Synthesis of Biogenic Silver Nanoparticles with Biological Eco-Friendly Procedures Using Aqueous Stem Bark Extract of *Boswellia papyrifera* (DEL.) And Evaluation of Their Antimicrobial Activity.

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Authors' contributions

This work was carried out in collaboration among all authors. Authors IS, TMA and YA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors YSI and MM managed the analyses of the study. Authors RKM managed the literature searches. All authors read and approved the final manuscript.

Abstract

Biological synthesis procedures are gaining importance in these days because they are single step, fast, low cost and environment friendly alternative of well-known chemical and physical synthesis procedures for preparing metallic nanoparticles. The aim of this work is to synthesize silver nanoparticles from aqueous stem bark extract of *Boswellia papyrifera ,* Characterize and test its antimicrobial properties against two bacterial strains (*Streptococcus pneumonie*a and *Shigella dysentriea*).

The AgNPs were synthesized biologically, and they were characterized using visual color development, UV-VIS spectroscopy, Fourier transform infrared ray (FTIR), and scanning electron microscopy (SEM). The antimicrobial activities of the synthesized *Boswellia papyrifera* silver nanoparticles (BP- AgNPs) were evaluated using the agar well diffusion method, the MIC method, and the MBC method.

The results showed that silver nanoparticels were synthesized, as indicated by the color change from yellow to dark brown. The presence of AgNPs is indicated by UV peaks of 436.90, 458.20, and 459.40 for 1mM, 2mM, and 3mM, respectively. The aqueous stem bark extract of *Boswellia papyrifera* synthesized AgNPs show the presence of different functional groups such as C=C stretch, C stretch, and Alcohol OH stretch, which represent bioactive compounds such as phenol, amine, and so on. The BP-AgNPs were examined using a scanning electron microscope (SEM), which revealed that the nanoparticles had spherical, cuboidal, and triangular shapes.. The antimicrobial activities such as MIC and MBC showed the efficacy of the synthesized AgNPs against the test organisms *Streptococcus pneumonie*a and *Shigella dysentriea* which are gram-ve and gram+ve respectively.

The biologically synthesized silver nanoparticles of *Boswellia papyrifera* aqueous stem bark extract were found to have effective antimicrobial properties against *Streptococcus pneumoniae* and *Shigella dysenteriae* and they can be incorporated into a variety of materials, including bandages, antimicrobial paint, cutting boards, and surgical dressings materials, to control bacterial colonization on a variety of surfaces and prevent infections.

Key words: *Boswellia Papyrifera* , stem bark, silver, nanoparticle , antimicrobial , UV-VIS spectroscopy; FTIR.

1 INTRODUCTION

The biological synthesis of nanoparticles from green plant extract is more stable than microorganism-produced silver nanoparticles[1]. Biosynthetic methods based on naturally reducing agents such as polysaccharides, biological microorganisms such as bacteria and fungi, or plant extracts, also known as green chemistry, have recently emerged as a simple and viable alternative to more complex chemical synthetic procedures for obtaining AgNPs. Bacteria have been found to create inorganic compounds both inside and outside the cell. As a result, they could be used as biofactories for the production of nanoparticles such as gold and silver. Silver is particularly well-known for its biotical characteristics. Kalishwaralal [2] described the synthesis of AgNPs by reducing aqueous Ag+ ions using *Bacillus licheniformis* culture supernatant [3]. Because the organism used here is a nonpathogenic bacterium, the generated AgNPs are highly stable, thus this process has advantages over other methods. The biological method offers a diverse set of resources for the synthesis of AgNPs, and it can be considered a method of nanoparticle synthesis with benefits over traditional chemical approaches, as well as an ecologically benign and low-cost methodology.

Nanoparticles have also been utilized in nanoscaffolds to regenerate central nervous system cells [4], bio-separation membranes[5], medication delivery to target organs[6], gene transfection, medical imaging [7], nucleic acid sequencing and protein detection, and nanophase extractors[5] in medicine.

The tree *Boswellia papyrifera* (Del.) Hochst belongs to the *Burseraceae* family and is one of 20 species in the genus *Boswellia Roxb*. The presence of resin ducts in the bark and the production of aromatic oil or resins identify the family, which includes up to 600 species in 17 genera [8]. This fragrant and volatile oil is still used in religious ceremonies and for medical purposes. *Boswellia* species are found in the drylands of Africa, Arabia, and India[9], with two new species (*B. bullata* and *B. dioscoridis*) discovered lately in Yemen [10]. Phytochemistry study showed that Alkaloids, flavonoids, tannins, saponins, and cardiac glycosides were found in *Boswellia papryfera* aqueous stem bark extracts at various concentrations, with tannins being the most abundant [11]. In carbon tetrachloride induced liver damage and acetaminophen-induced acute renal damage model in wister rats, the aqueous stem bark extract or fractions were found to have a major effect in liver enzyme management and to be able to lower serum kidney function parameters respectively [12].This study is aim to synthesized, characterized silver nano-particles and evaluate it antimicrobial property using aqueous stem bark extract of *Boswellia Papyrifera*.

2 MATERIALS AND METHODOLOGY

2.1 Sample Collection

Boswellia papyrifera Stem bark was collected from Dan-madanho town of Gezawa local government, Kano state, Nigeria. After being collected, the stem bark was washed with clean water and then shade dried at room temperature before being ground to powder with a morter and pestle.

2.2 Sample Preparation

Ten (10) grams of the milled stem bark were weighed and suspended in 100 ml of distilled water. The extract was obtained by heating in a water bath at 60°C for 1 h. It was cooled and then filtered using Whatman No.1 filter paper and centrifuged at 4000 rpm for 20 minutes. The supernatants were collected and used for further studies.

2.3 Synthesis of AgNPs Using *Boswellia Papyrifera aqueous stem bark extract*

The respective supernatant of *Boswellia papyrifera* obtained was used to synthesized AgNPs as previously described [13] . 1 ml of the extract was added to the reaction vessel containing 40 ml of 1mM, 2mM and 3mM silver nitrate ($AgNO_3$) solutions for the reduction of silver ion. The reaction was carried out at room temperature (30±2°C) for 2 hours. The formation of AgNPs was monitored visually by observing color changes and measurement of the absorbance spectrum of the reaction mixture was carried out using UV-visible spectrophotometer.

2.4 Characterization of Synthesized AgNPs obtained from *Boswellia papyrifera Aqueous Stem Bark Extract*

UV-VIS spectroscopy was used to characterize the synthesized silver nanoparticles using a (LAMBDA 25/35/45) uv-spectrophotometer [14], and a sensitive technique fourier transform infrared (FTIR) spectroscopy analysis was performed on the powder sample of AgNPs using an ir affinity-1s spectrophotometer (Shimadzu, UK) according to

[15]. The AgNPs solution was centrifuged for 20 minutes at 10,000 rpm. The solid residue was subsequently dried at room temperature, and the resulting powder was used for ftir measurements with kbr pellets. After that, the nanoparticles were examined using a scanning electron microscope (SEM) on a LEO 1430 VP SEM equipment. Thin films of the sample were prepared on a carbon coated copper grid by dropping a very small amount of the sample on the grid, extra solution was removed using a blotting paper and then the film on the SEM grid were allowed to dry by putting it under a mercury lamp for 5 min.

2.5 Antimicrobial Activities of the Synthesized AgNPs

Using the agar well diffusion method, the antimicrobial activity of the synthesized Ag-NPs was investigated [6]. Bacteria were used to assess antimicrobial activity, including gram negative and gram positive strains such as Streptococcus pneumoniae and Shigella dysenteriae, respectively. Each bacteria was cultured in peptone water for 18 hours before being seeded onto Mueller-Hinton Agar plates. To form wells, the plates were then drilled using a cork borer (6 mm). The wells were watered with 100l of AgNPs dispersed in sterile distilled water in graduated quantities. After that, the plates were incubated at 37°C for 24 hours. The plates were checked for zones of inhibition at the end of the incubation period.

2.6 Determination of Minimum inhibitory concentration (MIC) and Minimum bacterial concentration (MBC) of synthesized AgNPs

The MIC of the Boswellia papyrifera AgNPs was determined by the broth dilution method. Different test tubes were labeled and 5 ml of nutrient broth was introduced into each test tube. 0.5 ml of bacteria suspension was inoculated. This was followed by the addition of the extract to the sterile nutrient broth test tubes and incubated at 37oC for 24 hours. In the control tubes, only extract was added (contains nutrient broth + bacteria), while the other control contains nutrient broth + nanoparticles. By comparing the three sets of tubes, the uninoculated test tubes were used to check the sterility of the medium and as a negative control, while the positive control tubes were used to check the suitability of the medium for growth of the microorganisms. The MIC was determined by the lowest concentration of the extract that prevented visible growth[17] .

The MBC of the extract was determined by sub culturing the contents of the tubes that showed inhibition of growth due to the presence of extract (nanoparticles). The tube(s) were plated out on nutrient agar plates which had neither antibiotics nor extract and incubated for 24 hours to determine whether there is growth of microorganisms or not, to confirm the effect of the extract (nanoparticles) on the Bacteria.

2.7 Statistical Analysis

Statistical analysis of the data was carried out through the Statistical Package for Social Science (SPSS) computer software version 11 using ANOVA and student's t-test at 95% confidence limit with P-value of (<0.05) being considered as significant. Results were expressed as mean ± standard deviation (mean ± SD).

3 RESULTS

3.1 Colour Confirmation of Synthesized AgNPs Using Aqueous stem bark Extract of *Boswellia papyrifera.*

The formation of AgNPs was catalyzed by the stem bark extract of *Boswellia papyrifera* over a period of 10-20 minutes with formation of dark brown colour stabilizing within 40 minutes .The formation of nanoparticles started after mixing the extract with the solution of Silver nitrate the extract served as reducing and stabilizing agents in the aqueous medium of *Boswellia Papyrifera* . Following the addition of Aqueous stem bark extract of *Boswellia papyrifera* to 1 mM, 3 mM and 5 mM AgNO3 solution at 1.1 (v/v), the colour changed dark brown after 40mins (figure 1a-c). Intensity of absorption increased as the concentrations of Aqueous stem bark extract of *Boswellia papyrifera* increased (Fig. 2a-c) [18]. This may be associated with biological mediating nanoparticles present in the solution which increased AgNPs reductive process. As such the higher intensity of the colour of solution was produced at 5mM of AgNO3 hence capping between Ag+ and Aqueous stem bark extract of *Boswellia papyrifra* occurred. The visible colour changes of the solution and spectral analysis from UV-visible spectrometer comfirmed the formation AgNPs of *Boswellia perpyrifera* stem bark extract (Figure 1. a,b and c).

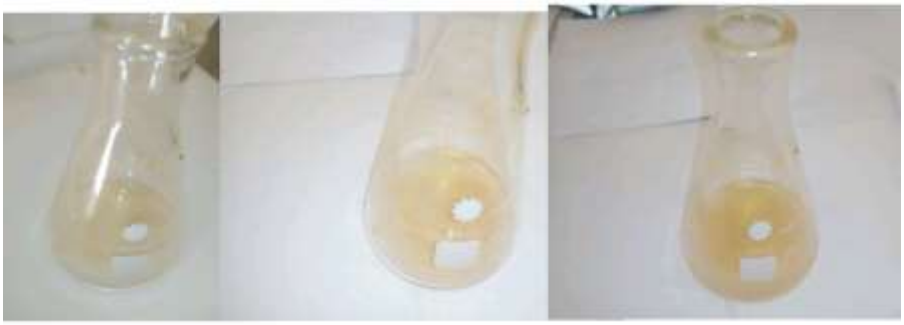

Figure1a: 1mM Figure1b:3mM Figure1c:5mM

Figure 2a, 2% w/v Figure 2b, 5% w/v Figure 2c, 15% w/v

Figure 1a ,b and c) showing The formation of colour observed after 40minutes at a) *1mM* b) *2mM* c) *3mM* while figure 2a,b,and c show the intensity of the coloured changed at different concentration of the extract.

3.2 Characterization of the Synthesized Silver Nanoparticles

The characterization of AgNPs from aqueous stem bark extract of *Boswellia perpyrifera* are presented using U/V visible spectrophotometer which confirm the formation of the AgNPs and fourier transform infrared (FTIR) which help in the identification of the bioactive molecules that reduced and stabilized the colloidal particles during interaction. Moreover the nanoparticles were further characterized using Scanning Electron Microscope which helps examine the shape and size of the nanoparticles.

3.3 U/V Visible Spectrophotometer Analysis of Synthesized Silver Nanoparticles Using stem bark extract of *Boswellia perpyrifera*

The UV-Vis spectra of the biosynthesized silver nanoparticles which shows different peaks in the range of 200 to 700nm of the visible region and confirmed the formation of AgNP in the range between 430 - 460 nm. for 1mM, 2mM and 3mM (Figure 3-5).

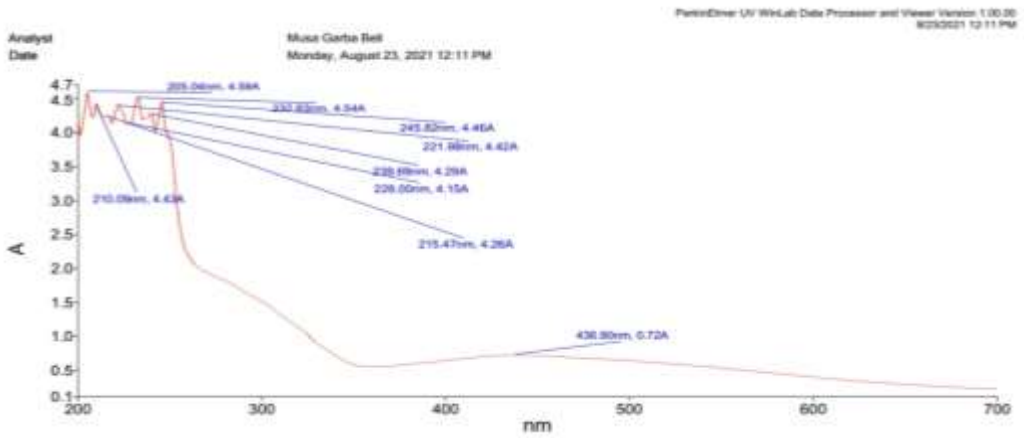

Figure 3. The UV-VIS absorption spectrum of the biosynthesized AgNPs for *1mM* silver nitrate solution

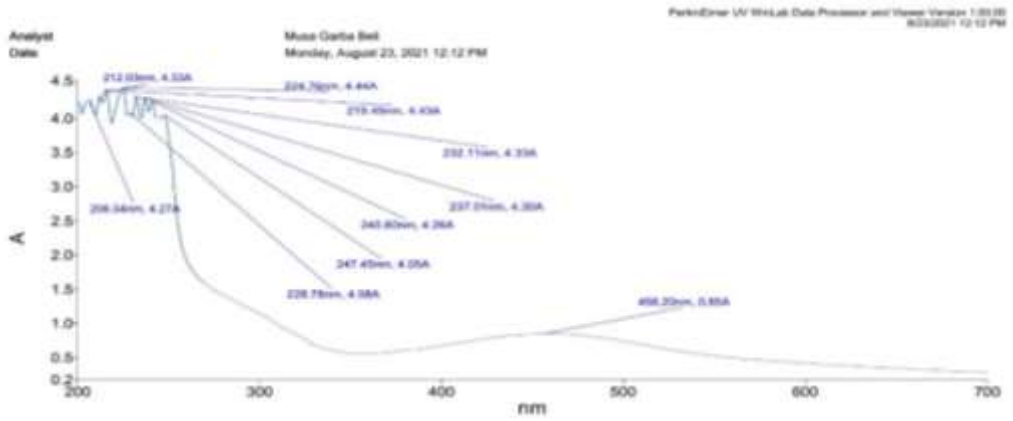

Figure 4. The UV-vis absorption spectrum of the biosynthesized AgNPs for *2mM* silver nitrate solution.

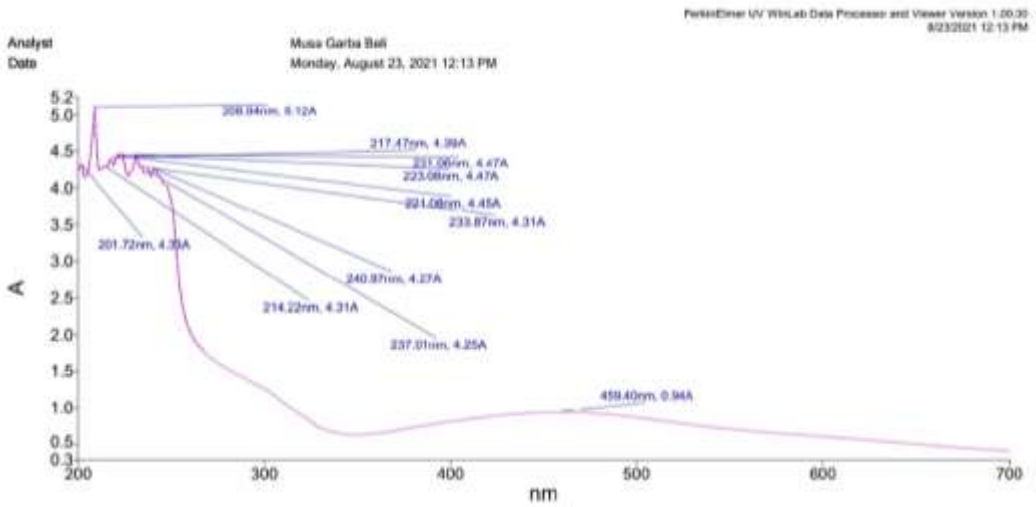

Figure 5. The UV-vis absorption spectrum of the biosynthesized AgNPs for *3mM* silver nitrate solution.

3.4 Fourier Transform Infrared Spectroscopy (FTIR) of the synthesized AgNPs Using stem bark extract of *Boswellia perpyrifera*

FTIR revealed some functional group that stabilized and capped the synthesized AgNPs at concentration of 3mM, 2mM, and 1mM. The functional groups are pointed within a distinctive frequency. The recorded FTIR spectrum of the synthesized silver nanoparticles is shown in Figure 6, 7 and 8. The spectrum consists of three distinct peaks in the entire range of recorded spectrum at all the three concentration of synthesized AgNPs. Bands at 1640 cm^{-1} can be attributed to C=C bending of alkenes, N-H bending of primary amine and C=O stretching vibration of carbonyl of amide[19] . The band at 2117,2124, and 2125 cm^{-1} denote the stretching C≡C bonds found in alkynes [20] whereas a band at 3257,3253 and 3260 cm^{-1} indicates the O-H stretching of phenol [21] (Table 1).

Table 1. FTIR Result of the Synthesized Silver Nanoparticles using Aqueous stem bark extract of *Boswellia papyrifera.*

Concentrations	Frequencies(Cm^{-1})	Functional group	Intensity	Assignment
5Mm	1640	C=C stretch	Strong	Alkene
	2125	C≡C stretch	Variable	Alkynes
	3260	O-H stretching	Strong	Alcohol
3mM	1640	C=C stretch	Strong	Alkene
	2113	C≡C stretch	Variable	Alkynes
	3260	O-H stretching	Strong	Alcohol
1mM	1637	C=C stretch	Strong	Alkene
	2129	C≡C stretch	Variable	Alkynes
	3257	O-H stretching	Strong	Alcohol

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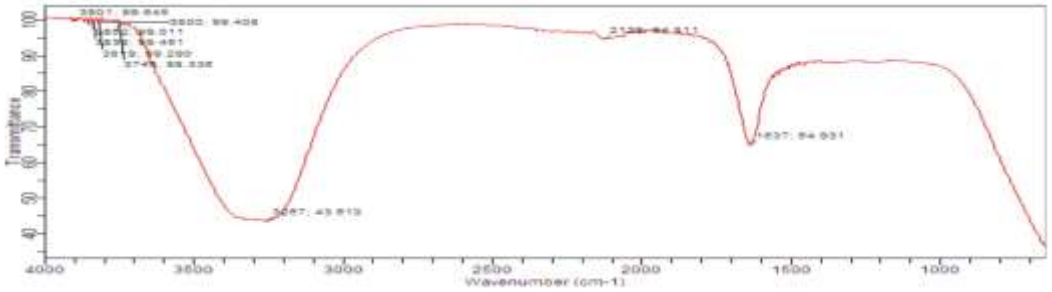

Figure 6: FTIR result of the biosynthesized BP- AgNPs for *1mM* silver nitrate solution

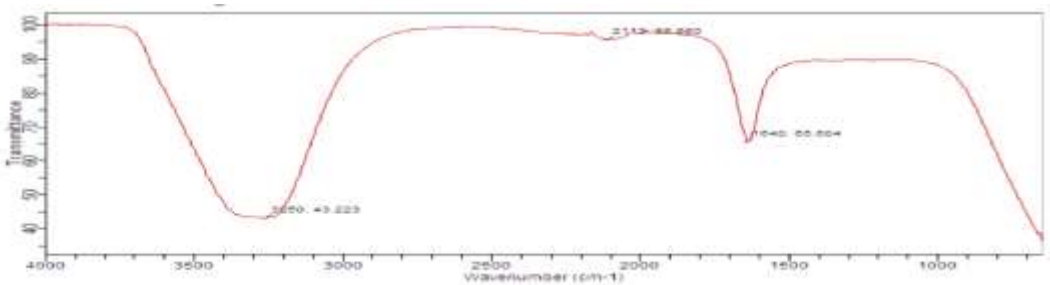

Figure 7. The FTIR result of the biosynthesized BP-AgNPs for *2mM* silver nitrate solution

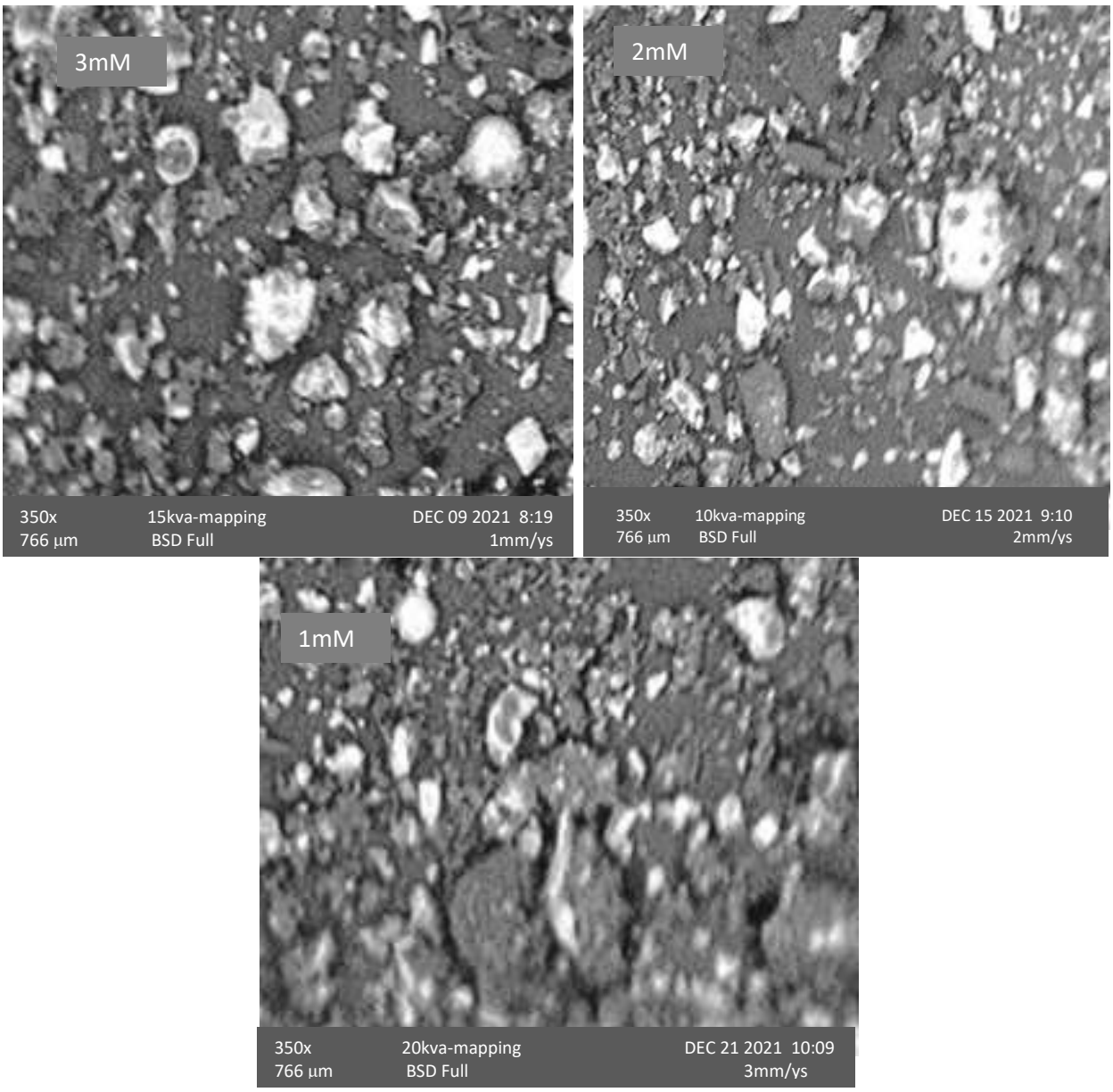

Figure 9: The SEM micrograph obtained for 5mM, 3mM and 1mM AgNPS synthesized from aqueous stem bark extract of *Boswellia papyrifera*

3.6 Antimicrobial Activity of the synthesized Silver Nanopaticles (AgNPs)

The antimicrobial activity of the synthesized silver nanopaticles were carried out using gram-ve and gram +ve bacteria such as *streptococcus pneumoniae and shigella dysenterea* respectively. Measurement of zone of inhibition, minimum inhibitory concentration and minimum bactericidal concentration were conducted to determine the antimicrobial efficacy of the synthesized silver nanoparticles in the presence of Ciprofloxacin as control(Table 2). The result showed that the diameter of inhibition zone is lower for gram negative bacteria than that of gram positive bacteria and the efficacy of the synthesized AgNPs is increasing as the concentration of the $AgNO_3$ is increased.

Table 2. Zone of Inhibition of the Synthesized silver nano-particles from *Boswellia papyrifera* aqueous stem bark extract at Different Concentration and Control (Ciprofloxacin).

Test Organism	Control	BP-AgNPs 1mM	BP-AgNPs 2mM	BP-AgNPs 3mM
Streptococcus p.	14.84±0.24	11.10±0.32	12.88±0.24	13.92±0.15
Shigella d.	13.68±0.47	10.94±0.23	11.98±0.26	13.02±0.20

Data are presented as the mean ± SD n ≥ 5

3.7 Minimum Inhibitory Concentration (MIC) of synthesized silver nanoparticles from *Boswellia papyrifera* aqueous stem bark extract

The minimum inhibitory concentration (MIC) of the synthesized silver nanoparticles obtained from (*Streptococcus pneumoniae* and *Shigella dysentriae*) was to ensure the presence or absence of inhibition caused by the synthesized silver nanoparticles against the test organisms (bacteria) or to ensure the presence or absence of growth of the test organisms (bacteria) in the dilute solution of nutrient broth. (Table 3). The MIC revealed negative result in all the bacteria tested.

Table 3. Minimum Inhibitory Concentration (MIC) Of silver nanoparticles from *Boswellia papyrifera* aqueous stem bark extract

Test Organisms	Control	3mM BP-AgNPs	2mM BP-AgNPs	1mM BP-AgNPs
Streptococcus p	-	-	-	-
Shigella d.	-	-	-	-

Key: negative absence of growths, positive presence of growths

3.8 Minimum Bactericidal Concentration (MBC) of silver nanoparticles from *Boswellia papyrifera* aqeuos stem bark extract

Minimum bactericidal concentration (MBC) is a confirmatory analysis carried out to ensure the significance of silver nanoparticles from *Boswellia papyrifera* aqueous stem bark extract against microbial activities of *streptococcus pneumoniae* and *shigella dysenteriea* and the result obtained in shows no any growth of bacteria (Table 4 .).

Table 4. Minimum bactericidal concentration

Test Organisms	Control	3mM AgNPs	2mM AgNPs	1mM AgNPs
Streptococcus p.	-	-	-	-
Shigella d.	-	-	-	-

Key: negative absence of growths, positive presence of growths

4 DISCUSSION

4.1 U/V Visible Spectrophotometer Analysis of *Boswellia papyrifera* of Silver Nano-particles (BP-AgNPs)

Metal nanoparticles have free electrons, which give a surface plasmon resonance (SPR) absorption band due to the combined vibration of electrons of metal nano-particles in resonance with light waves. The UV–VIS analysis was performed on the synthesized BP-AgNPs and the absorption maxima were scanned over the 200–700 nm wavelength range on a PerkinElmer LAMBDA 25/35/45 spectrometer. The synthesized silver nanoparticles using aqueous stem bark extract of *Boswellia papyrifera* showed the presence of some phytochemicals such as alkaloids, flavonoids, tannins, saponins, and cardiac glycosides [22], which are believed to be responsible for the reducing and capping ability of the synthesized silver nano-particles. After 40 minutes of extraction, addition, and incubation in a water bath at 60°C, the reacting mixture turned darker from a light brown solution, suggesting the formation of colloidal silver nano-particles in the mixture. The color intensified with reaction time and became dark brown after 2 hours of incubation in the oven at 32°C. The formation of silver nano-particles was monitored gradually by scanning the mixture under a UV-Vis spectrometer after two hours of incubation. Peak absorbance was measured at 438.90nm, 458.20nm, and 459.40nm for 1mM, 2mM, and 3mM, respectively, which could correspond to the surface Plasmon resonance of colloidal silver nanoparticles reported by [23].Similarly, the formation of silver nanoparticles by measuring the UV-visible spectrum of the reaction mixture at a range from 200 to 800 was reported, and the UV-visible absorption spectra of AgNPs revealed a Surface Plasmon Resonance band at 440 nm and 445 nm in the spectrum, which clearly indicated the presence of spherical silver nanoparticles [24]. Also, it is in accordance with the appearance of the brown color being due to the excitation of the surface plasmon vibrations, typical of AgNPs, having max values which are in the visible range of 400–500 nm [25]. Also, a similar report was of the formation of silver nanopaticles, reported in the range of 400-500 nm [26]. The UV–Vis spectrum shows the important role of $AgNO_3$ and the presence of ingredients in the stem bark of *Boswellia papyrifera* for the formation of silver nanoparticles [27]. This band corresponds to the absorption by colloidal silver nanoparticles in the region (400–450 nm) due to the excitation of surface plasmon vibration. In another work, the sharp bands of silver colloids were observed at 436 nm [28].

There is a relationship between the particle size and the plasmon peak, as the particles become larger when the plasmon peak shifts to longer wavelengths. Values for Ag particle size and plasmon maxima that were reported indicated that UV spectra were in lower wavelengths (384nm–414nm) with 10-to 14-nm particle size. It was revealed that UV spectra at 438 nm wavelength gave particle sizes of 60–80 nm. The results obtained indicated that lower wavelengths of UV spectra at 383 nm recorded particle sizes of 1–25 nm at 28 °C [29].

All the UV–Vis spectra at different concentrations (1 mM, 2 mM, and 3 mM) for aqueous stem bark extract of *Boswellia papyrfera* silver nanoparticles presented the same symmetry in the absorption band, in the wavelength interval characteristic of silver nanoparticles. The position and shape of the surface plasmon absorption band are dependent on the size, shape, and polydispersity of the particles [30]. If the size of the particle increases, the absorption band tends to shift to a longer wavelength. Also, the number of absorption peaks increases as the symmetry of the nanoparticle decreases [31].

4.2 FTIR Analysis of Aqueous Stem Bark Extract *Boswellia papyrifera* AgNPs

An FTIR analysis was carried out to detect the possible biomolecules responsible for the reduction of the metal ions and the capping of these silver nanoparticles. The recorded FTIR spectrum of the synthesized silver nanoparticles shows three distinct peaks in the entire range of the recorded spectrum at both 3 mM and 2 mM and 1 mM. C=C bending of alkenes, N-H bending of primary amines, and C=O stretching vibration of carbonyl of amide are responsible for the bands at 1638 and 1640 cm-1 [32].The bands at 2122, 2113, and 2125 cm^{-1} were found within the range of 2203–2114 cm-1, which indicates CC stretch for alkynes [33], whereas a band obtained at 3257, 3260, and 3260 cm^{-1} was within the range of 3600–3200 cm-1, which indicates the O-H stretching of phenol [34]. The bioactive functional molecules like phenols, amines, etc. present in the aqueous stem bark extract of *Boswellia papyrifera* might be responsible for the reduction of silver ions and stabilize the colloidal particles during interaction.

4.3 Scanning Electron Microscopy analysis of the synthesized silver nanoparticles using aqueous stem bark extract of *Boswellia papyrifera*.

The SEM image (Figure.9) of the 1Mm, 2mM, and 3mM AgNPs obtained from the colloidal Ag solutions prepared at 80 C at magnification x 350, confirms the existence of very small nanoparticles, which was determined using a SEM (LEO 1430 VP) machine operating at 15, 10, and 20 kva, respectively. The scanning electron microscopy (SEM) image showed the shape of the nanoparticles formed (Figure 9). The SEM image recording from drop coated films of the Ag nanoparticles synthesized with aqueous stem bark extract of *Boswellia Papyrifera* silver nanoparticles (BP-AgNPs) formed spherical, cuboidal, and triangular shapes, which proved to be one of the characteristic features of nanoparticles. The SEM images show that larger particles of BP-AgNPs are formed due to aggregation of nanoparticles, which might be induced by the evaporation of solvent during sample preparation. This could have contributed to the variation in particle size. Among various electron microscopy techniques, SEM is a surface imaging method, fully capable of resolving different particle sizes, size distributions, nanomaterial shapes, and the surface morphology of the synthesized particles at the micro and nanoscales [35]. Using SEM, we can probe the morphology of particles and derive a histogram from the images by either measuring and counting the particles manually or using specific software [36].

4.4 Antimicrobial Activity of Synthesized Silver Nanoparticles using *Boswellia papyrifera* aqueous stem bark extract (BP-AgNPs)

The antibacterial activity of these biogenic silver nanoparticles was studied against two bacterial strains: *Streptococcus pneumoniea* and *Shigella dysentriea*. After 24 hours of incubation (at 37°C), inhibition zones were around the wells where colloidal suspensions of AgNPs were added and the control antibiotic (Ciprofloxacin) was measured. This confirmed the effective antibacterial property of the biogenic silver nanoparticles against these two bacterial strains. It was observed that the diameter of the inhibition zone is higher for gram-positive bacteria than for gram-negative bacteria. This may be due to the difference in the composition of their cell walls [37] [74]. Gram negative bacteria have a single layer of peptidoglycan in their cell membrane, whereas gram positive bacteria have a multilayer of peptidoglycan in their cell wall [38].The mechanism of action of silver nanoparticles is unclear, but previous research suggests that antibacterial activity is caused by the release of Ag+ions from silver nanoparticles when they come into contact with bacterial cells [39].The bacterial cell wall, with negative charges, attracts the silver cations [40]. When the Ag+ions have an electrostatic attraction, they move towards the bacterial cell wall and get attached to it. As a result, the composition of the cell wall varies rapidly, affecting the wall permeability. This further degrades cellular transport and causes the death of the cells [41]. Moreover, the MIC was done using the broth dilution method to observe the growth of bacteria in the solution. In this study, silver nanoparticles inhibited the growth of the bacteria at all three different concentrations of the synthesized silver nanoparticles by revealing negative results in all forms of the bacteria. The MBC was performed by culturing the content of the MIC to ensure the antimicrobial strength of the synthesized AgNPs. The MBC in this study confirmed the death of the bacteria by showing negative growth in all two bacterial strains used. This shows that the synthesized AgNPs of the aqueous stem bark extract of *Boswellia Papyrifera* (BP-AgNPs) have a great potential for inhibiting the growth and causing the death of tested microorganisms.

5 CONCLUSION

In this research, silver nanoparticles were biologically synthesized using aqueous stem bark extract of *Boswellia papyrifera.* The biologically synthesized silver nanoparticles were characterized using UV-visible specrophotometry, FTIR, and SEM and the biomolecules responsible for reducing and stabilizing the colloidal particles were identified. The morphology of the synthesized silver nanoparticles was also analysed using SEM analysis. The biosynthesized nanoparticles of aqueous stem bark extract of *Boswellia papyrifera* were found to have effective antimicrobial properties against two bacterial strains (*Streptococcus pneumoniea* and *Shigella dysentriea). This shows* that AgNPs of aqueous stem bark extract of *Boswellia papyrifera* have a broad spectrum of activity, which can make them be incorporated into various materials such as bandages, antimicrobial paint,

cutting boards, and surgical dressing materials, to control bacterial colonization on diverse materials to prevent infections. and can be used as a potential candidate for other biomedical applications and in drug discovery.

ETHICAL APPROVAL

This study does not contain any studies involving human or animal subjects.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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