Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 13 [3] February 2024 : 304-312

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD

ORIGINAL ARTICLE **OPEN ACCESS**

Nanocomposite Preparation using Silver Nanoparticles and Activated Charcoal: Determining the Antibacterial Efficacy of SCC_{NC}

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ABSTRACT
Synthesizing a novel composite using green silver nanoparticles doped with natural charcoal is the primary aim of the research. Green synthesis of silver nanoparticles was performed using Ocimum basilicum extracts, and their characterization was analyzed using UV-Vis, SEM, FTIR, and XRD. The minimal inhibitory concentration and antibacterial activity of silver nanoparticles and silver-doped charcoal composite were evaluated. The colorless solution turned yellow brown due to the excitation of surface plasmon vibrations, confirming the formation of silver nanoparticles. UV–Vis analysis for the filtered sample revealed the formation of a plasmon peak that shifted to a longer wavelength at 414 nm. The FTIR spectrum revealed bands at 1636.34, 2156.94, and 3269.31 cm^{-1}, which were attributed to the presence of phenolic as well as aromatic compounds in the extract. SEM analysis of silver nanoparticles revealed that the particles were formed as agglomerates, with the size ranging from 77.17 nm to 84.18 nm. The antibacterial activity of green synthesized silver nanoparticles against test bacteria showed inhibitory zones ranging from 16 mm to 19 mm. The MIC of SCC_{NC} was recorded as 40 µg/ml for Escherichia coli, Shigella sp., and Klebsiella sp. and 30 µg/ml for Enterobacter sp. and Salmonella sp. The inhibitory zone of the antibacterial activity of SCC_{NC} against the test bacteria ranged from 15 mm to 17 mm for 30 µg/ml concentration. The novel silver nanoparticles doped with charcoal particles (silver nanoparticles + coconut charcoal nanocomposite - SCC_{NC}) open new way for an inexpensive, ecofriendly antibacterial compound that can be used in different applications.
Key words: *Green Synthesis, Silver Nanoparticles, Coconut Shell Charcoal, Composite, Inhibitory Zone*

Received 29.12.2023 Revised 02.02.2024 Accepted 27.02.2024

INTRODUCTION

Metal-incorporated nanoparticles have received wide interest in the area of industrial and medicinal applications. They find applications in various fields, such as medicine, electronics, energy saving, environment, textile, cosmetics, etc. Silver nanoparticles (AgNPs) have garnered interest not only with respect to fundamental development in research but also at the industrial level owing to their versatile properties [1].

Leela and Vivekanandan (2008) reported that nanomaterials are synthesized conventionally using physical and chemical methods (sol–gel process, micelles, chemical precipitation, hydrothermal method, pyrolysis, and chemical vapour deposition) [2]. Kowshik and Deshmukh (2008) highlighted that these methods are easy and provide control over crystallite size by restoring the reaction environment [3]. Nair and Pradeep (2002) synthesized AgNPs through green routes using microorganisms [4]. Similarly, Willner et al. (2006) used enzymes [5], and Kumar and Yadav (2009) used plant extracts. All of these were suggested as possible environmentally friendly alternatives to chemical methods [6].

Mandal et al. (2006) used bacterial as well as fungal species for silver nanoparticle synthesis, and they were able to accumulate AgNPs intracellularly [7]. Shankar et al. (2004) reported that plant extract–mediated synthesis always takes place extracellularly, and the reaction times have also been reported to be very short compared with those of microbial synthesis. In addition, the process can be suitably scaled up for large scale synthesis of nanoparticles. These methods were also reported to be cost effective and made the synthesized particles more stable [8].

Several medicinal plants, such as *Ocimum sanctum, lemongrass, Cinnamomum camphora, Vitex negundo, Solanum melongena, Azadirachta indica, Carica papaya, Brassica rapa, Capsicum annuum, Coccinia indica, Datura metel, Melia dubia*, and *Emblica officinalis*, have already been used to synthesize and stabilize metallic NPs, particularly biogenic AgNPs [9].

A thorough survey of the literature indicated that not much work has been performed on the use of basil, an aromatic herb (*Ocimum basilicum*), in nanotechnology.

Ocimum basilicum is a herb of medium size with a strong scent and smooth or velvety touch. Leaves of the herb are opposite, simple, entire, and ovate. They are toothed often and 3–5 cm long, and their petiole is slender. The flowers are 8–12 mm long in cluster-like circles of 6–10 flowers. *Ocimum basilicum* is considered to have originated from the warmer parts of the Indomalayan regions and is abundantly found in tropical and hotter parts of the Indian subcontinent. Phytochemical screening of *Ocimum basilicum* showed the presence of saponins, tannins, and cardiac glycosides. Bioactive compounds such as cinnamic acid methyl ester, linalool, eugenol, estragol, bergamotene, 1,8-cineol, α-cadinol, methyl cinnamate, and limonene were found to be present, from GC-MS analysis [10].

Shafique et al. (2011) emphasized that the essential oil of *O. basilicum* has antiviral, larvicidal, antinociceptive, and antimicrobial properties [11]. Bunrathep et al. (2007) stated that the plant extracts from its leaves and stems were used for thousands of years for the treatment of digestive and nervous disorders. It also acts as an anthelmintic, antipyretic, and cardio-protective agent [12]. Sarfraz et al. (2011) [13] highlighted its antioxidant and anti-inflammatory potential to cure fever, nausea, migraine, abdominal cramps, gonorrhea, dysentery, headache colic, dizziness, piles, cough, paralysis, nervous temperament, and numbness [14, 15]. Basil tea cures diarrhea, vomiting, constipation, and mental fatigue, and hyssop is used for cough [16].

As bamboo charcoal was recently used as a synergistic compound with different metals and polymers as composites, in this study, we tried a different type of charcoal from the natural source to develop a novel charcoal + metal composite. As a lot of coconut shells are dumped into the environment as waste, the shells are processed in the present study so that they are converted to activated charcoal and doped with metal nanoparticles to obtain a novel composite material.

Based on the medicinal and pharmacological applications of *Ocimum basilicum* and biomedical applications of charcoal obtained from natural sources, the present study was aimed at synthesizing a composite containing charcoal with silver nanoparticles, evaluating the antimicrobial properties of the developed composite, and investigating the topographical structures using FESEM analysis.

MATERIAL AND METHODS

Collection and processing of *Ocimum basilicum* leaves

Ocimum basilicum (basil in Tamil Nadu, India) leaves were collected from a farm house belonging to Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. These leaves were prewashed in deionized water and kept under shade until they are completely dried before milling.

Sample preparation: Drying and milling

The dried leaves were arranged separately in aluminum trays and oven-dried at 40°C to 50°C for 2h until the moisture content reached below 10%. The dried parts were ground to powder and sieved using a metal sieve. The sieved particles were stored at room temperature before testing.

Solvent extraction of *Ocimum basilicum*

Solvent extraction of *Ocimum basilicum* leaves were carried out using a standard Soxhlet extraction protocol. The extraction was carried out in such a way that the ethanol extracts of selected herbs will be collected separately. In brief, the extraction solvent is heated in the bottom flask, which vaporizes into the thimble, condenses in the condenser, and drips back. When the liquid content reaches the siphon arm, the liquid contents are emptied into the bottom flask again, and the process is repeated. The powdered herbs of *Ocimum basilicum* were filled in the thimble and placed in the Soxhlet extractor. The extract from the thimble was collected through a side arm tube in a round bottom flask and kept in a heating mantle.

Green synthesis of AgNPs using plant extracts (reduction method)

Chemicals

Silver nitrate was purchased from Sigma-Aldrich, Bangalore, India. All buffer solutions used for the preparation works were made using double-distilled Milli-Q water.

Preparation of 1mM silver nitrate ($AgNO_3$) solution

The concentration of 1 mM silver nitrate (Central Drug House Ltd.) was prepared by dissolving 0.169g $AgNO_3$ in 1L deionized water and stored in an amber-colored bottle to prevent self-oxidation of the silver nitrate solution.

Green synthesis of AgNPs

The preparation of AgNPs is a single step synthesis. About 10 ml of *Ocimum basilicum* leaf extracts extracted from the Soxhlet unit was added to 90 ml of silver nitrate solution, and the mixture was heated to 80^{o}C and maintained at that temperature for 15 minutes. The color of the solution turned from light yellow to brown, indicating the formation of AgNPs. In Figure 3, the steps involved in color change from yellow to brown are presented. The synthesized AgNPs were separated by the process of centrifugation from the reaction mixture and stored.

Purification of AgNPs

The synthesized AgNPs were kept in 12 N hydrochloric acid solution for 24 hours. The AgNPs were isolated by the process of centrifugation from the mixture. The mixture was washed with distilled water until the hydrochloric acid was completely removed. Purified AgNPs were further stored at room temperature for characterization studies.

Characterization of the synthesized nanoparticles

UV-Visible spectroscopy (UV-Vis) analysis

The synthesized AgNPs were confirmed by sampling the aqueous component at different time intervals, and the absorption maximum was scanned using a UV–Vis spectrophotometer at a wavelength of 300–800 nm on a Perkin-Elmer Lambda 25 spectrophotometer. The UV–Vis reading was recorded and then analyzed using the Origin Pro or Microsoft Excel analysis tool.

Fourier Transform Infra-Red Spectroscopy (FTIR)

The bioreduced silver nitrate solution was centrifuged at 10,000 rpm for 15 minutes, and the dried samples were ground with KBr pellets for FTIR measurements. The spectrum was recorded in the range of 4000–400 cm^{-1} using a Thermo Nicolet Nexus 670 spectrometer in the diffuse reflectance mode operating at a resolution of 4 cm^{-1}.

Scanning Electron Microscopy (SEM)

The morphology of the developed AgNPs was analyzed by field emission scanning-electron microscopy (JSM-7500F, JEOL). A minute drop of nanoparticle powder was cast on to a carbon-coated copper grid and subsequently transferred to the microscope. The high-resolution images of AgNPs were recorded, and the morphology was further studied.

Antibacterial activity of developed AgNPs against test bacteria

Escherichia coli, Salmonella sp., Vibrio sp., Enterobacter sp., and *Citrobacter* sp. were collected from the Research Department of Microbiology, RVS College of Arts and Science, Coimbatore, Tamil Nadu, India. All the cultures were checked for purity using standard microbiological parameters and subcultured onto nutrient agar plates and nutrient broth tubes. All the cultures were subcultured once every 15 days to maintain them as pure cultures throughout the research work.

The antibacterial activity of the *Ocimum basilicum* methanol extract was evaluated against the test organisms by the well diffusion method. All the test cultures were inoculated in a sterile nutrient broth and rested for 24 to 48 hours to attain growth. Sterile Mueller–Hinton agar plates were prepared and allowed to solidify. About 0.1% of inoculated suspensions of the test organism were swabbed uniformly over the agar surface separately. Under sterile conditions, 6 mm wells were cut on the agar surface of each plates. About 20 µl of *Ocimum basilicum* extract fractions were loaded into the well (100 µg/ml, 200 µg/ml, 300 µg/ml, 400 µg/ml, and 4µg/ml of streptomycin as the standard), and the plates were incubated at 37 ºC for 24 hours. The antimicrobial activity was evaluated in terms of the zone of inhibition around the wells in all the inoculated nutrient agar plates. The inhibition clear zones were measured and recorded in millimeter and compared with the standard.

Coconut shell charcoal preparation

The coconut shell was broken into several pieces (5 mm x 5 mm). Shells that are 2 to 3 months old were selected for this research, and they were dried in shadow for a period of 2 weeks. The fully dried pieces were carbonized in a flash-and-fire-point instrument, and the charcoal was developed. Finally, fine powdered charcoal particles were stored at room temperature for further processing.

FESEM analysis of the developed coconut charcoal

The morphology of coconut charcoal was analyzed by field emission scanning-electron microscopy (JSM-7500F, JEOL, Japan). A minute drop of charcoal powder was cast on to a carbon-coated copper grid and subsequently transferred to the microscope. The high-resolution images of coconut charcoal indicate that their respective morphology was recorded separately.

Development of novel composites using synthesized AgNPs and activated charcoal (AgNPs + coconut charcoal nanocomposite—SCC_{NC})

AgNPs and **coconut shell charcoal** were mixed together to develop as a composite in the present study. Initially, AgNPs were placed in a Petri dish under sterile conditions. Followed by the addition of coconut

charcoal powder, the product is mixed slowly with AgNPs at a ratio of 1:3. The developed composite was nomenclatured as SCC_{NC}.

Determining the minimal inhibitory concentration (MIC) of SCC_{NC} against water-borne pathogens

To determine the MIC of test organisms, a set of Mueller–Hinton broth tubes (5 tubes) were prepared under sterile conditions for each test organism. About 10 µg, 20 µg, 30 µg, 40 µg, and 50 µg of SCC_{NC} concentrations were added to each Mueller–Hinton broth tubes. Into all these tubes, about 10 µl of the test culture suspension was added separately. All the tubes were incubated for 24 hours at 37°C and observed for turbid growth. The lowest concentration of SCC_{NC} inhibiting the growth of the test organism was selected as the minimum inhibitory concentration (MIC) of SCC_{NC}.

Antibacterial activity of SCC_{NC} against water-borne pathogens

The antibacterial activity of SCC_{NC} was evaluated against the test organisms using a standard well diffusion method. All the test cultures were inoculated in a sterile nutrient broth and allowed to attain growth for 24 to 48 hours. Sterile Mueller–Hinton agar plates were prepared and allowed to solidify. About 0.1% of inoculated suspensions of the test organism were swabbed uniformly over the agar surface separately. Under sterile conditions, 6 mm wells were cut on the agar surface of each plate. The developed composite was mixed with DMSO solutions separately, and about 20 µl of SCC_{NC} fractions were loaded into their respective wells. As a positive control, 4 µg/ml of streptomycin was loaded in a separate well in the same plate to compare the size of inhibitory zones obtained. All the plates were incubated at 37 ºC for 24 hours. The antimicrobial activity was evaluated in terms of the zone of inhibition around the wells in all the test plates separately for each test bacteria. The inhibition clear zones were measured and recorded in millimeter and compared with the standard.

RESULTS AND DISCUSSION

Green synthesis of AgNPs

Green synthesis of AgNPs was carried out by reduction of silver nitrate after exposing to the extracts of plant leaves, and this was confirmed from the color change (from colorless to yellowish brown presented in Figure 1). The yellowish–brown color indicates the formation of AgNPs; this was mainly due to excitation of surface plasmon vibration that happened within 2 hours of reaction time. Formation indicated that silver ions were converted to elemental silver of nanoparticle size. As it was reported that natural antioxidants have strong reducing ability, the antioxidants in basil extracts had attributed the reduction process of reducing silver nitrate to AgNPs in the present study.

Characterization of the synthesized nanoparticles

UV-Visible spectroscopy (UV-Vis) analysis

The effect of filtration on the AgNP-produced green synthesis of *Ocimum basilicum* using a UV–Vis spectrophotometer is illustrated in Figure 2. After filtration of the sample, the plasmon peak shifted to a longer wavelength of 414 nm. The obtained plasmon band was found to be broad because of the biocomponents present in the basil extracts; it was also found that its intensity was increasing constantly. The nucleation of AgNPs with the initiation of reaction time indicated that there was no change in the peak position; hence, it was understood that the nanoparticle size will not change during the entire green synthesis reaction time.

Fourier Transform Infra-Red Spectroscopy (FTIR)

The FTIR spectrum revealed bands at 1636.34, 2156.94, and 3269.31 cm^{-1}. The band at 1636.34 cm^{-1} corresponded to the bending vibrations of the amide-I and amide-II bands of proteins, whereas their corresponding stretching vibrations of primary amines were observed at 3269.31 cm^{-1} [Figure 3]. In the present study, the peaks are more characteristic of eugenols, linalools, and terpenes that are abundant in the basil plant extract. The peaks found at 1636.34 cm^{-1} can be attributed to the C–C in alkene rings and C=C stretch of aromatic rings. Depending on the abovementioned observation, it can be assumed that stabilization is achieved by the phenolic as well as aromatic compounds present in the extract. These observations indicated the presence and binding of proteins with AgNPs, which can lead to their possible stabilization and prevent agglomeration. FTIR results revealed that the secondary structure of proteins had not been affected because of the reaction with silver ions or binding with AgNPs.

Scanning Electron Microscopy (SEM)

SEM analysis of AgNPs revealed that the particles were formed as agglomerates [Figure 4a, b]. In Figure 4a and 4b, small agglomerates containing nanoparticles with the size ranging from 77.17 nm to 84.18 nm were found.

Antibacterial activity of the developed AgNPs against test bacteria

The antibacterial activity of green-synthesized AgNPs against test bacteria is presented in Table 1. During the analysis, no inhibitory zones were obtained for the lower concentration. For 20 µg/ml concentration,

E. coli showed a 13 mm inhibitory zone, Salmonella sp. exhibited a 14 mm zone, and Shigella sp. expressed a 12 mm zone. Enterobacter sp. and Klebsiella sp. did not show any inhibitory zones. For higher concentration (30 µg/ml), 16 mm to 19 mm of inhibitory zones were found for all test bacteria. The maximum inhibitory zone of 19 mm was found for Klebsiella sp. *Escherichia coli* and Salmonella sp. exhibited an 18 mm zone, and *Enterobacter* sp. and *Shigella* sp. exhibited inhibitory zones of 17 mm and 16 mm, respectively. Standard streptomycin showed slightly more inhibitory zones, ranging from 20 mm to 22 mm, against all test bacteria. When compared with the developed nanoparticles, it was found that the zones were highly significant in restricting the growth of each test bacteria [Figure 5].

With reference to articles from the literature survey, similar antibacterial activity was reported. Mouzaki *et al*. (2022) synthesized green AgNPs with the aid of microalgae and evaluated the antibacterial activity against significant pathogens. Microalgae biomass-mediated AgNPs showed inhibitory zones of 8 mm, 12 mm, and 11 mm against Escherichia coli, Bacillus sp., and Staphylococcus aureus, respectively [17]. These values were found to support the activity expressed in our present study. In another study by Ankush Sharma *et al*. (2022), *Talaromyces purpureogenus*, fungus-mediated AgNPs were synthesized, and the effective antibacterial activity was evaluated against Escherichia coli, Shigella sp., Salmonella typhi, and Listeria sp. The maximum inhibitory zone of 18 mm was recorded for Shigella sp., followed by 17 mm for E. coli, 14mm for Salmonella typhi, and 13 mm for Listeria sp [18]. The obtained values were well in accordance with our study as a similar inhibitory zone size was recorded for 30 µg/ml concentration.

The antibacterial activity of AgNPs expressed in our study was well in accordance with their mode of action explained by researchers. Yakout and Mostafa (2015) reported that the bacterial wall structure would not be the only determining factor for the activity of nanoparticles and that the inhibitory effect of AgNPs may also be attributed to their nanometric size [19]. Sibiya et al. (2016) reported that AgNPs bind to DNA and RNA of organisms to cause denaturation, preventing gene proliferation and blocking the enzyme activity [20]. Phanjom et al. (2017) described further that the smaller sized nanoparticles attached to the cell wall and cell membrane of organisms eventually rattle the cellular functions such as cell permeability and respiration, leading to death [21].

FESEM analysis of developed nanocomposite (SCC_{NC})

FESEM analysis of SCC_{NC} determined the surface morphology and size distribution of AgNPs deposited on the coconut shell charcoal surface, respectively. As shown in Figure 6 and Figure 7, ultrafine and disaggregated AgNPs were homogeneously distributed on the surface of SCC_{NC}. The AgNPs are granular in nature and seem to be nanosized, typically in the range of 77.17 nm to 84.18 nm. The size was already confirmed and is presented in Figure 4.

MIC of SCC_{NC} against test bacteria

The MIC of SCC_{NC} against five different test bacteria was tested. The results are presented in Table 2. From the analysis, it was evident that all test bacteria were inhibited at certain concentrations of SCC_{NC}. Among the test organisms, Escherichia coli, Shigella sp., and Klebsiella sp were found to have an MIC value of 40µg/ml. In addition, the MIC obtained for Enterobacter sp and Salmonella sp. is 30 µg/ml.

Antibacterial activity of SCC_{NC} against test bacteria

The antibacterial activity of SCC_{NC} against test bacteria is presented in Table 4. During the analysis, no inhibitory zones were obtained for the lower concentration (10 ug/ml). For 20 µg/ml concentration, about 13 mm to 15 mm inhibitory zones were obtained against the respective test bacteria. Escherichia coli showed a 15 mm inhibitory zone, followed by Salmonella sp exhibited a 14 mm zone. All three organisms—Enterobacter sp, Shigella sp., and Klebsiella sp.—expressed 13 mm inhibitory zones. For the higher concentration (30 µg/ml), Enterobacter sp and Shigella sp exhibited 16 mm zones. Klebsiella sp. and Salmonella sp. showed 15 mm inhibitory zones. The maximum zone of 17 mm was evident for Escherichia coli. Standard streptomycin showed slightly more inhibitory zones, ranging from 19 mm to 21 mm against all test bacteria. When compared with the composite, the zones were highly significant in restricting the growth of each test bacteria [Figure 8].

The antibacterial activity of SCC_{NC} showed slightly better inhibitory zones than the activity expressed by the AgNPs against test bacteria. This is mainly due to the synergistic action of both charcoal and AgNPs present in the developed composite.

The results of a study conducted by Bardhan et al., (2014) were found to be in accordance with the results of our study. The researchers synthesized bamboo charcoal-silver composites and evaluated the antibacterial activity against Escherichia coli, Staphylococcus aureus, Pseudomonas putida, and Pseudomonas aeruginosa. About 11 mm to 19 mm of inhibitory zones were recorded for the developed composites against the respective test bacteria [22]. The obtained values were found to be almost similar to those of the composite developed in our study.

The micro-organisms which come in contact with the skin, through sweat or wounds, show an effective antimicrobial property against microbes such as *Staphylococcus aureus, Micrococcus luteus, Escherichia coli,* and Candida species. Klepp et al. (2016) reported that sweat, sebum, and bacterial metabolites are absorbed by the clothing and come in contact with the skin and cause malodor [23]. Charcoal finished fabric shall be used to prevent the adherence of odor-causing bacteria. Thierry Le Blan and Arnaud Vatinel, (2018) stated that activated charcoal has a good antimicrobial property and also controls odor while the fabric is finished with charcoal [24].

Table 1: Antibacterial activity of developed silver nanoparticles

S. No	Test Bacteria	Zone of Inhibition			
		10µg/ml	20µg/ml	30µg/ml	S
1	*Escherichia coli*	0	13	18	21
2	*Enterobacter sp*	0	0	17	20
3	*Shigella sp*	0	12	16	20
4	*Klebsiella sp*	0	0	19	22
5	*Salmonella sp*	0	14	18	21

Table 2: Minimal inhibitory concentration (MIC) of SCC_{NC} against test bacteria

S. No	Test Bacteria	Minimal Inhibitory Concentration					
		10µg/ml	20µg/ml	30µg/ml	40µg/ml	50µg/ml	Control
1	*Escherichia coli*	+	+	+	(MIC)	-	-
2	*Enterobacter sp*	+	+	(MIC)	-	-	-
3	*Shigella sp*	+	+	+	(MIC)	-	-
4	*Klebsiella sp*	+	+	+	(MIC)	-	-
5	*Salmonella sp*	+	+	(MIC)	-	-	-

Table 3: Antibacterial activity of SCC_{NC} against test bacteria

S. No	Test Bacteria	Zone of Inhibition				
		NC	10µg/ml	20µg/ml	30µg/ml	S
1	*Escherichia coli*	0	0	15	17	21
2	*Enterobacter sp*	0	0	13	16	20
3	*Shigella sp*	0	0	13	16	20
4	*Klebsiella sp*	0	0	13	15	20
5	*Salmonella sp*	0	0	14	15	19

Figure 1: Synthesis of silver nanoparticles

Synthesis was confirmed by the change in the solution's color from colorless to yellowish brown

Figure 2: UV-Visible spectroscopy (UV-Vis) analysis

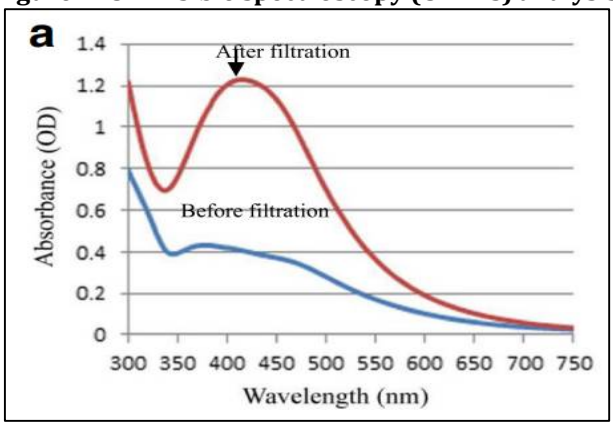


Figure 3: Fourier Transform Infra-Red Spectroscopy

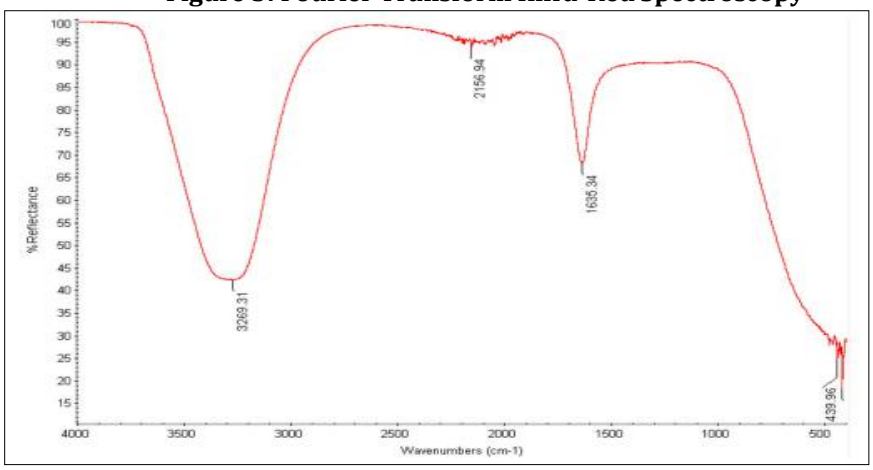
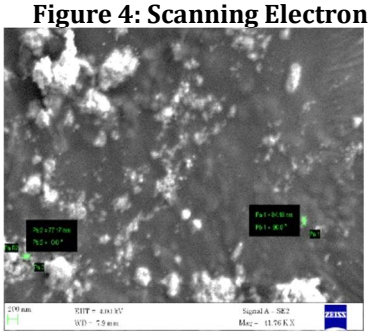
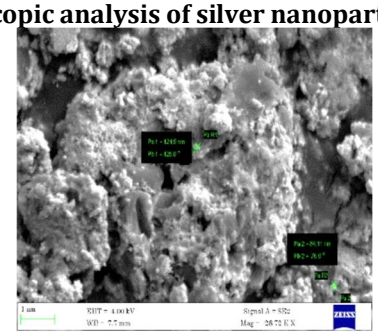


Figure 4: Scanning Electron Microscopic analysis of silver nanoparticles

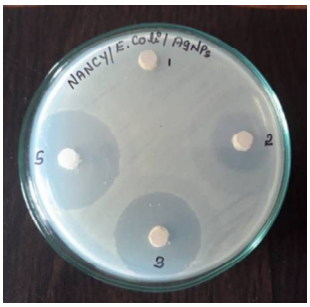


4a: Magnification 1X



4b: Magnification 2X

Figure 5: Antibacterial activity of developed silver nanoparticles



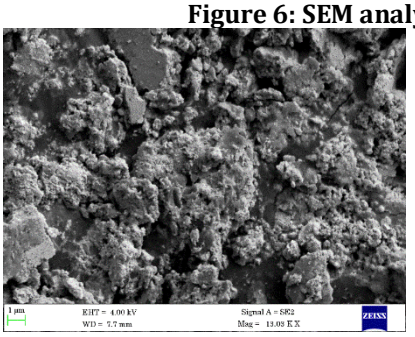
Escherichia coli

Enterobacter sp

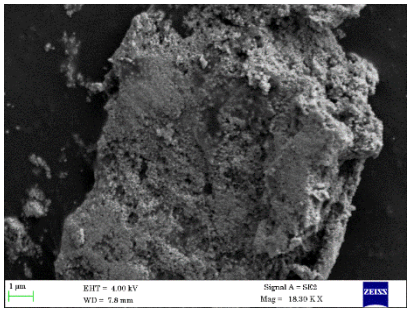
Klebsiella sp

Salmonella sp

Figure 6: SEM analysis of coconut charcoal

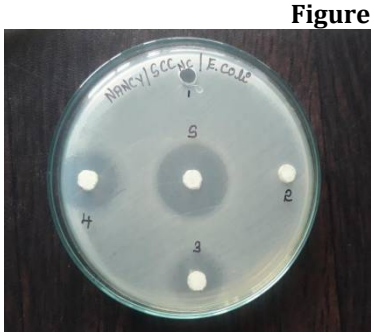


6a: Magnification 1X



6b: Magnification 2X

Figure 8: Antibacterial activity of SCC_{NC} against test bacteria

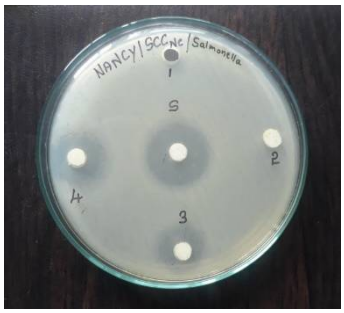


Escherichia coli

Enterobacter sp

Shigella sp

Klebsiella sp



Salmonella sp

CONCLUSION

Green synthesis of AgNPs using *Ocimum basilicum* extracts was performed, and their characterization using UV-Vis, SEM, FTIR and XRD was analyzed. A composite was developed using coconut charcoal (SCC_{NC}) after doping with silver nanoparticles. Antibacterial studies of the nanoparticles and developed composite were carried out against test organisms. The findings of characterization studies and inhibitory studies revealed that the composites are well developed and found to inhibit the test bacteria to a significant level. The green synthesis of AgNPs and doping with charcoal particles open the way to new methods for an inexpensive, ecological, less toxic synthesis without the use of chemical reducers. Besides the abovementioned findings,

advanced analysis on the developed composites in terms of applications in different sectors such as textiles, pharma, and medical sciences need to be studied after optimizations in the near future.

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CITATION OF THIS ARTICLE

J Nancy Paul and S Balachandar. Nanocomposite Preparation using Silver Nanoparticles and Activated Charcoal: Determining the Antibacterial Efficacy of SCC_{NC}. Bull. Env. Pharmacol. Life Sci., Vol 13[3] February 2024: 304-312