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Biosynthesis, Characterization and Antibacterial Properties of Silver Nanoparticles From the Edible Mushroom Pleurotus Ostreatus

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Research Article

Keywords: Pleurotus ostreatus, silver nanoparticles (Ag-NPs), UV-Vis spectrophotometer, FTIR, antibacterial activity

Posted Date: November 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11506564/v1

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Additional Declarations: No competing interests reported.

Abstract
The most common sterilising silver nanoparticles used in consumer and medical products include fabrics, food storage bags, refrigerator surfaces and personal care products. This study exhibits the synthesis of silver nanoparticles using *Pleurotus ostreatus*. The biosynthesized Ag-NPs were characterized using a UV-Vis spectrophotometer, Fourier transform infrared spectroscopy (FTIR), Scanning electron microscope (SEM), Transmission electron microscope (TEM), X-ray diffractometer (XRD) and antibacterial activity. The maximum absorption peak was measured in the UV-Vis spectra of silver nanoparticles at 460 nm. The next analysis is performed with a comparison of control and concentration 10mM. The FTIR were detected by the presence of functional groups necessary for the conversion of silver nitrate to silver ions. The formation of silver nanoparticles was observed by SEM analysis of the brown colour stable samples, while silver nitrate-treated samples revealed well-dispersed nanoparticles. The TEM images revealed that the size of Ag-NPs was found to be about 50 and 100 nm. Ag-NPs, XRD pattern showed 2θ values, which are related to the silver (111) crystalline phase index. *Aeromonas hydrophila, Bacillus cereus, B. subtilis, Escherichia coli, Klebsiella pneumoniae, Vibrio cholera* and *Staphylococcus aureus* were the microbes selected for the current study for the antibacterial activity of the silver nanoparticles was performed by well diffusion method. The maximum zone of inhibition was found in the control (10.16±0.18mm) at *Klebsiella pneumoniae* and concentration 10mM (12.20±0.08mm) at *Bacillus cereus* and least against the control (7.30±0.22mm) at *E.coli* and concentration 10mM (7.67±0.72mm) at *Klebsiella pneumoniae*. This study concluded that the silver nanoparticles have a significant amount of potential as an antimicrobial compound against the pathogenic microorganisms studied and can be used to treat infectious diseases caused by bacteria. Silver nanoparticles have a major role on nanotechnology and nanomedicine.
Keywords: *Pleurotus ostreatus*, silver nanoparticles (Ag-NPs), UV-Vis spectrophotometer, FTIR, antibacterial activity.

INTRODUCTION

The synthesis of extracellular and intracellular silver, gold, selenium, lead, and iron nanoparticles has been utilised using a wide range of amino acids, proteins, and polysaccharides present in mushrooms [1]. Nanoscience is the application of nanoparticles with sizes ranging from 1 to 100 nanometers (nm) [2, 3]. Microorganisms are effective in synthesising metal nanoparticles, a field where nanotechnology has been used in both agriculture and medicine [4]. Recently, a range of characteristics in metal nanoparticles have been discovered that have proven their efficacy in treating a variety of diseases caused on by multiple resistance pathogens [5]. One of the most edible oyster mushrooms is *Pleurotus*. All of the species of this genus are edible, and the most of them have been developed into the largest cultivated fungus in the world. It is a healthy food which is low in calories, significant in proteins and polyunsaturated fats and rich in keratin, a group of B vitamins, including Thiamin (B1), Riboflavin (B2), Niacin (B5), Pyridoxine (B6) and Biotin (B7). It is also an important source of minerals and enzymes that break down lignins and phenols. In fact, proteins and external enzymes produced in large quantities by mushroom fungi play an important role in the reduction of nitrate silver particularly when nanoparticles are formed [6]. Mushrooms are also some of the easiest fungi to grow and propagate in a laboratory. conditions or on high productivity industrial farms [7]. Due to the presence of numerous

bioactive compounds, mushrooms provide a variety of nutritional and therapeutic benefits [8]. The most of fruit bodies available in Egyptian markets are either *Pleurotus* or *Agaricus* mushrooms [9]. The importance of mushrooms as a food source derives from both their pleasant organoleptic properties and their rich biological activity content which is essential for a healthy human diet [10]. Gas chromatography mass spectrometry (GC-MS) has established its position as an important technical platform for secondary metabolite profiling in both plant and non-plant species over the last few years [11]. Ag-NPs are increasingly being used in medical treatments and health care to understand the role of their antiviral, anticancer, antibacterial, and antifungal activities [12,13]. Since toxic chemicals are not used in the synthesis method, the development of environmentally friendly materials like fungus for the synthesis of Ag-NPs offers several advantages of eco-friendliness and compatibility for pharmaceutical and other biomedical applications. Nanoparticles have a variety of applications as drug/gene delivery systems [14]. *Pleurotus* spp. is an important medicinal mushroom due to the presence of bioactive compounds [15]. Mushrooms are a new potential source for the synthesis of NPs because of the large number of bioactive compounds [16]. A new hope and dimension for the development of nanodrugs leading to their successful delivery in the biological system has been provided by the synthesis of nanoparticles and their application in various fields of biological sciences and medicine [17]. Although nanoparticles have certain characteristics such as extremely small size, high surface to volume ratios, high reactivity and unique interactions with structural components which improve the pharmacokinetics and therapeutic index of the drugs [18]. This method of producing nanoparticles using mushrooms is extremely promising for the synthesis of non-toxic, ecofriendly and mostly stable nanomaterials [19]. However, there are specific limitations to using microorganisms for the synthesis of metallic nanoparticles including maintaining aseptic culture conditions, the potential for sample contamination and the uneven size of the nanoparticles produced [20, 21]. Accordingly, a rapidly developing area of nanobiotechnology is microbial assisted biosynthesis of nanoparticles [22]. Using bacteria that are resistant to heavy metals has reduced the amount of metal ions [23]. Nanomaterials are expected to improve cancer diagnosis and therapy [24]. Because of their large secretome, which contains enzymes, active molecules and proteins that play a role in capping and reducing Ag-NPs, fungi are more realistic than bacteria for producing large quantities of nanoparticles including Ag-NPs [25, 26]. Natural bioactive compounds are regarded as a rich source of many therapeutically active chemicals properties. There have been many natural compounds extracted from microorganisms, plants and other species to assess their potential as alternatives for antimicrobials and tumour treatments, as well as look into their various modes of action. Continuous attempts have developed a range of possible antibacterial and anticancer treatments [27]. In the present study, the eco-friendly biosynthesis of silver nanoparticles using Ag from *Pleurotus ostreatus* extracts and the evaluation of their antibacterial efficacy against diverse human pathogenic microorganisms.

MATERIALS AND METHODS

Sample collection

Oyster mushroom *Pleurotus ostreatus* was collected from Tamil Nadu Rice Research Institute, Aduthurai – 612 101, Thanjavur, Tamil Nadu, India.

Mushroom extract preparation

After sample collection, a fruiting body was washed several times in deionized water and dried for three days at 40˚C in the oven. A mortar and pestle were used to crush the dried sample into powder. 200 ml of water were used to extract 5 gram of dry powder using a Soxhlet extractor at 80˚C for 8 hours. Thus obtained extract was extracted using Whatman No. 1 filter paper and it was then concentrated to 100 ml using a rotary evaporator at 60˚C. Until it was used the extract was kept in the refrigerator at 4˚C.

Synthesis of Silver nanoparticles

For the synthesis of silver nanoparticles, 10 ml of mushroom extract was added to 150 ml in a conical flask that containing 90 ml of a solution of 1 mM silver nitrate. The mixture was again incubated at 60˚C in the dark while being stirred at intervals of a different time interval. Over the period of 24 hours, the resulting reduction in silver ions (Ag+) was periodically monitored. The reaction mixture's colour changed from light yellow to pale yellow and finally to dark brown after 4 hours of incubation, indicating the formation of Ag-NPs [28].

Characterization techniques [29]

UV-Vis spectroscopy analysis

UV-Vis spectral analysis was done using an Elico UV-Vis spectrophotometer. After diluting of a small aliquot of the sample into distilled water, the UV-Vis spectrum of the reaction medium was measured at 72 hours to monitor the reduction of pure Ag^{+} ions.

FTIR analysis of Ag-NPs

Ag-NPs from fungus extracted samples was subjected to FTIR analysis using a Perkin Elemer Spectrum-1 to determine their chemical composition in the Mid Infrared (MIR) region of 400–4000 cm^{-1}.

SEM analysis of Ag-NPs

Scanning Electron Microscopic (SEM) analysis was done by FEI QUANTA 200 FEG HR-SEM model which was operated at 30 kV with an 8 mm working distance. A small amount of the sample was used to create thin films on a carbon-coated substrate. After putting the specimen on the sample holder and blotting away excess solution with a piece of paper the film on the SEM was subjected to a mercury lamp for 5 minutes to dry.

TEM analysis of Ag-NPs

As mentioned in the IR sample preparations, a sample for TEM analysis was prepared. The sample was first sonicated for five minutes using a Vibronics VS 80. On carbon-coated copper grids, Ag-NPs were loaded and the solvent was allowed to evaporate under infrared light for 30 minutes. On a Phillips model CM 20 instrument operating at 200 kV of accelerating voltage, TEM measurements were taken.

XRD measurement

The Phillips PW 1830 instrument was used to perform XRD measurements on the Ag-NPs that were cast into glass slides and biologically synthesised film. Operating at a voltage of 40 kV and a current of 30 mA while radiating Cu k_{α} radiation with a wavelength of 0.1541 nm and a step size of 0.02/θ in the 2 range of 10-80˚.

Antibacterial activity [30]

By using the well diffusion method, antibacterial activity against the silver nanoparticles (Ag-NPs) synthesised from *P. ostreatus*. The pathogenic organisms such as *Aeromonas hydrophila, Bacillus cereus, B. subtilis, Escherichia coli, Klebsiella pneumonia, Vibrio cholera* and *Staphylococcus aureus* were tested. Pure organism cultures were subcultured on

Muller-Hinton broth at 35°C and 200 rpm using a rotary shaker. Using gel puncture, each strain was uniformly swabbed onto the individual Muller-Hinton agar plates. 25 µl, 50 µl, 75 µl and 100 µl of the sample nanoparticle solution were poured into the wells on each plate using a micropipette. The various levels of zone of inhibition were measured following an 18-hour incubation period at 35°C. Each experiment was carried out thrice and zones (%) of inhibition were presented as mean ± standard deviations (SD).

Statistical analysis

The average of three independent replicates with standard deviations was used to represent the results of each experiment (SD). One-way analysis of variance (ANOVA) and Duncan's test were used to statistically analyse the significant differences between the mean values of the data at a 5% level of significance ($p<0.05$).

RESULTS AND DISCUSSION

The observation suggested that the Ag+ ions were reduced extracellularly. According to earlier reports, these nobel metal particles exhibit silver's typical absorbance at about 430 nm [31]. The silver nanoparticles were synthesised in small monodisperse as indicated by the peak that was attained at 440 nm [32, 33]. The appearance of brown and yellowish solutions gave the absorbance intensity above the highest peak of the solutions of a dark brown colour at the same wavelength of the radiation Ultraviolet, that falls within the range associated with the surface of the silver metallic particles [34-36]. This indicates that the concentration of nanoparticles in solutions has increased [37]. According to [38], a spectroscopic characterization study based on the UV absorption scale of silver nanoparticle manufactured by some types of mushrooms (*Pleurotus*) lies within the wave range (430-420) nm. The highest UV absorption peak for nanoparticle silver particles manufactured by *P. florida* was found to be at 410 nm. In the current study, the biosynthesis of silver nanoparticles is the colour changes from yellow to ruby-brown and finally to dark brown for the mushroom extract of *Pleurotus ostreatus* respectively, as shown in (Fig 1). The mushroom extract (*P. ostreatus*) are constant for 1g and after addition of four concentration of silver nitrate (1mM, 5mM and 10mM) are used including control (without silver nitrate). It was observed that the color of the solution turned from dark brown after 48 h of the reaction, which indicated the formation of silver nanoparticles. Using UV-vis spectrophotometer analysis, the formation and stability of the reduced silver nanoparticles in the colloidal solution were monitored. The UV-vis spectra showed absorbance at 300-500 nm, the showed increased absorbance in various concentration (control, 1mM, 5mM and 10mM) and the silver nanoparticles surface Plasmon resonance is where the peaks were detected. The biosynthesized Ag-NPs from the mushroom extract showed the maximum absorbance reaches 0.916 in control, 1.865 in 1mM, 2.916 in 5mM and 3.822 in 10mM at the peak of 380nm. The concentration 10mM are highest peak in all wavelength at absorbance process were analyzed. The spectra also clearly showed the increase in silver solution intensity with time, which is a sign that there are increasingly Ag-NPs forming in the solution. The highest values are recorded at higher concentration (10mM) is synthesized silver nanoparticles from *Pleurotus ostreatus* (Fig 2). So further analysis will be compared with the control and higher concentration obtained previously.

According to [39], the stretching of -OH in the extract's proteins, enzymes, or polysaccharides may be the source of these bonds. The -CH stretching of alkanes was the

cause of the small band at 2931.60. At 1442.66 and 1380.94, respectively, the analogous scissoring and bending vibration was seen. The stretching vibrations of the C=O functional groups of aldehydes, ketones, and carboxylic acids were implied by the medium band observed at 1720.39. The FTIR spectrum is shown in the range of 1200 to 1800 cm-1 in figure 3, and the amide bands have been identified. The amide linkages of the proteins — C=O and N—H stretch vibrations, respectively, cause the bands at 1650-(1) and 1450-(2) cm. These bands' molecular vibrational positions are in line with previous literature for native proteins by [40]. In the present study, the atomic level background vibration and frequency analysis of compounds by FTIR spectroscopy is specific and each compounds molecular fingerprint is represented by a specific group of chemical bonds. FTIR spectral bands of the mushroom extract (control) and silver nanoparticles synthesized using *P. ostreatus* extract (concentration 10mM). (Fig 3) The peaks in transmittance were observed at 3431.77, 2970.97, 2843.72, 2076.43, 1640.53, 1455.40, 1405.98, 1109.39, 1053.98, 1015.24, 685.90 cm^{-1} in the control (mushroom extract) and (Fig 4) comparable spectral bands were observed at 3432.53, 2844.15, 2076.62, 1638.42, 1455.11, 1384.09, 1106.33, 1051.90, 1014.84 and 677.58 cm^{-1} in synthesized Ag-NPs using extract (concentration 10mM). In comparison, both the mushroom extract and the synthesized Ag-NPs show similar transmittance bands. The appearance of strong peaks in control and concentration (10mM) at 1640.53 and 1638.42 cm^{-1} is indicative of N-H bending vibrations in primary and secondary this could be attributed to the existence of amines, 1053.98 and 1051.90 cm^{-1} is S-O stretching vibration in sulfoxides and sulfonic acids this can be related to the existence of sulfur compounds and 1015.24 and 1014.84 cm^{-1} is C-X stretching vibration in C-Cl this can be explained to the existence of halogen compounds respectively. It is clear that the functional groups associated to the mushroom extracts have left their imprint on the Ag-NPs that were synthesized. The Ag-NPs from the mushroom extract may have seen prominent shifts in the positions of the distinct peaks as a result of the reduction of $AgNO_3$ by the mushroom extracts with capping and the stabilization of Ag-NPs by specific secondary metabolites. Therefore, it is clear from the FT-IR experiment in this study that bioactive compounds found in *P.ostreatus* such as polyphenols, anthocyanins, flavonoids and nitro-compounds (proteins) are necessary for the capping and stabilisation of silver nanoparticles (Fig 3 & 4). The interaction of the proteins in the *P. ostreatus* fungus with Ag+ ions or nanoparticles, as well as a number of aggregates, does not appeared to have an impact on their secondary structures according to the FTIR measurement. The nanoparticles morphology obviously varies.

According to investigation, silver nanoparticles in filterate are spherical in shape, evenly distributed in solution without aggregation, and have an average size of about 5–50 nm [41]. Through scanning electron micrographs at different magnifications ranging from 300 nm to 100 nm, the size and form of Ag-NPs were determined. SEM scans of silver nanoparticles reveal highly aggregated crystalline spherical SNPs with a range of particulate sizes between 10 and 30 nm [42]. The majority of the particles are generally spherical, homogeneous, 59–36 nm in size, distributed evenly, and little agglomeration. The pH (6.8)-produced particles were larger than those manufactured at pH (9). Given its crucial role in the way it interfaces with cell membranes of microorganisms, the spherical shape of nanoparticles is also considered as one of its desirable properties. According to various studies using scanning electron microscopy, nanoparticles with diameters between (50-40)

nm are spherical [43]. The mushrooms can produce spherical nanoparticles that are 40 nm in size on average [44]. In the current study, for scanning electron microscopy (SEM), the surface morphology and topography of the Ag-NPs were investigated using different magnification forces (Fig 5 & 6). SEM images showed nanoparticles with diameters of 100, 200, and 500 nm that were relatively spherical shape agglomerates in mushroom extract (control) and results in the formation of sheet like structure in synthesized from *P.ostreatus* extract (concentration 10mM). The selected area diffraction pattern recorded from one of the nanoparticles in the aggregates in showed that the silver particles are crystalline. For transmission electron microscope (TEM), a representative TEM image taken from an Ag-NPs film which was deposited on a copper TEM grid that has been coated with carbon can be observed. These assemblies were later determined to be Ag-NPs aggregates with sizes ranging from 50 and 100 nm. The TEM images showed nanoparticles were comparatively poly dispersed rod and spheres shape in mushroom extract (control) and the formation of mostly lotus leaf like structure with small percentage of spheres in synthesized from *P.ostreatus* extract (concentration 10mM) were formed. Even within the aggregates, the nanoparticles not directly contact, indicating that a capping agent was maintained nanoparticles. The separation of the Ag-NPs visible in the TEM image may be the result of protein capping which would also explain for the measurements from the UV-Vis spectroscopy, which is a characteristic of well-dispersed silver nanoparticles. Agglomerates of small grains and a few dispersed nanoparticles may be showed in this image. The silver particle size histograms (Fig 7 & 8) show that the mean diameter of the particles ranges from 1 to 100 nm.

The expansion of the bundles of peaks (111) and (200) reveals the nanoscale dimensions of the produced particles, and some unknown peaks that are less intense than the crystal tops of the nanoscale silver may appear as a result of the existence of some organic and biological filtrate components that surround a massive surface [45]. From observations [46], *P. djamor* oyster mushrooms produced nanoscale silver particles with a peak 111 that was stronger and higher than those of 200 and 220, while *P. ostreatus* oyster mushrooms produced particles that were more crystallised, with four peaks appearing at level 111 [43]. This is mostly because pH levels and the amount of filtrate used have an impact on the size and properties of the produced nanoparticles [47]. The values of the diffraction peaks were used to calculate the mean value, or 45.26 nm, for the average crystal size of the Ag-NPs. The crystalline structure of silver nanoparticles is explained by the four major peaks in Figure 5 with characteristic shifts of (222), (111), (112) and (100) [48, 49]. In the current study, the XRD plot shown in (Fig 9) showed that at different diffraction angles, ranging from 20 to 80, different lattice planes of (111), (200), (220), (311) and (222) exhibited various crystalline lattices. Thus, it is completely obvious from the XRD pattern that the Ag-NPs were essentially crystalline. The diffraction's intensity was much higher than that of the other diffractions. In this case, the XRD diffraction measurements produced the four strong peaks seen in figure 4. Thus, it agrees with the silver nanocrystals Bragg's reflection. This provides more evidence that silver nanocrystals Ag-NPs formed in the extracellular filtrate are present. The maximum peaks are presented at (111), (200) are common for control and concentration (10mM). In the lattice parameters were 32.1 nm and 36.5 nm for control and 33.6 nm and 38.4 nm for concentration (10mM) of synthesized silver nanoparticles respectively.

Silver nanoparticles have been shown to exhibited antibacterial properties in several studies, the exact mechanisms underlying their antimicrobial properties against pathogenic bacteria remains unclear. According to physical entities have a role in the antibacterial mechanism. According to research, the bactericidal effects of AgNPs may be caused by electrostatic forces between positively charged AgNPs and negatively charged bacterial cells [50]. At the crucial site, the antimicrobial concentration rises, increasing the amount of bacteria that are destroyed. Thus, the process of generating an antimicrobial group essentially includes increasing the concentration of an antimicrobial agent [51]. The susceptibility of gram-positive and gram-negative bacteria to silver nanoparticles differed slightly. Also, it really is possible that Ag- NPs can penetrate the thick wall of Gram-positive bacteria in addition to interacting with the membrane's surface [52]. This ensures that the particle's surface area is in significant contact with the surface of the bacterial cell which is expected to enhance the extent of bacterial exclusion [53]. In the present study, the four concentrations are the used in the antibacterial activity such as 25µl, 50µl, 75µl and 100µl. The concentration 100µl are highest zone of inhibition and 25µl are lowest zone of inhibition in all bacteria. The Ag-NPs showed antibacterial activity against seven bacteria (*Aeromonas hydrophila, Bacillus cereus, B. subtilis, Escherichia coli, Klebsiella pneumoniae, Vibrio cholera* and *Staphylococcus aureus)* using well diffusion method and the highest antibacterial effect on *Klebsiella pneumonia, Vibrio cholera and B. cereus* was found with zone of inhibition (10.16±0.18 mm), (9.68±0.62 mm), (9.10±0.81 mm) and lowest effect in control (mushroom extract) on *Escherichia coli* (7.30±0.22mm). The synthesized Ag-NPs from *P.ostreatus* (concentration 10mM) was maximum effect on *B. subtilis, B. cereus and Vibrio cholera* found in the zone of inhibition (12.20±0.08 mm), (10.15±0.68 mm), (9.66±0.17 mm) and minimum effect was found in *Klebsiella pneumoniae* (7.67±0.72 mm). Results were summarised as follows: due to their antibacterial properties, biologically significant nanoparticles could be extremely useful in the medical field (Table 1).

Table 1: Antibacterial activity of mushroom extract and synthesized silver nanoparticles using *P. ostreatus* of different concentration against clinical bacteria

Name of the bacteria	Zone of inhibition (mm)							
	Control				Concentration (10mM)			
	25µl	50µl	75µl	100µl	25µl	50µl	75µl	100µl
Aeromonas hydrophila	07.11±0.06^{a}	07.25±0.65^{a}	07.58±0.01^{a}*	08.96±0.12^{b}	04.50±0.71^{a}	06.10±0.72^{b}	07.18±0.81^{c}	09.12±0.82^{d}
Bacillus cereus	07.06±0.23^{a}	07.60±0.07^{a}	08.11±0.19^{b}	08.42±0.17^{b}	09.22±0.04^{a}*	09.86±0.02^{a}*	09.96±0.54^{a}	10.15±0.68^{b}
B. subtilis	08.05±0.07^{a}	08.72±0.66^{a}	09.00±0.02^{b}*	09.10±0.81^{b}	07.26±0.19^{a}	10.60±0.82^{b}	11.82±0.16^{c}	12.20±0.05^{d}*
Escherichia coli	06.15±0.08^{a}	06.73±0.01^{a}*	07.12±0.57^{b}	07.30±0.22^{b}	06.12±0.80^{a}	07.25±0.05^{b}*	07.61±0.25^{b}	08.12±0.13^{c}
Klebsiella pneumoniae	08.60±0.75^{a}	09.68±0.52^{b}	09.71±0.16^{b}	10.16±0.18^{c}	06.21±0.18^{a}	06.52±0.29^{a}	06.81±0.03^{a}*	07.67±0.72^{b}
Vibrio cholera	07.18±0.16^{a}	08.19±0.19^{b}	08.28±0.26^{b}	09.68±0.62^{c}	08.15±0.01^{s}*	08.19±0.26^{s}	09.41±0.72^{b}	09.66±0.17^{b}
Staphylococcus aureus	06.60±0.02^{a}*	07.90±0.11^{b}	08.06±0.22^{c}	08.42±0.17^{d}	06.09±0.07^{a}	06.68±0.13^{a}	08.16±0.08^{b}	08.29±0.51^{b}

The data, which represent the mean ± SD (n = 3), are expressed as a percentage of bacterial inhibition. According to Duncan's Multiple Range Test, the mean values in each row, which are followed by several superscripts, *are significantly different from each other ($p<0.05$). The values represent the mean ± SD of three individual observations.

Fig 1: Biosynthesis of silver nanoparticles using *P.ostreatus*

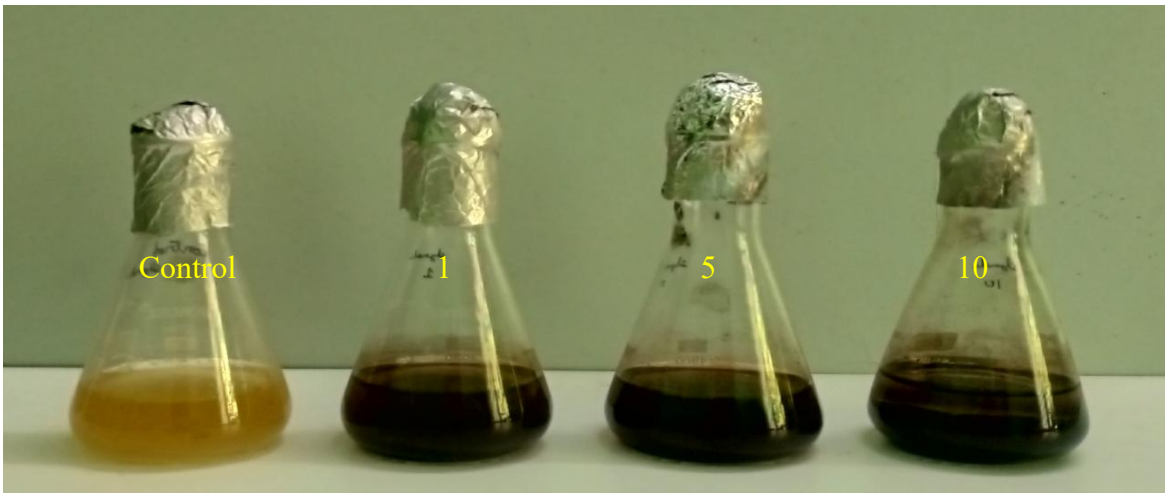


Fig 2: Characterisation of UV-Vis spectra of silver nanoparticles (Ag-NPs) synthesized from *P. ostreatus*

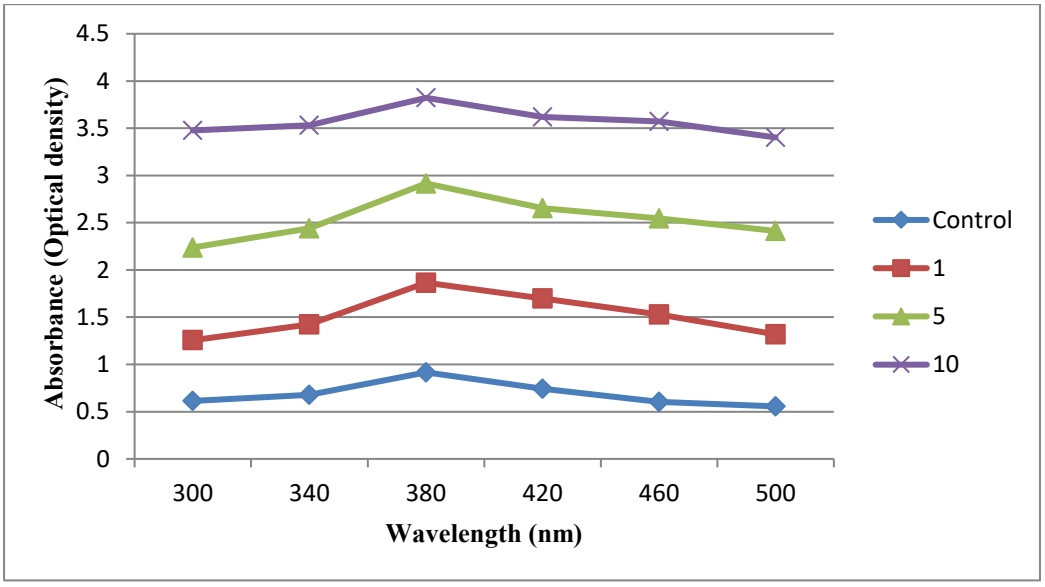


Fig 3: Analysis of functional group of *P.ostreatus* by FT-IR spectrum

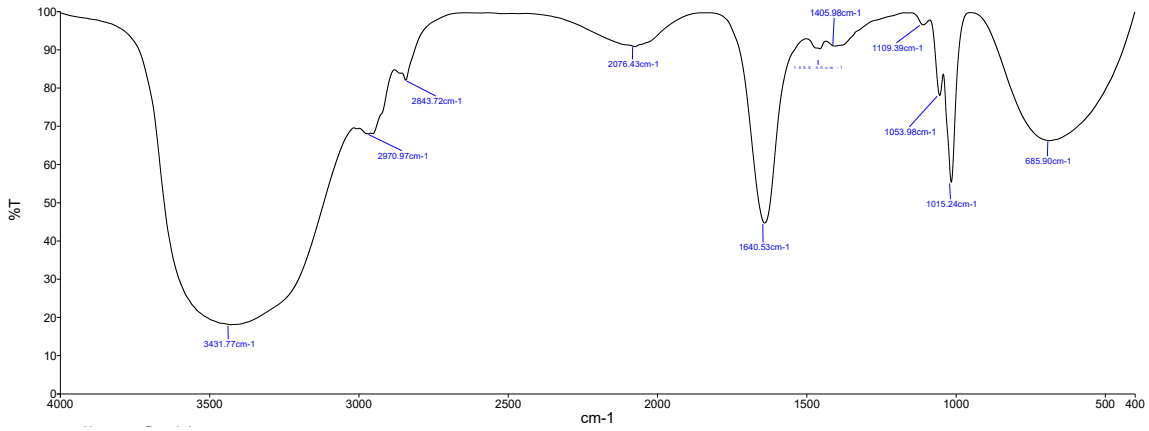


Fig 4: Analysis of functional group of synthesised Ag-NPs from *P.ostreatus* by FT-IR spectrum

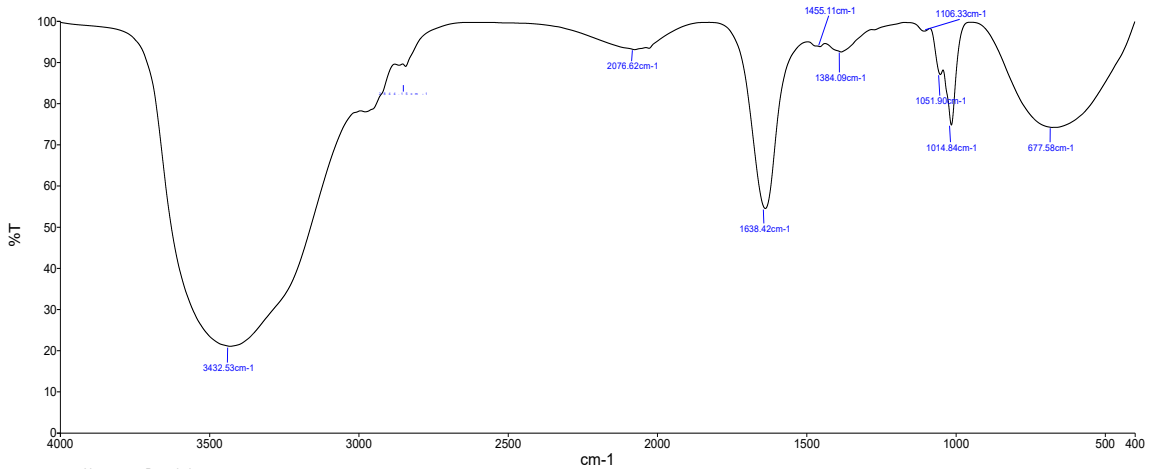


Fig 5: SEM image of the mushroom extract *P. ostreatus*

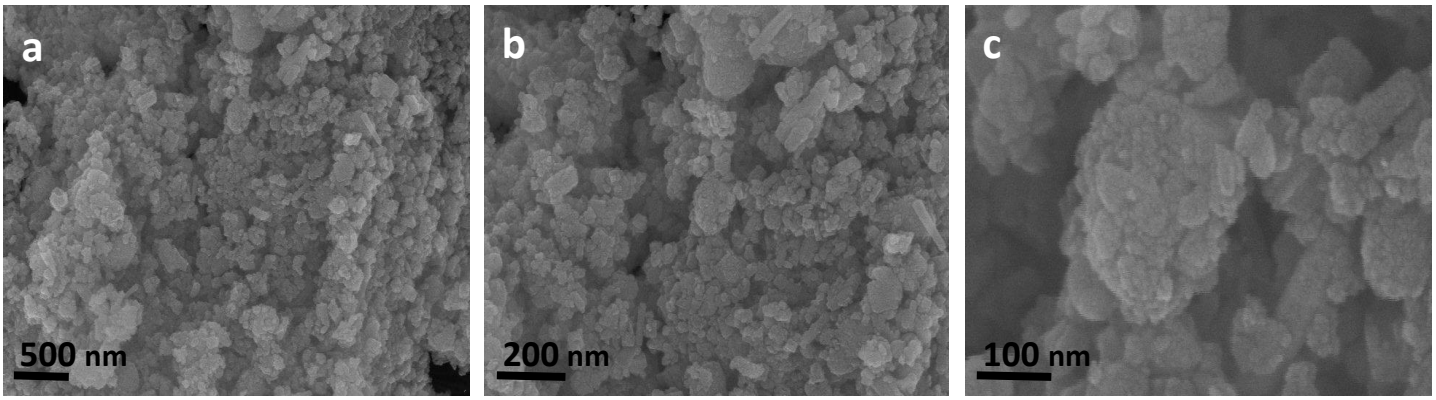


Fig 6: SEM images of the synthesized Ag-NPs using *P.ostreatus*

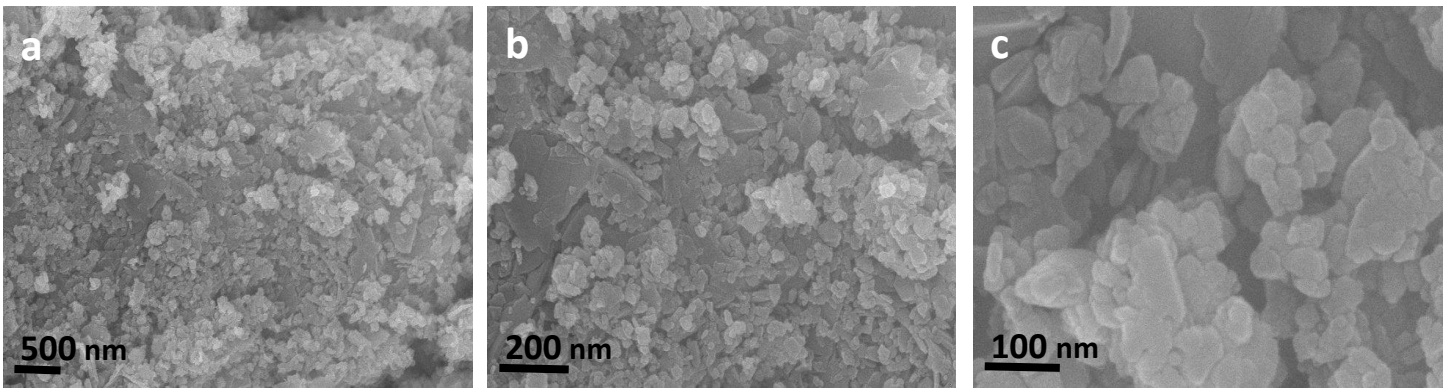


Fig 7: TEM images of the mushroom extract *P. ostreatus*

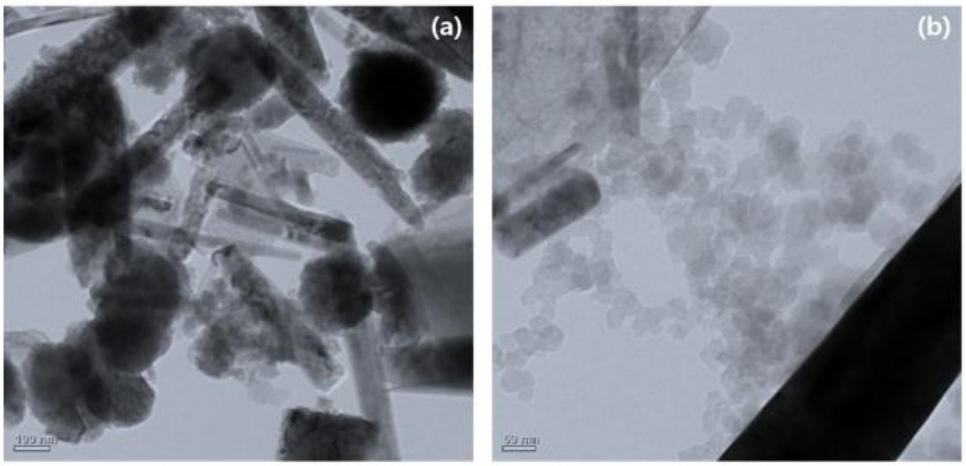


Fig 8: TEM images of the synthesized Ag-NPs using *P.ostreatus*

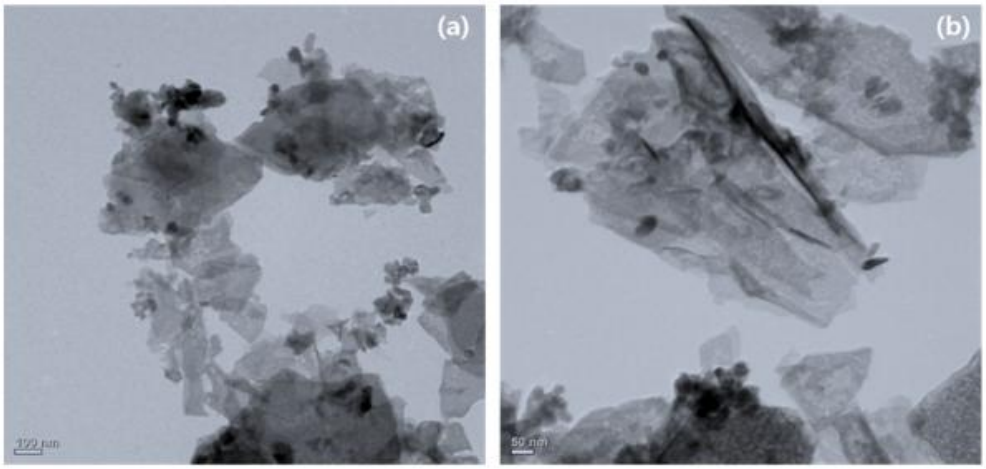
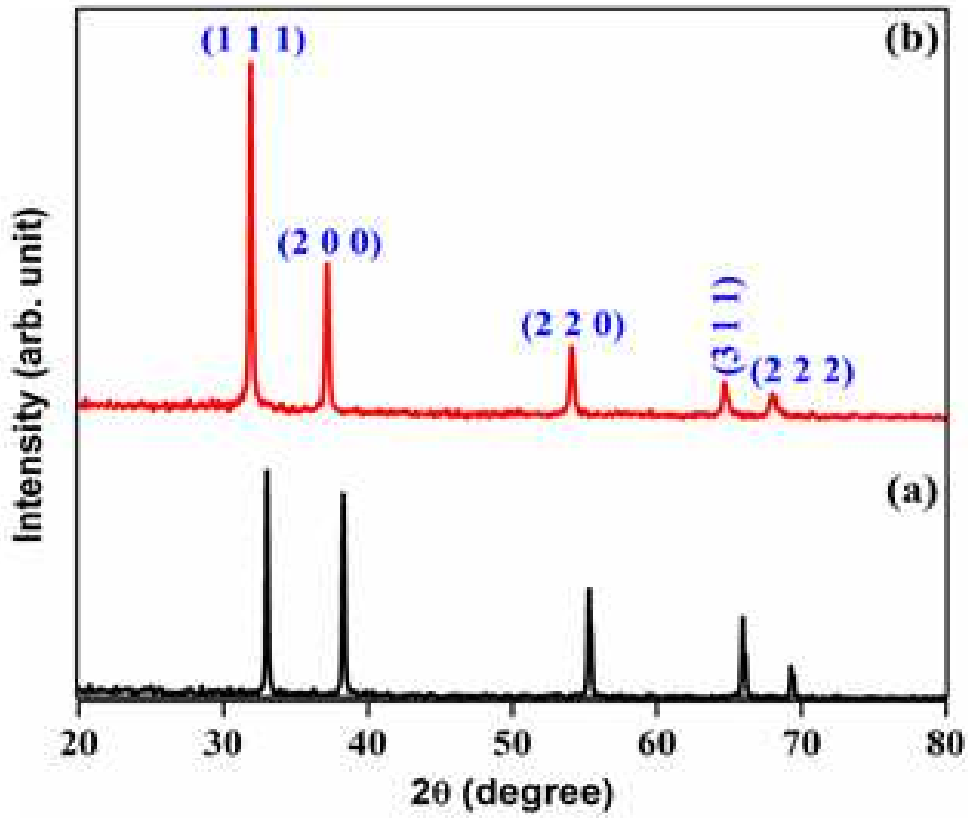


Fig 9: X-ray diffraction pattern of the mushroom extract and synthesized Ag-NPs using *P. ostreatus*



CONCLUSION

The present study concluded that it is possible to treat infectious diseases caused by pathogenic microorganisms using silver nanoparticles (Ag-NPs), which have great potential as antimicrobial compounds. The food industry will benefit from the potential antimicrobial activity against food-borne bacteria by using such metallic nanoparticles to both prevent contamination of food and preserve it for a long time. Ag-NPs have been characterised by UV-Vis spectroscopy, FTIR, SEM, TEM and XRD. It has recently been shown that the biosynthesis of Ag-NPs using *P. ostreatus* aqueous extract as a reducing and stabilising agent is an effective and environmentally friendly system. As a result, the biological approach appears to be a more affordable alternative than the conventional physical and chemical methods of synthesising Ag-NPs and it would be suitable to develop a biological process for large-scale production. With the continuous use of metal nanoparticles, the major food industry complications, such as food contamination and spoilage by bacteria, can now be resolved. These results suggest that silver nanoparticles may be selected as a potential antibacterial agent in the near future. As demonstrated by this study, Ag-NPs synthesised from *P. ostreatus* species appear to be a promising and effective antibacterial agent against multidrug-resistant bacteria strains.

ACKNOWLEDGEMENT
The authors would like to express their gratitude to Principal, MASS College of Arts and Science, Kumbakonam, Tamilnadu, India for kind encouragement and providing all necessary infrastructural facilities for carrying out the present work.
CONFLICTS OF INTEREST
The authors have no conflicts of interest to declare.
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