https://doi.org/ 10.33472/AFJBS.6.5.2024. 730-753

African Journal of Biological Sciences

Phyto mediated Biogenic Synthesis of Silver Nano Particles using *Syzygium cumini* bark extracts and its bio efficacy on antimicrobial and hepatoprotective activity

Tara Shankar Basuri[1*], Ranjit Mohapatra[2], Sopan N. Kharat[3], Vipul D Prajapati[4], Dibyalochan Mohanty[5]

[1,2]Department of Pharmaceutical Sciences, Utkal University, Vani Vihar, Bhubaneswar – India.

[3]Department of Botany, Adarsh College of Arts, Commerce and Science, Hingoli

[4] Department of Pharmaceutics, SSR College of Pharmacy, Silvassa, U.T. of D.N.H. & D.D., India.

[5]Centre for Nanomedicine, Department of Pharmaceutics, Anurag University, Hyderabad, India.

Article History
Volume 6, Issue 5, Apr 2024
Received: 17 Apr 2024
Accepted: 24 Apr 2024
doi: ***10.33472/AFJBS.6.5.2024. 730-753***

ABSTRACT

The biosynthesis of silver nanoparticles, or AgNPs, has received increased attention recently because to their substantial potential in drug administration, catalysis, imaging, nano-device manufacturing, and medicine.We suggest creating silver nanoparticles by synthesizing plant extract of Syzygium cumini and assessing their antibacterial and chemocatalytic properties. Silver nitrate in aqueous solution is used to create AgNPs. The produced silver nanoparticles (AgNPs) were examined using Fourier transform infrared (FTIR), X-ray diffraction (XRD), transmission electron microscopy (TEM), UV-Vis spectroscopy, and EDX analysis. The UV–Vis absorption spectra of the generated AgNPs showed a large absorption peak between 375 and 390 nm. TEM analysis of AgNPs showed that they had a hexagonal matrix shape and an average particle size of about 30 nm. AgNPs. An XRD examination reveals the crystalline structure of AgNPs. EDX analysis verified the elemental silver's presence. Protein amide groups are significant reducing agents and are essential for the bio-reduction of Ag+ ions to Ag0, according to FTIR studies. In this work, the antibacterial and hepatoprotective properties of extracts from the medicinal plant Syzygium cumini are studied in relation to manufactured AgNPs. The biosynthesized AgNPs show strong antibacterial and hepatoprotective efficacy.

Keywords:AgNPs, Syzygium cumini, particle size, reducing agents, antibacterial, hepatoprotective.

1. Introduction

1.1. Nanotechnology

Nanotechnology is currently one of the most active fields of materials science study. The next industrial revolution has been named nanotechnology, based on the development of nanomaterials[1]. The compound term nano is derived from the Greek word "nanos," which meaning "dwarf." In mathematics, a nanometer is commonly defined as one billionth of a quantity or phrase[2]. One way to describe this is 1 x 10^{-9}, or simply 10^{-9}. It is the science of little things, encompassing almost all academic disciplines that are involved in comprehending the cosmos and functioning with materials at the atomic and molecular levels[3]. In his famous address at the California Institute of Technology on December 29, 1959, Nobel winner Richard Feynman first presented the idea of nanotechnology.Richard Feynman discussed the idea of nanoparticles in his 1960 book "There is plenty of room at the bottom." He pointed out that if all that was needed to hold a bit of information was just 100 atoms, then every book ever written could fit inside a cube with sides measuring just 0.02 inches. A Japanese researcher at the University of Tokyo named Norio Taniguchi coined the word "nanotechnology" in 1970. Taniguchi was primarily involved in the development of materials at the nanoscale level. Another technologist, K. Eric Drexler, highlighted the importance of nanotechnology in 1980. Solid colloidal particles with a size range of 10 to 1000 nm (1.0 μm) are known as nanoparticles. These include of physiologically active substances or active medications that have been dissolved, imprisoned, or on which the active ingredient has been adsorbed or bound. Nanotechnology and medicine share the same objective of using targeted and controlled drug delivery to treat patients as effectively and without side effects as possible and to diagnose as early and accurately as possible.[4] Nanoparticles are solid colloidal particles that range in size from 10 to 1000 nm (1.0 μm). Physiologically active compounds or active pharmaceuticals that have been dissolved, trapped, or on which the active component has been bonded or adsorbed are among them. Targeted and regulated drug delivery is used in both medicine and nanotechnology to treat patients as effectively and without side effects as possible and to identify them as early and correctly as possible. The characteristics of nanoscale particles are highly significant since they differ greatly from those of bulk scale particles. Large molecules, micelles, colloids, aggregation molecules, and polymer molecules are all related to the size range in chemistry. The most common links between electrical engineering, physics, and nanoscience are related to quantum and electron behaviour in small structures. As biological molecules like DNA, RNA, and subcellular organelles can be thought of as nanostructures, biology and biochemistry have also been closely linked to nanoscience[5]. The use of nanoscale structures in medication administration, gene sequencing, and diagnostics is creating the

nanotechnology-biomedical engineering interface. The Royal Society and Royal Academy of Engineering define "nanotechnology" as "the design, characterisation, production, and application of structures, devices, and systems by controlling shape and size at nanometre scale," or "the study of phenomena and manipulation [6]of materials at atomic, molecular, and macromolecular scales, where properties differ significantly from those at a larger scale." Through meticulous atomic and molecular manipulation of matter, distinct particles can be created.By carefully modifying matter at the atomic and molecular level to create particles with unique physico-chemical properties that enhance conductivity, strength, durability, reactivity, or other properties of products and applications, nanotechnology[7] is used to create new materials and products at the nanoscale. Nanotechnology[8] has the potential to significantly minimize environmental impact and save energy. Currently, there are over 800 consumer products on the market that include nanotechnology in some way[9]. According to estimations, the nanotechnology industry, currently valued in the billions of dollars, is expected to reach $1 trillion by 2015[10] and $3 trillion by 2018[11]. Currently, the globe produces millions of tonnes of nanomaterials each year, and in the near future, there will probably see a big rise in output.

1.2. Nanomaterial types

Both inorganic and carbon-based materials, such as fullerenes and nanotubes, can be used to create nanomaterials. Metals (iron, zinc oxide, cerium oxide, gold, and silver), metal oxides (titanium dioxide, iron oxide, zinc oxide, and cerium oxide), and quantum dots (cadmium sulfide and selenium) are some examples of these.[12]

1.2.1. Natural nanoparticles

Naturally occurring nanoparticles (1 to 100 nm) as suspended particles smaller than 25 nm are seen in aquatic surface and ground water[13, 14, 15]. Viruses, polysaccharides, and bacterial exudates are a few examples of complex nanostructured proteins that are present in biological systems and govern a range of biological activities. In addition to sea spray, volcanoes, fires, and rock weathering[16], other sources of nano-sized components include microbial activity and chemical hydrolysis[17].

1.2.2. Anthropogenic nanoparticles

Anthropogenic nanoparticles, sometimes referred to as accidental or adventitious, have existed since the beginning of human civilization. However, because of inorganic nanomaterial emissions from human activity, the amount of naturally occurring nanoparticles in the atmosphere has increased by almost twofold[18]. According to a recent definition, nanomaterials include colloids found in soil, which include clays, organic matter, iron oxides, and other minerals crucial for biogeochemical processes; ultrafine particles found in the air, which include nanomaterials from stationary combustion sources and diesel and gasoline-

fueled vehicles; and colloids found in water, which include macromolecules, humic and fulvic acids, proteins and peptides, and hydrous iron and manganese oxide[19].

1.2.3. Carbon based nanomaterials

Applications for carbon-based nanomaterials include biology, electronics, and optics.

1.2.3.1. Fullerenes

Fullerenes are carbon compounds consisting of sixty atoms. The poor solubility of fullerenes and their derivatives in biofluids[20] restricts their use in the field of medicine. Nevertheless, they have drawn the interest of numerous scientists because to their many fascinating applications in this field, and early research has examined their effects on apoptosis, DNA photocleavage, neuroprotection, HIV protease inhibition, and other biological aspects[21].

1.2.3.2. Carbon nanotubes

The cylindrical carbon particles known as carbon nanotubes, or CNTs, have a diameter of one to ten nanometers and a length of several micrometres. They can have many walls or just one wall (SWCNT or MWCNT). They have been employed as microelectrodes in electrochemical processes, supports for heterogeneous catalysis, nanoprobes in atomic force microscopy, electron field emitters, and are presently being investigated as potential hydrogen storage devices[22]. They have applications outside of the manufacturing sector and are strong yet adaptable (i.e., aircrafts, sports equipment, etc.).

1.2.4. Metal oxide nanoparticles

The natural environment contains significant concentrations of iron oxide nanoparticles[23]. In order to facilitate successful transport of the desired gene and release inside the cell, gene therapy, clinical diagnostics, drug delivery, magnetic resonance imaging, and other uses, they have already been employed as contrast agents[24,25,27,28]. For nanobiotechnological applications, their super magnetic characteristics and relatively low toxicity make them perfect[29]. Zinc oxide nanoparticles are conventional band gap semiconductors, meaning that they have an energy range in a solid where there are no electron states. These nanoparticles have drawn attention due to their potential applications in sunscreens, chemical sensors, solar cells, water remediation technologies, electronic devices, antimicrobials, and cosmetics[30]. Their capacity to block UV-A and UV-B radiation while maintaining optical transparency has also drawn research attention[31,32].Titanium dioxide has attracted a lot of interest[33,34,35] for application in photocatalytic activity[36] and photocells[37] because of its stability and affordability. TiO2 particles can also be found in other products energy storage devices[38], paints and coatings[39,40] and sunscreens. Three crystalline phases—rutile, brookiteand anatase can be produced from TiO2[41,42].

1.2.5. Metal nanoparticles

1.2.5.1. Zero-valent iron nanoparticles

Usually employed in bioremediation processes, zero-valent iron nanoparticles have a size-dependent ability to partially break down and adsorb pollutants[43, 44]. Their enormous volume to surface area boosts their efficacy and raises the quantity of electron transfer required to eliminate dangerous atoms.

1.2.5.2. Silver nanoparticles

Because of its extraordinary and distinctive qualities, including as conductivity, chemical stability, catalytic activity, nonlinear optical behaviour, and antibacterial activity[45], silver nanoparticles have been the subject of a significant lot of research. Their characteristics enable their employment in a multitude of applications, such as bacterial disinfectants for use in infusion systems, catheters, etc.[46]microelectronics[47], medical textiles[48], and inks. Since consumers value antibacterial qualities, adding silver nanoparticles to products like plastics, apparel, lotions, and soaps boosts their commercial value. The cost of producing silver nanoparticles is likewise reasonable. Currently, more consumer goods include silver than any other nanomaterial[49]. Because of their ability to be implanted in a variety of textiles and their antibacterial qualities, silver nanoparticles have multiple applications in hospitals.These include medical bandages, burn treatment dressings, and surgical dressings[50]. Silver nanoparticles are being used in an increasing number of domestic appliances, such as refrigerators, washing machines, and food containers, to prevent surface mold growth[51]. It has been demonstrated that washing socks containing embedded silver nanoparticles reduces the quantity of silver released into the atmosphere [52, 53]. In a similar vein, water filtering anti-fouling membranes may leak silver[54]. Due to their optical responses to environmental pollutants, such as the potential for silver nanoparticles to be utilized as herbicide detectors, gold and silver have demonstrated promise as environmental sensors[55]. Zero-valent iron can be utilized to build subterranean reactive barriers, which can be used to treat contaminated groundwater[56]. Ohio State University researchers are utilizing polymer semiconductors, which are solar energy absorbers with the capacity to produce electricity. They have found that the plastic's ability to generate electrical current is increased when small amounts of silver are added[57].

1.2.5.2.1 Importance of silver nanoparticles

1) Because of their special chemical and physical characteristics, silver nanoparticles are used in military, medicinal, and cosmetic applications. The characteristics of nanoscale particles areoften marginally different from those of their bulk counterparts[58].

2) It is used in medication delivery systems, biosensing, imaging, and air filtration and quality control.

3) There are many applications for organically produced silver nanoparticles, including antimicrobials, optical receptors, chemical reaction catalysts, solar energy absorption coatings, and biolabeling. They are also utilized in electrical batteries as an intercalation material[59].

4) Silver nanoparticles are helpful in several areas, such as microelectronics, antimicrobials and therapies, high sensitivity biomolecular detection, and catalysis, despite their cytotoxicity.

5) A number of well-known producers of consumer goods are already creating household products that take advantage of silver nanoparticles' antibacterial qualities. These goods include air conditioners, washing machines, and refrigerators with nano silver inside[60].

6) Because silver nanoparticles are antibacterial, a number of new items have been developed, including antibacterial dryers, toothpaste, and soap, sheets that lessen the smell of textiles (especially socks), and apparel that has been infused with nanoparticles.[61]

The metabolism and detoxification of toxins that enter the body and have the potential to damage the liver and cause catastrophic diseases are two of the liver's many essential tasks. As a result, important toxicological problems associated with some illnesses have centered on how they

2. Materials and Methods

2.1 Collection, authentication and processing of plant materials

The plant materials will be either collected from the field or purchased from the market. The herbarium will be prepared and preserved for the herbs collected from the field and the material will be authenticated by a taxonomist. For the samples procured from the market, authentication will be done by performing morphological and microscopical studies and comparing the observations with those reported in the literature. The plant material will be dried at a temperature not exceeding 50°C and then coarsely powdered[62]. The material will be stored in an airtight container protected from light at room temperature.

2.2 Preparation of extracts of plant materials

The different extracts of the drug will be prepared by different extraction techniques such as soxhlet extraction, hot maceration etc. The extracts will be separated from the marc by filtration, concentrated to dryness and stored at -20°C until further use[63].

2.3 Synthesis of silver nanoparticles by using plant extract[64]

Plant extract (0.1 g) will be vigorously stirred for 4 hours after being introduced to 20 mL of distillation deionized water. Following that, forty milliliters of AgNO3 (1 × 10−3 M) will be added and stirred for 24 hours at room temperature (25°C). Ag-NPs will be acquired gradually throughout the course of the incubation time. Throughout the reduction process, the

solution will be kept at room temperature and in the dark to avoid any photochemical reactions. Before being used, nitrogen gas is used to cleanse the solution component. After that, reduction took place with nitrogen present in order to remove oxygen[65]. Following a 20-minute centrifugation at 15,000 rpm, the resulting colloidal suspensions of Ag/plant extract will be rinsed four times to eliminate any remaining silver ion residue. The Ag/plant extract[66] will then be obtained by vacuum-drying the precipitate nanoparticles for an entire night at 30°C.

2.4 Characterisation of plant extract mediated silver nanoparticles[67]

2.4.1 UV-Vis Spectroscopy

In this study, the absorption of nanoparticles in the UV-visible spectral region will be determined using ultraviolet-visible spectrophotometer (UV-Vis -Model Lab India, UV3200). In other words, it utilizes light ranging from visible to near-UV and near-infrared (NIR) spectrum. Absorption in the visible range directly affects the compounds' perceived color. Molecules change electrically in this area of the electromagnetic spectrum.

2.4.2 Scanning Electron Microscope (SEM) Analysis

Scanning Electron microscope (SEM) Scanning Electron Microscope (SEM) analysis will done using SEM machine. The SEM equipment will be used for analysis utilizing a scanning electron microscope (SEM). To make thin films, a small portion of the sample will be deposited onto a copper grid covered in carbon. After using blotting paper to remove any remaining solution, the film on the SEM grid will be exposed to a mercury light for five minutes to dry[68]. The SEM analysis was done using HITACHI, S3700 N Model.

2.4.3 Fourier Transmission Infra-Red Spectroscopy (FTIR)

FTIR is a chemical analysis technique that calculates the infrared intensity of light in relation to its wavelength or wave number. It will be applied to the analysis of the biomolecule and the bonding interactions among the silver nanoparticle molecules. IR spectroscopy is used to determine the vibrational characteristics of the chemical functional groups in the sample. When infrared light interacts with matter, chemical bonds will display bending, stretching, and contracting behaviors. This chemical functional group has a tendency to absorb infrared light within a particular wave number range of the remaining molecule's structure[69].FTIR analysis was performed using 2-3 drops of colloidal solution synthesized silver nanoparticles; it was mixed with KBr powder for moisture absorption in a clean mortar and pestle. This method was also used for the plant extract. FTIR analysis was carried out using Shimadzu, 8400 S spectrum model.

2.4.4 X-Ray Diffraction (XRD) Measurements

The phase formation of bio-reduced silver nanoparticles will be investigated using XRD. The diffraction data of fully dried nanoparticle thin films on glass slides will be captured with an

X-ray diffractometer[70]. XRD analysis was performed using colloidal solution of synthesized AgNPs. The diffraction pattern of XRD (XRD – Bruker D8 model) was recorded on the angle range of 20° to 80°. XRD method was used for the determination of crystalline structures and the positions as well as intensities of diffraction pattern.

2.4.5 Transmission electron microscopy (TEM)

Transmission electron microscopy (TEM) was used to confirm the morphology of the produced AgNPs. The sample was prepared using *Syzygium cumini* extract and AgNPs (Phytosynthesized). The TEM analysis was performed using (JOEL, JEM-F200 model) a drop of synthesized silver nanoparticles colloidal solution, it was exposed to infrared light (30 min) up to the sample evaporation.

2.4.6 Zeta potential analysis

Zeta potential was measured with the Malvern Zetasizer instrument for the zeta potential analysis sample was prepared using mixer of AgNPs colloid solution in zeta dip cell. Using this type of analysis the potential stability of the colloidal system and noble properties was confirmed.

2.5 Evaluation of Antibacterial activity

The antibacterial activity of the plant extracts as well as synthesized AgNPs will be assessed using agar diffusion method. By spreading the bacterial inoculums on the media[71], nutrient agar will be inoculated with the specified microorganisms, including *Staphylococcus aureus, Escherichia coli,* and *Aspergillus niger, Aspergillus flavus*. Using a sterile cork borer, wells will be punched into the agar and then filled with plant extracts (10 mcg/disc) a common reference antibiotic, will be utilized as controls for the examined bacteria. Following a 24-hour incubation period at 37° C, the diameter of the zone of inhibition will be utilized to measure the antibacterial activity of the plates. By comparing the zones of inhibition of the various extracts, the antibacterial capability of each will be assessed.

3. Result and Discussion

3.1. Preparation of Extracts

The Plant material for present analysis was collected from local area of Baripada.*Syzygium cumini* barks are washed for 15-minute rinse under running water, they were allowed to air dry for two days under shade. Using a hand grinder, dry barks were pounded into fine powder[72].Afterwards, the bark powder was placed in a 500 ml Erlenmeyer flask, 100 ml of double-distilled water was added, and a magnetic stirrer was used to continually stirred the mixture for ten minutes[73].First, the extract was run through Whatman filter paper No. 1. (**Fig.1**) After being collected, the filtrate was kept at 4°C and used in all subsequent experiments[74].

Figure.1. (a) Powdered bark of Syzium cumini (b) powder bark material and distilled water mixed with the help of magnetic stirrer (c) plant extract

3.2. Synthesis of Silver nanoparticles

10 mL of the bark extract was combined with 50 mL of aqueous silver nitrate (1 mM) while being constantly stirred. A visible shift in colour from colourless to yellowish-brown(**Fig.2**) indicates the formation of AgNPs[75].

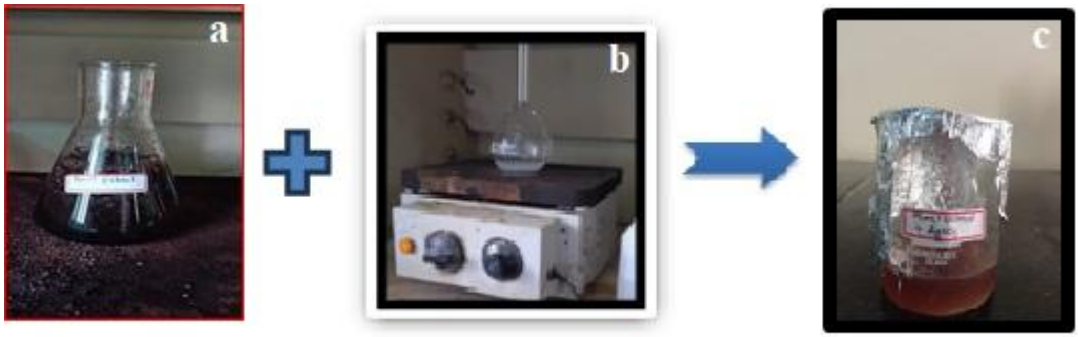


Figure.2. (a) Plant extracts (b) 1mM AgNO3 (c) silver nanoparticle formation

3.3 UV-Visible spectroscopy

To track the optical properties and electrical structure of the generated nanoparticles and learn more about how AgNPs are made, UV-visible spectroscopy is a helpful tool. A nanoparticle's electron cloud may vibrate on its surface when it absorbs electromagnetic waves at a particular frequency[76]. Surface plasmon resonance, or SPR, is the name given to this phenomenon, which the UV-Vis spectrophotometer records as electromagnetic wavelengths. Fig. 3 shows the optimization of incubation duration during the synthesis of AgNPs. UV wavelengths of SGC-AgNP-B (AgNPs from Bark extract) were measured from 15 minutes to 24 hours of incubation based on the spectra. As the incubation period increased, the peaks became more intense. The wavelength absorbance increases in intensity due to the increasing amount of nanoparticles created by the reduction of silver ions and biomolecules in the aqueous plant extract solution. With extract concentrations of 2%, 4%, 6%, 8%, and 10% (v/v), the analysis for extract concentration was carried out for 24 hours at 25°C. The produced SGC-AgNP-B peaks were detected at wavelengths ranging from 375 nm

to 390 nm. The peak's sharpness suggests that the synthesized AgNPs have formed a spherical shape and are distributed uniformly[77].

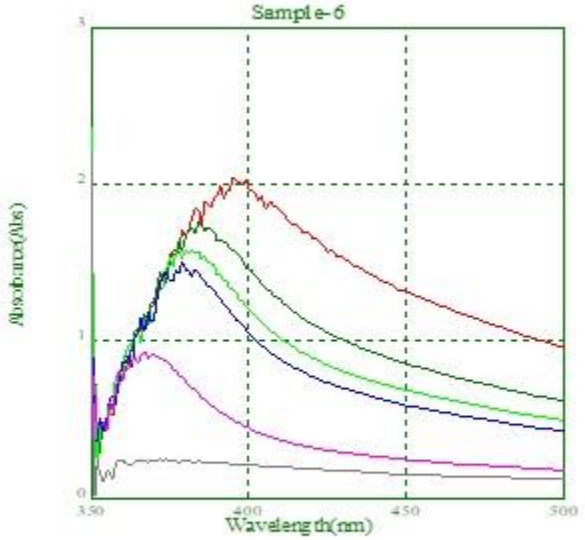


Figure.3. UV-Visible spectra of silver nanoparticles of aqueous bark extract of *Syzygium cumini*

3.4. FT-IR Spectroscopy SGC-Plant extract and AgNPs

FT-IR spectrum investigation verified the SGC interaction on the SGC-AgNPs[78] surface. The IR spectrum of SGC showed intense bands at 3329, 2130, 1636, 620 cm−1 (Fig. 4) and that of SGC-AgNPs showed intense bands at 3325, 2139, 1636, 592and 577 cm-1 (Fig.4). The significant difference observed between the of FT-IR bands of SGC and SGC -AgNPs was due to the reduction process. The stretching vibration mode of –OH groups in SGC was identified by a strong and intense band centered at 3325 cm−1 (Fig. 4a & 4b), while the stretching vibration of C–H groups was identified by another band at 2139 cm−1.

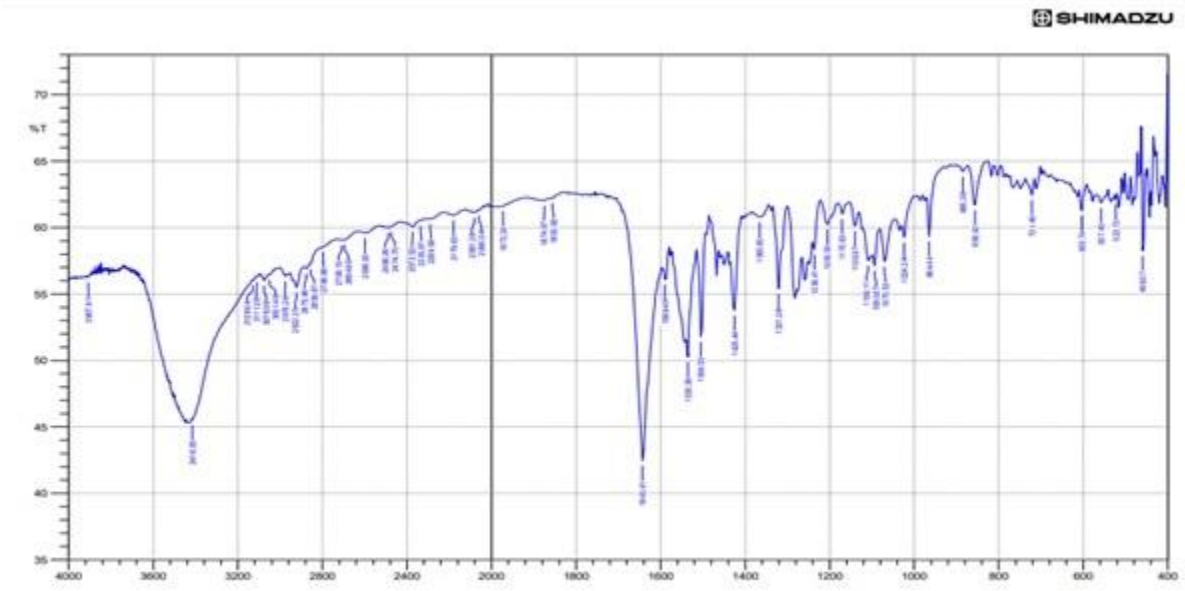


Figure 4a. FT-IR Spectroscopy SGC plant Extract

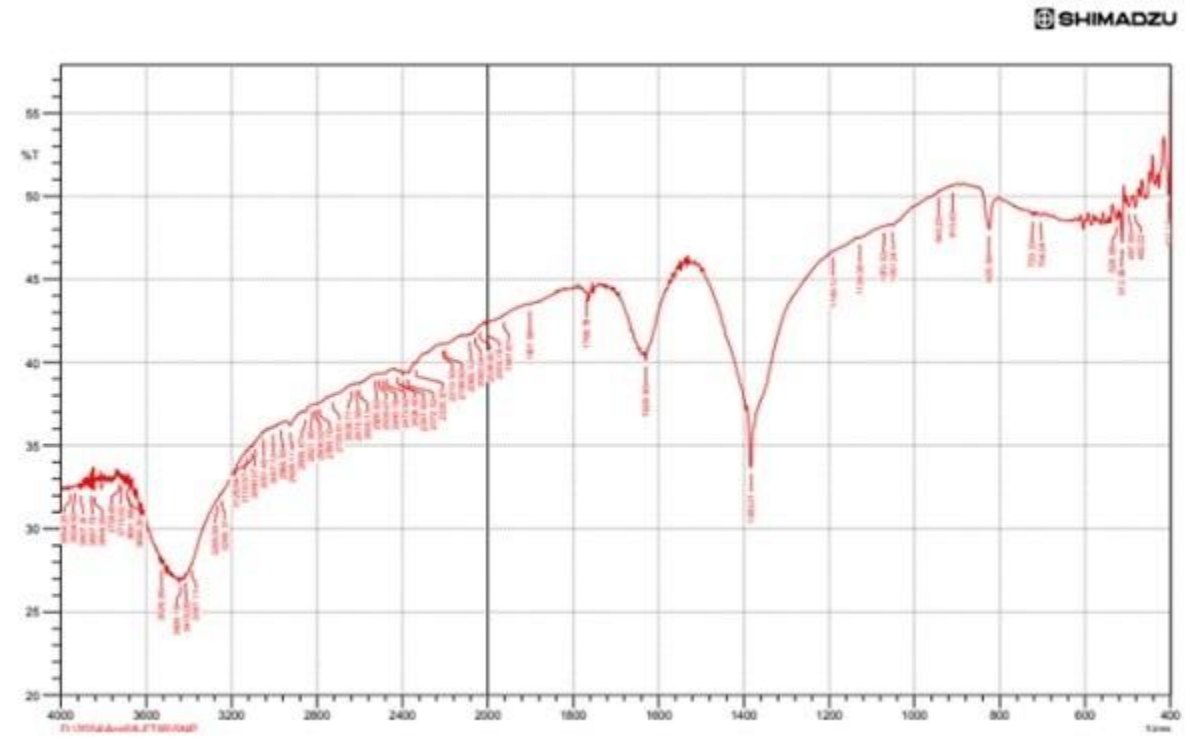


Figure 4b. FT-IR Spectroscopy SGC- AgNPs

3.5. X-Ray Diffraction (XRD)

Various Bragg reflections clearly showed the presence of (13), (18.9), (20.1), and (24.9) sets of lattice planes that may be indexed to a face-centered-cubic (fcc) structure for silver in the XRD pattern of the SGC-AgNPs, as shown in Fig. 5.Therefore, it is evident from the XRD pattern that the SGC-AgNPs that were produced were primarily crystalline in character. Apart from the Bragg peaks that are indicative of fcc AgNPs, there were also unassigned peaks that were found, which indicated the formation of a bioorganic phase crystal on the surface of SGC-AgNP.

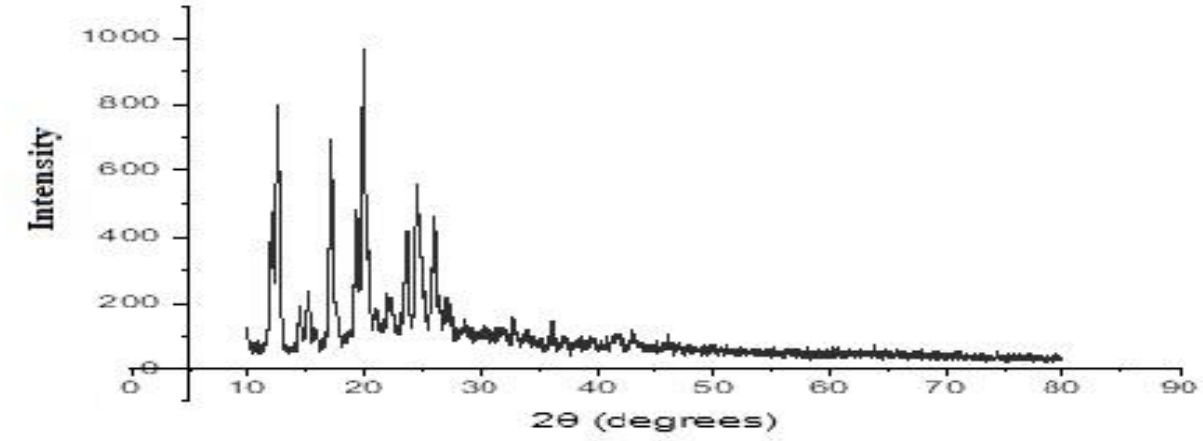


Fig. Figure 5. X-ray diffraction of AgNPs in *S. cumini*

3.6. SEM Analysis SGC-AgNPs[79]

The material becomes colloidal with the electrons inside it that are knocked out of their orbit when it is exposed to an electron beam inside a scanning electron microscope (SEM), according to SEM analysis. SEM morphology obtained from the present analysis Nano crystals was identified (**Fig. 6**).

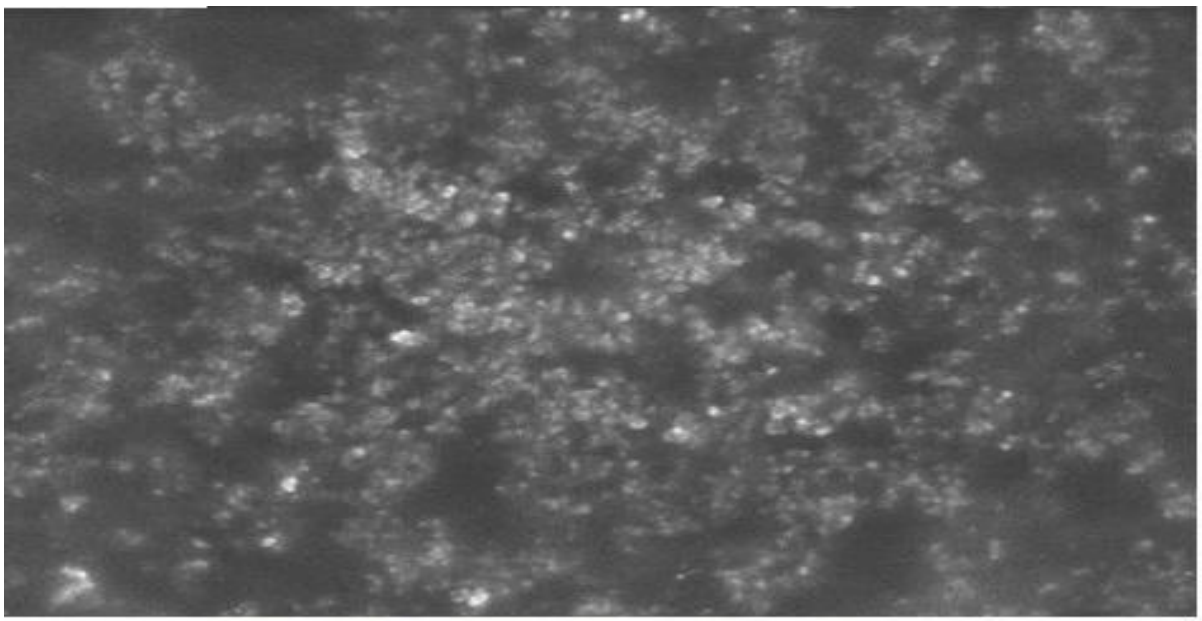


Figure 6. SEM Analysis SGC-AgNPs

3.7. DLS (Particle size) and zeta potential of SGC-AgNPs

The data of Dynamic light scattering studies[79]indicated uniformity in the distribution of particles and the average size of the DLS-AgNPs (**Fig. 7a**) to be 30 nm. The PDI is 0.507 The stability of the SGC-AgNPs was inferred from zeta potentiometer measurements. A zeta

potential value of -18.1 mV (**Fig. 7b**) essentially indicated avoiding of aggregation of nanoparticles in suspension.

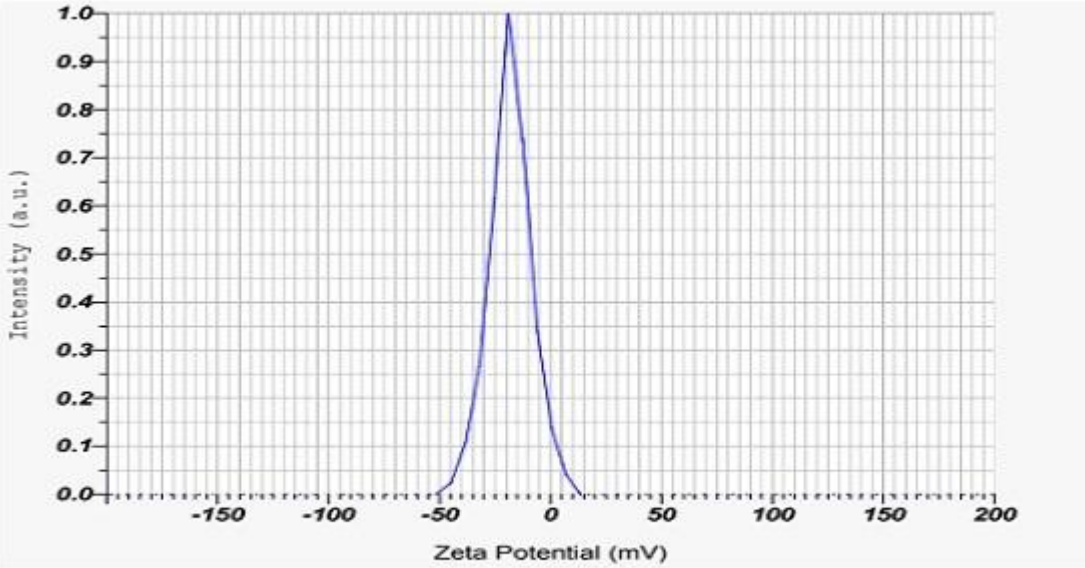


Figure 7a. Zeta Potential of SGC-AgNPs

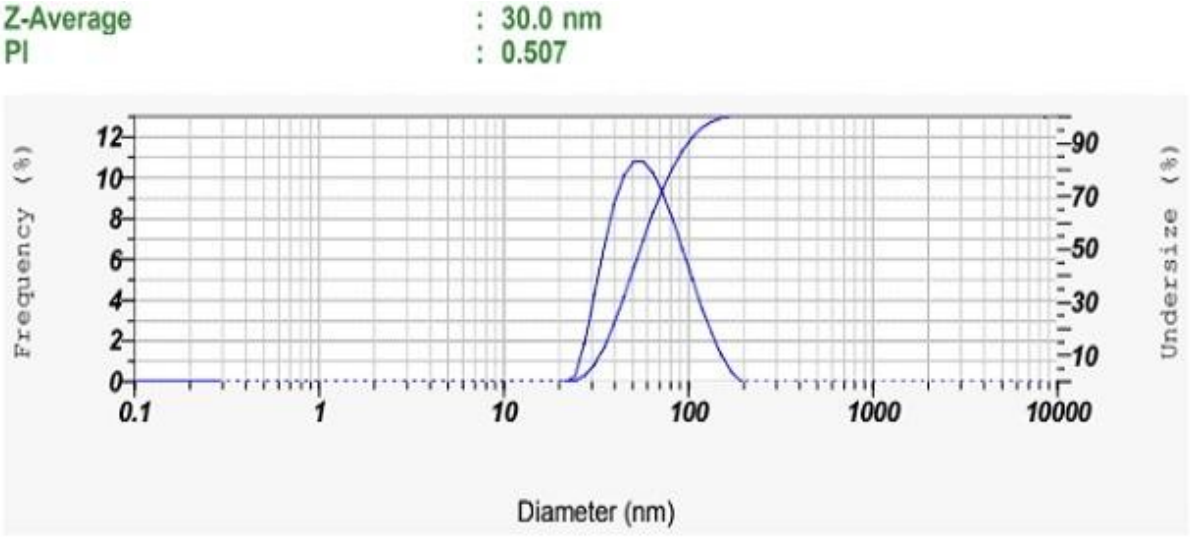


Figure 7b. Particle size of SGC-AgNPs

3.8. TEM images of SGC-AgNPs

Using TEM analysis the shape, size and morphology was confirmed. The TEM investigation verifies that the produced AgNPs were spherical and ranged in size from 20 to 200 nm. The TEM images[80]of SGC-AgNPs are shown in **Fig.9**. From the 100 nm magnification of nanoparticles the morphology of SGC-AgNPs was found to be spherical in shape. The DLS-AgNPs size distribution histogram showed a broad particle size distribution with nanoparticle sizes of 30 nm (Fig. 8).

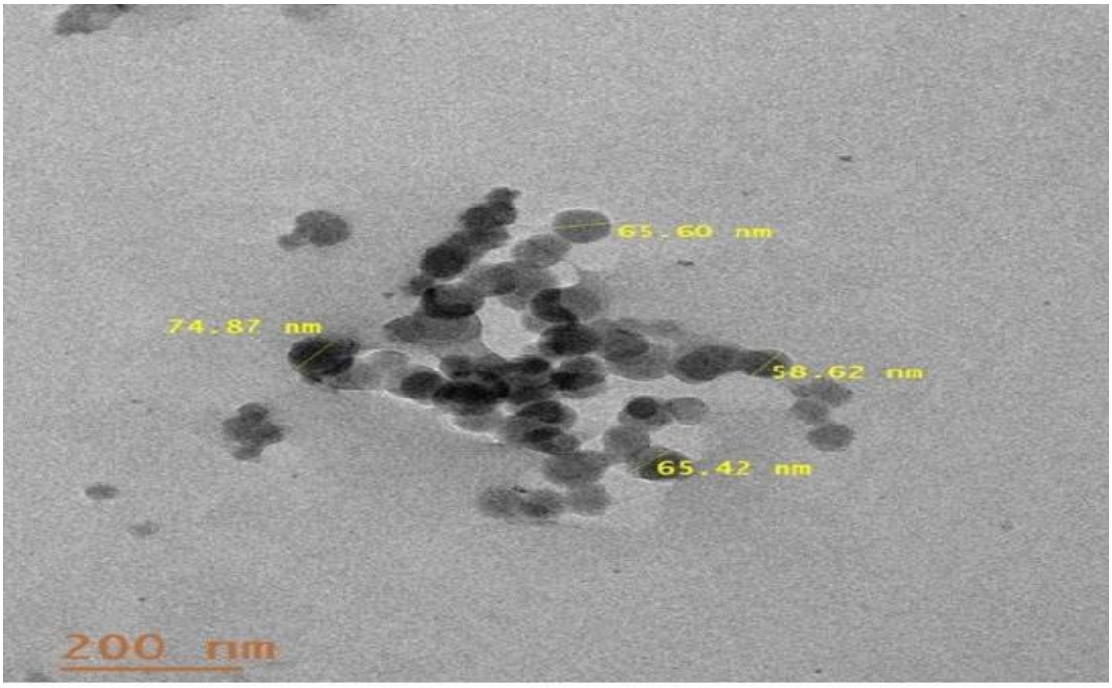
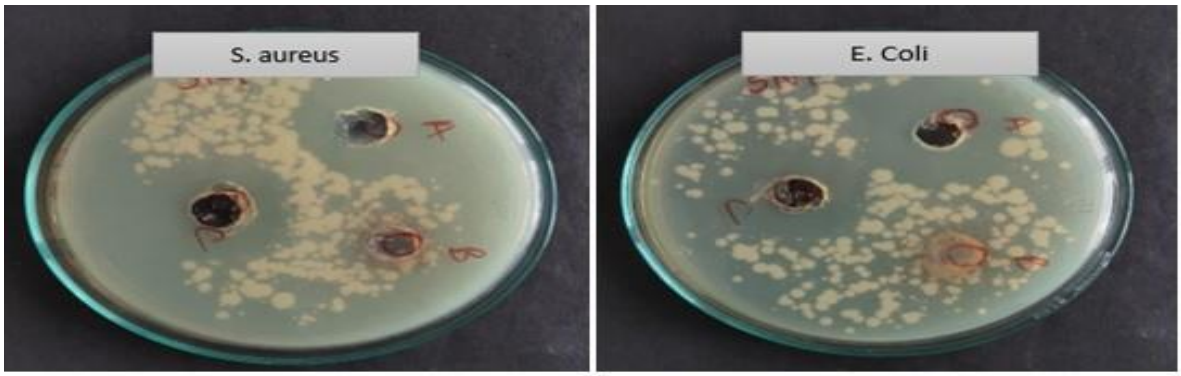


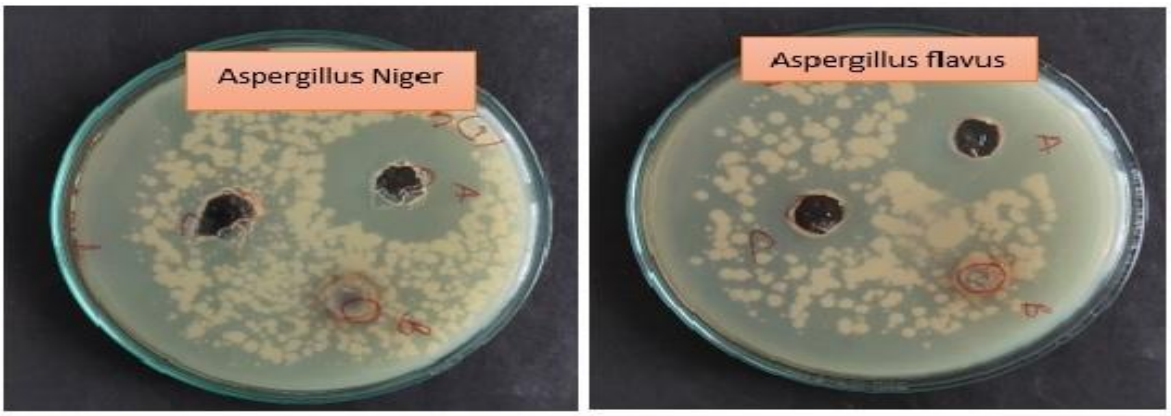
Figure 8. TEM Image of SGC-AgNPs

4.0AntimicrobialactivityofSGC-AgNPs

Table 1 and Figure 9 report the findings of an Agar well diffusion method test of antibacterial activity[81] against four selected pathogens *S. aureus, E. coli, A. niger, and A. flavus*. The results showed that the zone of inhibition of SGC-AgNPs was often higher than that of SGC and standard. Maximumzoneofinhibitionof 22 ±0.9mmwasobservedagainst*S.aureus*at 100µg/mLconcentrationsofSGC-AgNPs,whilestandardAmpicillin showedonly 8.1± 0.1mm(**Table1**&**Fig. 9**).Thezones of inhibitions of SGC-AgNPs against other microorganisms are*E. coli*(16 ± 0.6 mm),the fungal strain showed zone of inhibition *A. niger* (14 ± 0.3mm),and *A. flavus*(13 ± 0.4 mm) whilestandardKetoconazole showedonly 7.9± 0.9 mm(Table1).The zone of inhibition was nearly two fold in the case oftested microorganism for SGC-AgNPs when compared to standardgentamicinat thesame concentration. Although the precise mechanism underlying SGC-AgNPs' bactericidal impact is unknown, it has been hypothesized that the particles may adhere to the pathogen's cell membrane and interfere with vital processes like respiration and permeability. The surface area available for interaction determines how well SGC-AgNPs bind to bacteria; smaller particles with greater surface area available for interaction will have greater antibacterial and antioxidant effects than bigger particles[82,83].The manufactured nanoparticles' comparatively smaller size allowed them to adhere to the bacterium's cell wall more easily, creating disruption that ultimately resulted in cell death. Furthermore, it has previously been documented that the size of the particles may have an impact on the antibacterial properties of silver nanoparticles.



Zone of inhibtion against bacterial strains- A- AgNPs, B- Plant extract & C- Ampicillin (Std.)



Zone of inhibtion against fungal strains- A- AgNPs, B- Plant extract & C- Ketoconazole (Std.)

Figure 9. Antimicrobial activity of SGC-AgNPs

5.Hepatoprotective activity

Normal control animals' livers' histopathological sections (**Figs. 10.A & B**) showed a typical hepatic architecture with discrete hepatocytes and sinusoidal spaces. The hepatic architecture was disturbed in the CCl4-intoxicated group, suggesting an anomaly inside the hepatic cells. (Fig. 10C & D).Mild sinusoidal hemorrhages were observed in sinusoidal spaces of liver.In the liver's portal, periportal, and centrilobular regions, hepatocytes had normal morphology (arrow). After receiving regular treatment, the liver showed no abnormalities at all (Fig. 10E & F).Hepatocytes are appeared normal and normal hepatic architecture was restored after treatment with extract of silver nanoparticles (Fig. 10G & H).

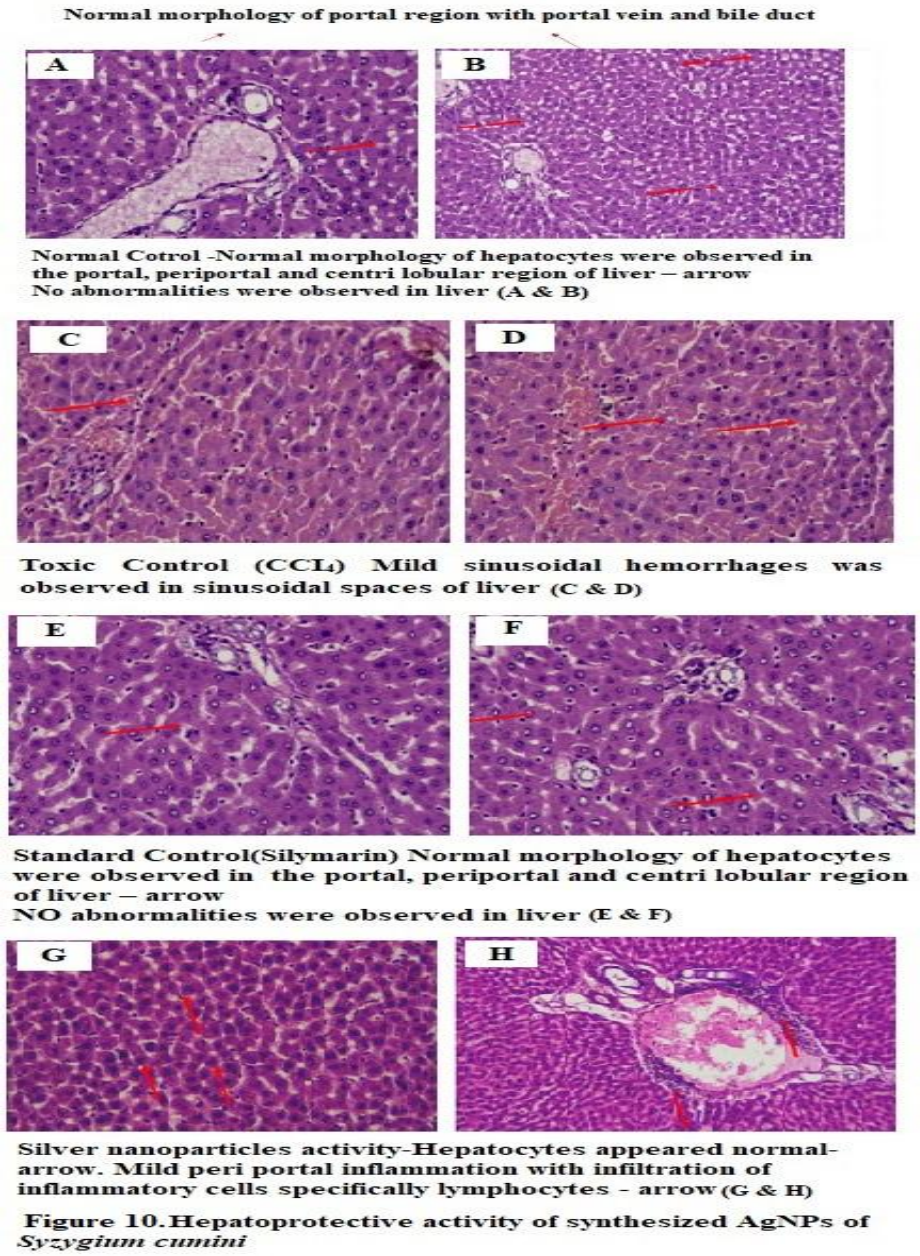


Figure 10.Hepatoprotective activity of synthesized AgNPs of *Syzygium cumini*

CONCLUSION

Using *S. cumini* aqueous bark extracts as a unique reducing and stabilizing agent of silver salts, the present work offers a straightforward, innovative, and effective synthesis of silver nanoparticles. Ag-NPs that were biosynthesized showed surface plasmon resonance, as demonstrated by UV-Vis spectral analysis. The produced Ag-NPs' size is less than 30 nm, according to the DLS and TEM image investigations. For biosynthesized Ag-NPs, the zeta potential value was (-18.1 mV), showing the nanoparticles' stability.Based on FT-IR spectra, it was discovered that the heterocyclic water-soluble chemicals detected in the *S. cumini* aqueous extracts were the biomolecules that capped and stabilized Ag-NPs. The zone of inhibition was nearly two-fold in the case of tested microorganism for SGC-AgNPs when compared to standard gentamicin at the same concentration. Present studies will help us to access the antibacterial and hepatoprotective activities of the synthesized Ag-NPs. Results

obtained from present analysis it is concluded that this method is quick cheap and economic. *S. Cumini* extracts has great medicinal value which were further focused on the biomedical and pharmaceutical applications of the synthesized Ag-NPs. The biomedical and pharmaceutical sectors will benefit from the easy promotion of medication delivery by the synthesis of phyto-medicated Ag-NPs from medicinal plants utilizing a biological technique at a marketable level. Researchers studying nanobiotechnology will gain more understanding from these kinds of investigations.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Ethical Review Board of Jeeva life Sciences with approval no. CPCSEA/IAEC/JLC/20/11/23/067

ACKNOWLEDGEMENT

The authors thanked to the UDPS, UtkalUniversity, Vanivihar for carry out present experiment.

AUTHORS CONTRIBUTIONS

All the authors have contributed equally.

CONFLICT OF INTERESTS: Declared none.

REFERENCES

1. Suresh K.P. Gavhane A.J. Padmanabhan P. *et al*.: 'Synthesis of silver nanoparticles using extract of neem leaf and triphala and evaluation of their antimicrobial activities', *Int. J. Pharm. Biol. Sci.*, 2012, 3, (3), pp. 88 –100.
2. Sangiliyandi G. Zhi- Guo L. Xi- Feng Z. *et al*. 'Silver nanoparticles: synthesis, characterization, properties, applications, and therapeutic approaches', *Int. J. Mol. Sci.*, 2016, 17, pp. 19 –34
3. Jeyasundari J. Praba S.P. Vasantha V.S. *et al*.: 'Synthesis of plant mediated silver nanoparticles using *Ficus microcarpa* leaf extract and evaluation of their antibacterial activities', *Eur. Chem. Bull.*, 2015, 4, (3), pp. 116 –120.
4. Yun Y.S. Lee S.Y. Krishnamurthy S. *et al*.: 'Biosynthesis of gold nanoparticles using *Ocimum sanctum* extracts by solvents with different polarity', *ACS Sustain. Chem. Eng.*, 2016, 4, (5), pp. 2651 –2659.
5. Katiyar D. Singh V. Ali M.: 'Recent advances in pharmacological potential of *Syzygium cumini*: a review', *Adv. Appl. Sci. Res.*, 2016, 7, (3), pp. 1 –12
6. Mukhopadhyay K. Chaudhary B.: '*Syzygium cumini* (L.) Skeels: a potential source of nutraceuticals', *Int. J. Pharm. Biol. Sci.*, 2012, 2, (1), pp. 46 –53
7. Singh N. Gupta M.: 'Effects of ethanolic extract of *Syzygium cumuni* (Linn) seed powder on pancreatic islets of alloxan diabetic rats', *Ind. J. Exp. Biol.*, 2007, 45, pp. 861 –867

8. Ahsan N. Paul N. Islam N. *et al*.: 'Leaf extract of *Syzygium cumini* shows anti- vibrio activity involving DNA damage', *J. Pharm. Sci.*, 2012, 11, (1), pp. 25 –28.
9. Siti- Azima A. Noriham A. Nurhuda M.: 'Antioxidant activities of *Syzygium cumini* and *Ardisia elliptica* in relation to their estimated phenolic compositions and chromatic properties', *Int. J. Biosci. Biochem. Bioinform.*, 2013, 3, (4), pp. 314 –317.
10. Chan K. Shaw D. Simmonds M.S. *et al*.: 'Good practice in reviewing and publishing studies on herbal medicine, with special emphasis on traditional Chinese medicine and Chinese materia medica', *J. Ethnopharmacol.*, 2012, 140, (3), pp. 469 –475.
11. Ahmed S. Ikram S.: 'Silver nanoparticles: one pot green synthesis using *Terminalia arjuna* extract for biological application', *Int. J. Pharm. Sci. Res.*, 2015, 6, (1), pp. 14 –30.
12. Ahmed S. Annu Zafeer I. Ikram S.: 'One- step method for formation of silver nanoparticles using *Withaniasomnifera* extract for antimicrobial activities', *J. Bionanosci.*, 2016, 10, (1), pp. 47 –53.
13. Nazeema T.H. Sugannya P.K.: 'Synthesis and characterisation of silver nanoparticle from two medicinal plants and its anticancer property', *Int. J. Res. Eng. Technol.*, 2014, 2, (1), pp. 49 –56.
14. Balaji D.S. Basavaraja S. Deshpande R. *et al*.: 'Extracellular biosynthesis of functionalized silver nanoparticles by strains of *Cladosporium cladosporioides* fungus', *Colloids Surf. B, Biointerfaces*, 2009, 68, (1), pp. 88 –92.
15. Mukherjee P. Ahmad A. Mandal D.: 'Fungus- mediated synthesis of silver nanoparticles and their immobilization in the mycelial matrix: a novel biological approach to nanoparticle synthesis', *Nano Lett.*, 2001, 1, (10), pp. 515 –519.
16. Kim J.S. Kuk E. Yu K.N. *et al*.: 'Antimicrobial effects of silver nanoparticles', *Nanomedicine*, 2007, 3, pp. 95 –101.
17. Gajbhiye M. Kesharwani J. Ingle A. *et al*.: 'Fungus- mediated synthesis of silver nanoparticles and their activity against pathogenic fungi in combination with fluconazole', *Nanomedicine*, 2009, 5, pp. 382 –386.
18. Philip D.: 'Mangifera *indica* leaf- assisted biosynthesis of well dispersed silver nanoparticles', *Spectrochim. Acta A, Mol. Biomol. Spectrosc.*, 2011, 78, (1), pp. 327 –331
19. Velmurugan P. Lee S. Iydroose M. *et al*.: 'Pine cone- mediated green synthesis of silver nanoparticles and their antibacterial activity against agricultural pathogens', *Appl. Microbiol. Biotechnol.*, 2013, 97, (1), pp. 361 –368.

20. Yen F.L. Wu T.H. Lin L.T. *et al*.: 'Nanoparticles formulation of *Cuscuta chinensis* prevents acetaminophen- induced hepatotoxicity in rats', *Food Chem. Toxicol.*, 2008, 46, (5), pp. 1771 –1777.
21. Ahmed S. Annu Zafeer I. Ikram S.: 'Synthesis of silver nanoparticles using leaf extract of *Crotolaria retusa* as antimicrobial green catalyst', *J. Bionanosci.*, 2016, 10, (4), pp. 282 –287.
22. Wijnhoven S.W.P. Peijnenburg W.J. Herberts C.A. *et al*.: 'Nano- silver: a review of available data and knowledge gaps in human and environmental risk assessment', *Nanotoxicology*, 2009, 3, pp. 109 –138
23. Yudha S.S. Notriawan D. Angasa E. *et al*.: 'Green synthesis of silver nanoparticles using aqueous rinds extract of *Bruceajavanica* (L.) Merr. at ambient temperature', *Mater. Lett.*, 2013, 97, pp. 181 –183.
24. Ahmed S. Ahmad M. Swami B.L. *et al*.: 'A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: a green expertise', *J. Adv. Res.*, 2016, 7, pp. 17 –28. doi: 10.1016/j.jare.2015.02.007.
25. Ojo O.A. Oyinloye B.E. Ojo A.B. *et al*.: 'Green synthesis of silver nanoparticles (AgNPs) using *Talinum triangulare* (Jacq.) Willd. leaf extract and monitoring their antimicrobial activity', *J. Bionanosci.*, 2017, 11, pp. 292 –296. doi: 10.1166/jbns.2017.1452.
26. Ahmed S. Ullah S. Ahmad M. *et al*.: 'Green synthesis of silver nanoparticles using *Azadirachta indica* aqueous leaf extract'. *J. Radiat. Res. Appl. Sci.*, 2016, 9, (1), pp. 1 –7. 10.1016/j.jrras.2015.06.006.
27. Castillo-Henríquez L, Alfaro-Aguilar K, Ugalde-Álvarez J, Vega-Fernández L, Montes de Oca-Vásquez G, Vega-Baudrit JR. Green Synthesis of Gold and Silver Nanoparticles from Plant Extracts and Their Possible Applications as Antimicrobial Agents in the Agricultural Area. Nanomaterials. 2020;10(9):1763
28. Sriramulu M, Sumathi S. Photocatalytic, antioxidant, antibacterial and anti-inflammatory activity of silver nanoparticles synthesised using forest and edible mushroom. Advances in Natural Sciences: Nanoscience and Nanotechnology. 2017;8(4):045012
29. Aljabali AA, Akkam Y, Al Zoubi MS, Al-Batayneh KM, Al-Trad B, Abo Alrob O, et al. Synthesis of gold nanoparticles using leaf extract of Ziziphus zizyphus and their antimicrobial activity. Nanomaterials. 2018(3):174
30. Kumar V, Yadav SC, Yadav SK. *Syzygium cumini* leaf and seed extract mediated biosynthesis of silver nanoparticles and their characterization. Journal of Chemical Technology & Biotechnology. 2010;85(10):1301-1309

31. Asghar MA, Zahir E, Asghar MA, Iqbal J, Rehman AA (2020) Facile, one-pot biosynthesis and characterization of iron, copper and silver nanoparticles using *Syzygium cumini* leaf extract: As an effective antimicrobial and aflatoxin B1 adsorption agent. PLoS ONE.2020;15(7): e0234964
32. Kumar V, Yadav SC, Yadav SK. *Syzygium cumini* leaf and seed extract mediated biosynthesis of silver nanoparticles and their characterization. Journal of Chemical Technology & Biotechnology. 2010;85(10):1301-1309
33. Ojo OA, Oyinloye BE, Ojo AB, Ajiboye BO, Olayide II, Idowu O, et al. Green-route mediated synthesis of silver nanoparticles (AgNPs) from *Syzygium cumini* (L.) Skeels polyphenolic-rich leaf extracts and investigation of their antimicrobial activity. IET Nanobiotechnology. 2017;12(3):305-310
34. Siddiqi KS, Husen A, Rao RA. A review on biosynthesis of silver nanoparticles and their biocidal properties. Journal of Nanobiotechnology. 2018;16(1):1-28
35. Loo YY, Chieng BW, Nishibuchi M, Radu S. Synthesis of silver nanoparticles by using tea leaf extract from Camellia sinensis. International Journal of Nanomedicine. 2012; 7:4263
36. Kannan RR, Arumugam R, Ramya D, Manivannan K, Anantharaman P. Green synthesis of silver nanoparticles using marine macroalga Chaetomorphalinum. Applied Nanoscience. 2013; 3:229-233
37. Ghosh S, Patil S, Ahire M, Kitture R, Gurav DD, Jabgunde AM, et al. Gnidia glauca flower extract mediated synthesis of gold nanoparticles and evaluation of its chemocatalytic potential. Journal of Nanobiotechnology. 2012;10(1):1-9
38. Gangula A, Podila R, Karanam L, Janardhana C, Rao AM. Catalytic reduction of 4-nitrophenol using biogenic gold and silver nanoparticles derived from Breyniarhamnoides. Langmuir. 2011;27(24):15268-15274
39. Dudhane AA, Waghmode SR, Bhosale MA, Mhaindarkar VP. Caesalpinia pulcherrima mediated green synthesis of silver nanoparticles: Evaluation of their antimicrobial and catalytic activity. International Journal of Nanoparticles. 2017;9(3):153-165
40. Dudhane AA, Waghmode SR, Dama LB, Mhaindarkar VP, Sonawane A, Katariya S. Synthesis and characterization of gold nanoparticles using plant extract of Terminalia arjuna with antibacterial activity. International Journal of Nanoscience and Nanotechnology. 2019;15(2):75-82
41. A. Frattini, N. Pellegri, D. Nicastro, O. D. Sanctis, *Mater.*Effect of amine groups in the synthesis of Ag nanoparticles using aminosilane. *Chem. Phys.*2005; 94 (1):148-152.

42. D. Roe, B. Karandikar, N. Bonn-Savage, B. Gibbins, J.-B. Roullet. Antimicrobial surface functionalization of plastic catheters by silver nanoparticles. *J. Antimicrob. Chemotherapy*. 2008; 61 (4): 869-876.
43. A. Pasricha , S.L. Jangra , N. Singh, N. Dilbaghi, K.N. Sood, K. Arora, R. Pasricha. Comparative study of leaching of silver nanoparticles from fabric and effective effluent treatment. J. Environ. Sci. (China).2012; 24 (5) 852-9.
44. N. Duran, P. D. Marcato, G. I. H. De Souza, O. L. Alves, E. Esposito. Antibacterial Effect of Silver Nanoparticles Produced by Fungal Process on Textile Fabrics and Their Effluent Treatment. *J. Biomed.Nanotechnol.*2007;3(2): 203- 208.
45. K. Zodrow, L. Brunet, S. Mahendra, D. Li, A. Zhang, Q. Li, P. J. J. Alvarez. Polysulfone ultrafiltration membranes impregnated with silver nanoparticles show improved biofouling resistance and virus removal. *Water Res,*2009;43 (3):715-723.
46. D. G. Rickerby, M. Morrison. Nanotechnology and the environment: A European perspective. *Sci. Technol. Adv. Mater.*2007;8 (1): 19-24.
47. L. Sun, Z. Zhang, S. Wang, J. Zhang, H. Li, L. Ren, J. Weng, Q. Zhang. Effect of pH on the Interaction of Gold Nanoparticles with DNA and Application in the Detection of Human p53 Gene Mutation. *Nanoscale Res. Lett.*2009;4:216-220.
48. H. K. Patra, S. Banerjee, U. Chaudhuri, P. Lahiri, A. K. Dasgupta. Cell selective response to gold nanoparticles. *Nanomed. Nano technol. Biol. Med.* 2007; 3 (2): 111-119.
49. Y. Lu,Y. Yin, B.T. Mayers, Y. Xia. Modifying the Surface Properties of Superparamagnetic Iron Oxide Nanoparticles through A Sol−Gel Approach.*Nano Lett.* 2002;,2 (3): 183-186.
50. D.G. Yu. Formation of colloidal silver nanoparticles stabilized by Na+-poly(gamma-glutamic acid)-silver nitrate complex via chemical reduction process. *Colloids Surf. B.* Biointerfaces. 2007; 59(2):171– 178.
51. K. Mallick, M. J. Witcombb, M. S. Scurrella. Self-assembly of silver nanoparticles in a polymer solvent: formation of a nanochain through nanoscale soldering. Material Chemistry and Physics.2005; 90 (2-3): 221–224.
52. Y.C. Liu, L.H. Lin. New Pathway for the synthesis of ultrafine silver nanoparticles from bulk silver substrates in aqueous solutions by Sono electrochemical methods. *Electrochemistry Communications.* 2004; 6 (11):1163–1168.
53. A.B. Smetuna, K.J. Klabunde, C.M. Sorensea. Synthesis of spherical silver nanoparticles by digestive ripening stabilization with various agents, and their 3-D and 2-D super lattice formation. *Journal of. Colloid Interface Science.*2005; 284(2)*:*521–526.

54. M. P. Mallin, C. J. Murphy. Solution Phase Synthesis of Sub-10 nm Au-Ag Alloy Nanoparticles. *Nano Letter.* 2002; 2: 1235-1237.
55. E. I. Isaeva, V.V. Gorbunova, N.V. Sirotinkin, A.V. Shchukarev, T. B. Boitsova, Phytochemical formation of silver nanoparticles in elastomer films. Rassian Journal of General Chem*istry. 2006;*76: 687-693.
56. A. Hozumi, M. Inagaki, N. Shirahata. Vapor phase formation of a well-ordered aldehyde-terminated self-assembled monolayer on a SiO_2 surface and formation of silver film on the surface based on the silver mirror reaction. *Surface Science*,2006; 600(18)*:*4044-4047.
57. R. A. Salkar, P. Jeevanandam, S. T. Aruna, Y. Koltypin, A. Gedanken. The Sono chemical preparation of amorphous silver nanoparticles. Journal of Material Chemistry. 1999; 9: 1333-1335.
58. C. Richmonds, R. M. Sankaran. Plasma-liquid electrochemistry: rapid synthesis of colloidal metal nanoparticles by microplasma reduction of aqueous cations.Appl. Phys. Lett. 2008; 93: 131501-131503.
59. P. T. Murray, E. Shin, *Mater*. Formation of silver nanoparticles by through thin film ablation. Materials Letters. 2008; 62(28): 4336-4338.
60. W. L. Chou, D. G. Yu, M. C. Yang. The preparation and characterization of silver-loading cellulose acetate hollow fiber membrane for water treatmen. Polymers Advance Technology. 2005;16:600- 607.
61. N.A. Begum, S. Mandal, S. Basu, R. A. Laskar, D. Mandal. Biogenic synthesis of Au and Ag nanoparticles using aqueous solutions of Black Tea leaf extracts. Colloids Surf. B Biointefaces. 2009; 71:113–118.
62. H. Bar, D. K. Bhui, G. P. Sahoo, P. Sarkar, S. Pyne, A. Misra, Green Synthesis of Silver Nanoparticles Using Latex of Jatropha curcas. Colloids and Surfaces A: Physicochemical and Engineering Aspects,*Colloids Surf. A Physicochem. Eng. Aspects*. 2009; 339: 134–139.
63. V. Parasher, R. Parasher, B. Sharma, A. C. Pandey. Parthenium leaf extract mediated synthesis of silver nanoparticles: A novel approach towards weed utilization. *Digest J. Nanomater. Biostruct.* 2009;4(1):45-50
64. V. K. Sharma, R. A. Yngard, Y. Lin,.Silver nanoparticles: green synthesis and their antimicrobial activities. *Adv. Colloid Interface. Sci.*2009; 145 (1-2):83-96.
65. M. A. Albrecht, C. W. Evans, C. L. Raston. Green chemistry and the health implications of nanoparticles. *Green Chem*. 2006; 8: 417-420.
66. J. M. Koziara, P. R. Lockman, D. D. Allen, R. J. Mumper. In situ blood-brain barrier transport of nanoparticles. *Pharm. Res. 2003;*20 (11): 1772-1778.

67. L. K. Limbach, P. Wick, P. Manser, R. N. Grass, Bruinink, W. J. Stark. Exposure of engineered nanoparticles to human lung epithelial cells: influence of chemical composition and catalytic activity on oxidative stress. *Environ. Sci. Technol.* 2007;41 (11): 4158-4163.
68. T. Xi, M. Kovochich, J. Brant, M. Hotze, J. Sempf, T. Oberley. Comparison of the abilities of ambient and manufactured nanoparticles to induce cellular toxicity according to an oxidative stress paradigm. *Nano Lett.* 2006; 6 (8):1794-1807.
69. M. Shafiq, S. Anjum, C. Hano, I. Anjum and B. H. Abbasi. "An Overview of the Applications of Nanomaterials and Nanodevices in the Food Industry", *Foods*, 2020; 9 (148):1-27.
70. S. Belluco, F. Gallocchio, C. Losasso and A. Ricci, "State of art of nanotechnology applications in the meat chain: A qualitative synthesis", *Crit. Rev. Food Sci. Nutr*. 2018; 58:1084–1096.
71. P. Sharma and M. Bhargava. "Applications and Characteristics of Nanomaterials in Industrial Environment", *International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development.*2013; 3(4): 63-72.
72. Diksha Diksha,Shailesh K Gupta,Pratima Gupta, Uttam C Banerjee, and Deepjyoti Kalita. Antibacterial Potential Of Gold Nanoparticles Synthesized From Leaf Extract Of *Syzygium cumini* Against Multidrug-Resistant Urinary Tract Pathogens. Cureus.2023; 15(2): e34830
73. Archana Chakravarty, Iftkhar Ahmad, Preeti Singh, Mehraj Ud Din Sheikh, Gulshitab Aalam, Suresh Sagadevan and Saiqa Ikram. Green synthesis of silver nanoparticles using fruits extracts of *Syzygium cumini* and their bioactivity. Chemical Physics Letters. 2022; 795(16): 139493
74. Nalinee K. Kadiyala, Badal K. Mandal, Shivendu Ranjan, Nandita Dasgupta. Bioinspired gold nanoparticles decorated reduced graphene oxide nanocomposite using *Syzygium cumini* seed extract: Evaluation of its biological applications. Materials Science and Engineering: C. 2018; 93(1): 191-205.
75. Wagner Luís de Carvalho Bernardo, Marcelo Fabiano Gomes Boriollo, Caroline Coradi Tonon, Jeferson Júnior da Silva, Fernando Moraes Cruz, Adriano Luis Martins, José Francisco Höfling, Denise Madalena Palomari Spolidorio. Antimicrobial effects of silver nanoparticles and extracts of *Syzygium cumini* flowers and seeds: Periodontal, cariogenic and opportunistic pathogens. Archives of Oral Biology. 2021;125: 105101
76. E. Chandra Sekhar, K. S. V. Krishna Rao, K. Madhu Sudana Rao, S. Bahadur Alisha. A Simple Biosynthesis of Silver Nanoparticles from *Syzygium cumini* Stem

Bark Aqueous Extract and their Spectrochemical and Antimicrobial Studies. Journal of Applied Pharmaceutical Science. 2018; 8 (01): 073-079,

77. Paula E.R. Bitencourt Chapter 34 - Nanoparticle formulation of *Syzygium cumini*, antioxidants, and diabetes: Biological activities of *S. cumini* nanoparticles. Diabetes (Second Edition) Oxidative Stress and Dietary Antioxidants. 2020; 343-350
78. Wagner Luis de Carvalho Bernardo et al. Biosynthesis of silver nanoparticles from *Syzygium cumini* leaves and their potential effects on odontogenic pathogens and biofilms. Frontiers Microbiology. 2022; 13
79. M.Arshad1, A.Qayyum, A.Asrhad1, S.Ahmad and A. Sultan. Photocatalytic and Antibacterial Potential of Green Synthesized Silver Nanoparticles by Using Leaf Extract of *Syzygium cumini*.The Nucleus. 2016; 53(4):264-268
80. Vijay D Mendhulkar, Sopan N Kharat, Snehal R Mahadik. Plant Extract Mediated AgNps Synthesis in Averrhoa bilimbi and *Syzygium cumini* Leaf Extract, their Characterization and Antioxidant Potential Assessment. Der Pharma Chemica. 2018;10(11): 24-33.
81. Kharat S.N. and Mendhulkar V.D. Synthesis, characterization and studies on antioxidant activity of silver nanoparticles using Elephantopus scaber leaf extract. Materials Sci. Engg. C, 2016, 62, 719-724.
82. Rajeswari Anburaj and Vinoth Jothiprakasam. Enhanced Mechanism of Metal Nanoparticles Using *Syzygium cumini* As A Potential Synthesizer And Its Inhibitory Effect. International Journal of Pharmaceutical Sciences and Research. 2019;10(3): 1448-1454
83. Ajay Kumar Sahu, Dr. Rupali Sinha, Prangya Paramita Acharya, Deepthi Kiran K. Characterization of *Syzygium cumini* Silver Nanoparticles (SCSNPS) and Analyzing Their Effect on Glucose Induced Cardiac Stress. Haya: The Saudi Journal of Life Sciences. 2019; 4(3): 123-130.