biocidal properties of silver nanoparticles against microorganisms. First, silver nanoparticles attach to the negatively charged cell surface, alter the physical and chemical properties of the cell membranes and the

cell wall and disturb important functions such as permeability, osmoregulation, electron transport and respiration (Marambio-Jones & Hoek, 2010; Nel et al., 2009; Sondi & Salopek-Sondi, 2004; Su et al., 2009). Second, silver nanoparticles can cause further damage to bacterial cells by permeating the cell, where they interact with DNA, proteins and other phosphorus- and sulfur-containing cell constituents (AshaRani, Mun, Hande, & Valiyaveettil, 2009; MarambioJones & Hoek, 2010; Nel et al., 2009). Third, silver nanoparticles release silver ions, generating an amplified biocidal effect, which is size- and dose-dependent (Liu, Sonshine, Shervani, & Hurt, 2010; Marambio-Jones & Hoek, 2010). silver nanoparticles act as reservoirs for the Ag+ bactericidal agent. Combination of silver nanoparticles and antibiotic levofloxacin show a synergistic effect, the antimicrobial activity against *S. aureus, P. aeruginosa, and E. coli.*

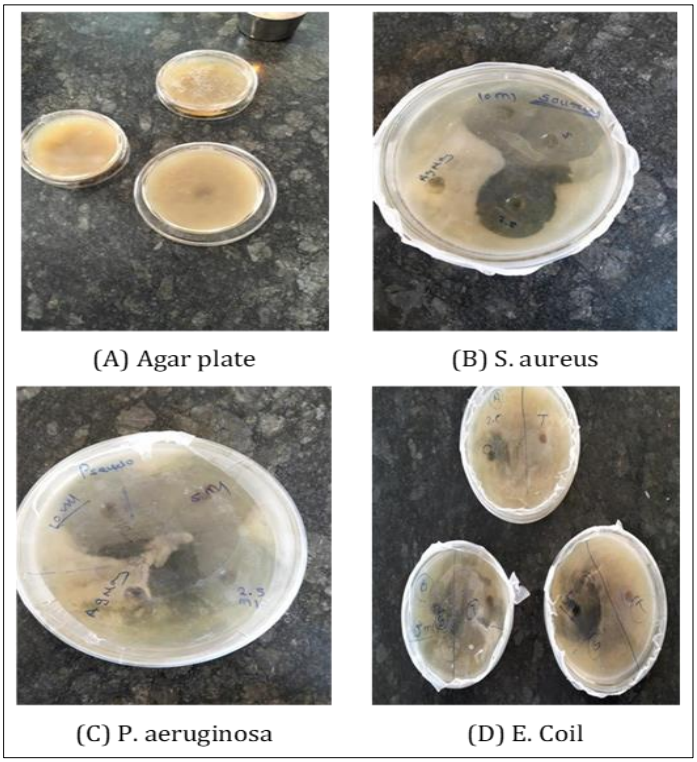

Figure 11 Zone of inhibition of silver nanoparticles against various pathogenic microorganisms

3.5. Studying plant growth promoting activity

Figure 12 *Aspergillus nigar*

3.6. Tray Assay

The plant growth promoting activities of three variations as discussed in material and methods were checked by using the Tray Assay. The highest length of shoot and root of the three variations was observed in the plants whose seeds were prior soaked in nanoparticles.(Karishma Nagpure, Shubham Pate, Amruta Marne, Vedashree Sirdeshmukh).

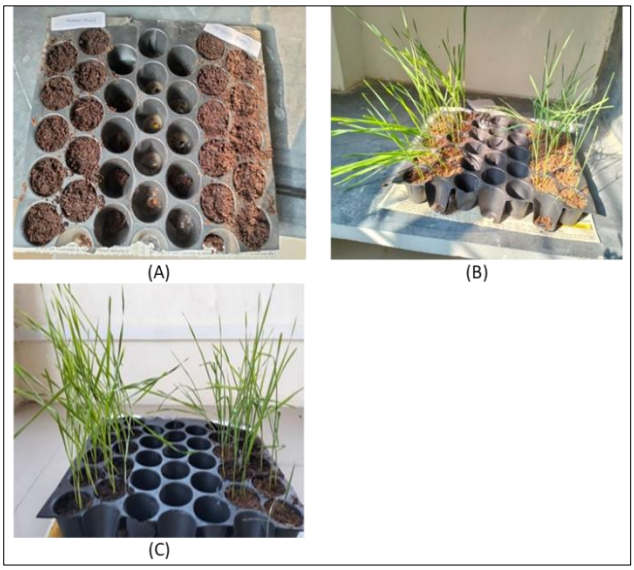

Figure 14 Tray assay (A) Day 1 normal seed & infectious seed (B) Day 12 of normal seed & infectious seed (C) Day 18 after fumigation of silver nanoparticle

Table 2 Seed soaked in water

Sr no	Length of root (cm)	Length of shoot (cm)
1	4 cm	26 cm
2	5 cm	27cm
3	4.5 cm	21 cm
4	6 cm	26 cm
5	3.5 cm	25 cm
6	7 cm	29 cm
7	5 cm	23 cm
8	4.5 cm	24 cm
9	3.5 cm	25 cm
10	5 cm	26 cm

Table 3 Seed soaked in infectious *Aspergillus niger* solution

Sr no	Length of root (cm)	Length of shoot (cm)
1	1.5 cm	11 cm
2	1 cm	10 cm
3	1.3 cm	12 cm
4	1.6 cm	13 cm
5	1.9 cm	15 cm
6	2 cm	16 cm
7	1.8 cm	14 cm
8	2 cm	15 cm
9	1.4 cm	16 cm
10	1.7 cm	10 cm

Table 4 Pouring synthesized nanopartical solution at 70 ^{0}C

Sr no	Length of root (cm)	Length of shoot (cm)
2.5ml AgNP+5ml BPE		
1	2.5 cm	19 cm
2	2.8 cm	20 cm
3	2.9 cm	25.3 cm
4	3 cm	21.2 cm
5	2.7 cm	23.4 cm
5ml AgNP+5ml BPE		
1	3 cm	26 cm
2	2.7 cm	23.2 cm
3	3.5 cm	22.5 cm
4	4 cm	24.5 cm
5	3.5 cm	20.5 cm
10ml AgNP+5ml BPE		
1	4.3 cm	26.8 cm
2	4.5 cm	27 cm
3	5 cm	25.3 cm
4	3.5 cm	24.6 cm
5	3.7 cm	25.9 cm

3.7. Average values

Table 5 Average value of (a) seed soaked in water (b) Seed soaked in infectious *Aspergillus niger* solution (c) pouring synthesized nanopartical solution at 70 ^{0}C

Seed soaked in	Average length of root (cm)	Average length of shoot (cm)
Seed soaked in water		
1	7 cm	29 cm
Seed soaked in infectious *Aspergillus niger* solution		
1	1.9 cm	15 cm
Fumigation of silver nanopartical solution at 70 ^{0}c		
2.5 ml AgNO3+5 ml BPE	2.7 cm	23.4 cm
5 AgNO3 + 5ml BPE	3.5 cm	22.5 cm
10 AgNO3 +5 ml BPE	4.5 cm	27 cm

It was also demonstrated that nanoparticles produced through banana peel extract acts as antifungal agent and plant growth promoter. The plant growth promoting activity was checked by using the Tray Assay. The maximum growth was observed in the seeds prior soaked in silver nanoparticles. Thus, AgNPs acts as plant growth promoter, Antifungal Agent.

4. Conclusion

Banana peels as agricultural waste material was successfully utilized for the consistent and quick synthesis of silver nanoparticles. The biosynthesized silver nanoparticles using BPE were characterized. Synthesized silver nanoparticles revealed good antimicrobial activity against the selected pathogenic microorganisms. Moreover, they showed a synergistic effect on the antimicrobialactivity of the standard antibiotic levofloxacin against Gram-positive and Gram-negative bacteria under investigation. This green synthesis approach appears to be a cost-effective, non-toxic, ecofriendly alternative to the conventional microbiological, physical and chemical methods, and would be suitable for developing a biological process for large-scale production. These silver nanoparticles may be used in effluent treatment process for reducing the microbial load .AgNPs acts as plant growth promoter, Antifungal Agent.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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