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ORIGINAL ARTICLE

Phyto-Mediated Green Synthesis of Silver Nanoparticles using *Acmella oleracea* Leaf Extract: Antioxidant and Catalytic Activity

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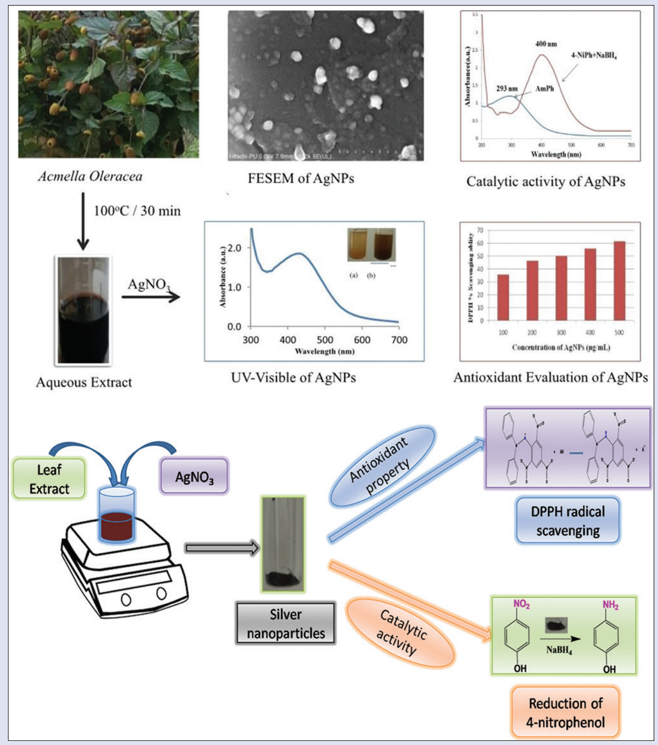
ABSTRACT

Background: Green synthesis has attracted the attention of all researchers due to its nontoxic, energy-saving, cost-effective, and eco-sound features. In the last decades, the usage of medicinal plants or herbs in the form of extract has been pursued to synthesize nanosized materials with added potential benefits that are manifested in various sectors. **Aim:** In the current study, an easy, economical and environmentally friendly one-pot synthesis technique has been proposed to obtain silver nanoparticles (AgNPs) using *Acmella oleracea* leaf extract. **Materials and Methods:** Color transition and ultraviolet-visible spectroscopy were availed to assess the formation of bio-mediated AgNPs while Fourier transform infrared (FTIR) was used to detect the functionalities in the leaf extract and the obtained 4-nitrophenol (NPs). Field emission scanning electron microscope (FESEM) analysis was used to analyze the morphological features of the NPs. The AgNPs were analyzed for the imminent antioxidant impact using 2,2-diphenyl-1-picrylhydrazyl test. In addition, the catalytic potential of AgNPs in reducing NP to 4-aminophenol (AP) was explored. **Results:** The absorption maximum for AgNPs was obtained at 435 nm and the FTIR analysis confirmed the capping of NPs by secondary metabolites of leaf extract with shift in peaks. FESEM analysis revealed the spherical shape of NPs with size ranging from 45 to 60 nm. AgNPs were found to exhibit significant antioxidant potential with IC_{50} value as 298.69 µg/mL and efficiently reduced NP to AP. **Conclusion:** The study signified that *A. oleracea* extract can be employed for the phyto-mediated synthesis of AgNPs with the latent antioxidant and catalytic applications that could be applied in the bio-medical field and environmental remediation in addition to other potential applications.

Key words: *Acmella oleracea*, antioxidant activity, catalytic activity, phyto-mediated synthesis, silver nanoparticles

SUMMARY

- Nanoparticles exhibit their significant role in biotechnology, optics, water purification, cosmetics, drug delivery. Green synthesis of nanoparticles by using the extract from various medicinal plants as reducing medium and capping agent has been found to be efficient, eco-friendly, and economical. The present work reports the easy and green synthetic technique to synthesize silver nanoparticles (AgNPs) with potential antioxidant and catalytic properties. *Acmella oleracea,* a medically important plant was used to prepare leaf extract that was further used as a reductant to obtain AgNPs using $AgNO_3$ as a precursor. Characterization of 4-nitrophenol (NPs) revealed the spherical shape and size lying in between 45 and 60 nm. The NPs were found to exhibit significant antioxidant properties. These NPs were further used to catalyze the reduction of NP, a significant organic pollutant to 4-aminophenol. Thus, the results provided affirmation for use of *A. oleracea* leaf extract as a reductant for the synthesis of AgNPs. All the authors have equally contributed to the work including conceptualization, visualization; investigation, data curation, software analysis, writing, and editing of the paper.



Plant-mediated synthesis of silver nanoparticles with potential antioxidant and catalytic applications

Abbreviations used: AgNPs: Silver nanoparticles; NPs: Nanoparticles; UV-Vis: UV-Visible; FTIR: Fourier transform infrared; FESEM: Field Emission Scanning Electron Microscope; DPPH: 2,2-diphenyl-1-picrylhydrazyl; IC_{50}: Half Maximal Inhibitory Concentration; NP: 4-nitrophenol and AP: 4-aminophenol.

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INTRODUCTION

Green nanotechnology is the development of clean and green technology that proactively affects the nanomaterials and their products through their design at the nanoscale. The green approach triggers the clean production of the nanomaterials from natural sources.[1] Although 4-nitrophenol (NPs) are mainly synthesized by employing conventional physical, chemical, and biological approaches, yet, nowadays biological methods have been explored a lot due to low-cost process rate, easy to handle, bulk production, use of waste materials, relatively high energy saving, as well as eco-friendly features as it reduces the use of toxic substances.[2] Plant-mediated green synthesis is more beneficial over the microbe-mediated synthesis as their reduction rate is fast and stability of NPs can be established using a single precursor.[3] Moreover, the usage of medicinal plant or herbal extracts for the synthesis of NPs incorporates the medicinal properties in the synthesized NPs.[4] In the green/biogenic/biosynthesis of the NPs, the phytochemicals extant in the extract function as reductants, capping besides stabilizing mediators.[5] Karnan and Selvakumar prepared zinc oxide NPs by the use of Rambutan (*Nephelium lappaceum*) peel extract[6] while Filip *et al*. have prepared gold and silver NPs using an aqueous fruit extract of *Cornus mas*.[7] Devi *et al*. have synthesized the silver NPs using fruit extract of *Aegle marmelos*.[3] Moodley *et al*. highlighted that major phytochemicals in the plant extract that help in synthesizing as well as stabilizing the NPs are phenols, dihydric phenols, alkaloids, terpenoids, flavonoids, and steroids.[8]

Midst the most commonly used nanoparticles, the metal NPs, specifically silver nanoparticles (AgNPs) have been extensively used.[9] Nanosized metallic silver particles display unique characteristics due to fine size such that the physicochemical and biological properties differ from its bulk particles.[10] Bio-mediated AgNPs have profound claims in various fields such as antioxidant,[11] dye degradation,[12] catalytic reduction,[13] biosensors for food and agriculture diagnostics,[14] antimicrobial activity,[15] anticancer,[16] and wastewater treatment[17] to name a few. Nowadays, human beings are facing many degenerative diseases that distress our normal body functions due to the presence of free radicals. Such free radicals popularly known as reactive oxygen species can induce the risk of DNA damage, inflammation, asthma, diabetes, cancer, etc.[16] Antioxidants are compounds that inhibit oxidation reactions which produce free radicals and protect humans by terminating the chain reactions. AgNPs can act as efficient free radical scavengers thus showing excellent antioxidant properties.[18]

Degradation and removal of hazardous compounds from the environment is another problem that continues to pose a significant threat to humanity, and any significant contribution in this direction will be enormously beneficial internationally.[19] Alamelu and Jaffar Ali signified that many nitro-aromatic compounds such as NPs are released as byproducts from many pharmaceutical and dye manufactured industries.[20] These compounds act as important intermediates that are formed during the synthesis of dyes, pesticides, fungicides, pharmaceuticals, etc. These are highly toxic compounds for the environment and difficult to remove naturally by degradation. Many metal NPs including AgNPs show effective catalytic potential for reducing such highly environment polluting organic compounds as reported by Zaheer[21] and Qu *et al*.[22]

Acmella oleracea is a medically important plant with many therapeutic applications due to the presence of biologically active secondary metabolites/phytochemicals in its various parts as reported by Abeysiri *et al*.[23] The present work addresses the phyto-mediated biosynthesis of AgNPs employing leaf extract of *A. oleracea*. As per literature survey, *A. oleracea* has not been explored much for synthesizing AgNPs. Various techniques namely ultraviolet-visible (UV-Vis), Fourier transform infrared (FTIR), and field emission scanning electron microscope (FESEM) analysis was used for the characterization of AgNPs and their antioxidant and catalytic activities were also analyzed.

MATERIALS AND METHODS

Plant and chemicals

A. oleracea was acquired from village Bagana in Distt. Kangra, Himachal Pradesh, India at altitude of 613 m. Silver nitrate ($AgNO_3$, 99.9%) was procured from S. D. Fine Chem. Limited, Mumbai. All analytical grade reagents including those for phytochemical screening were utilized without any additional processing. All formulations were prepared using double distilled water.

Preparation of aqueous leaf extract of *Acmella oleracea*

A. oleracea leaves were used to synthesize AgNPs as these are readily available, cost-effective and have medicinal properties. Fresh leaves were subjected to washing using tap water subsequent by double distilled water to ensure the removal of dirt and other contaminants. 20 g of the air-dried and powdered leaves were boiled for 30 min in 200 mL double distilled water with constant stirring [Figure 1]. The extract was kept at 4°C for further usage in experimental studies after cooling and filtration with Whatman filter paper.

Preparation of silver nanoparticles

The reduction of Ag^+ (+1 oxidation state) to Ag^0 NPs (zero oxidation state) was carried out using prepared leaf extract and $AgNO_3$ solution (50 mM) in the ratio of 2:8, respectively [Figure 2].

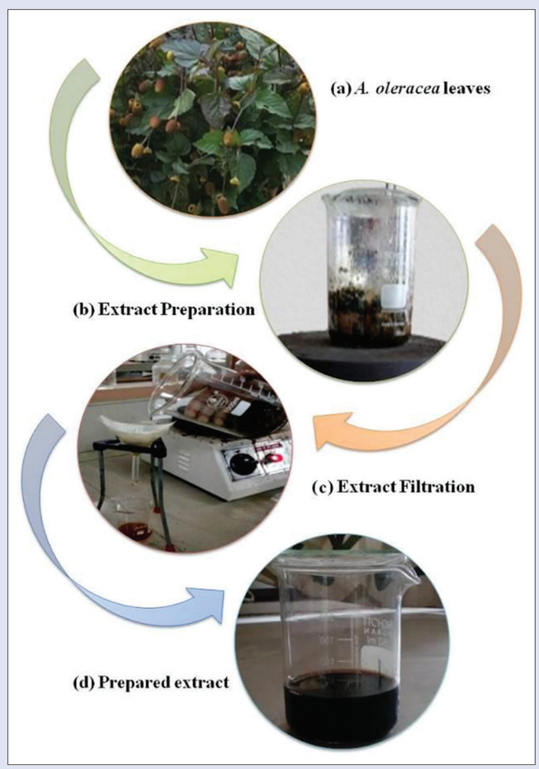


Figure 1: Preparation of plant extract from *Acmella oleracea* leaves (a-d)

The solution mixture was heated at 60°C ± 2°C temperature for 30 min. The color change was observed with an increase in time and after 30 min, the color transformed from yellowish-green to blackish leading to confirmation of Ag^+ ions reduction to AgNPs. The stable color of the solution specified the accomplishment of the reaction. The formation of NPs was also established using the ultraviolet-visible spectroscopic technique at varying time intervals.[24] The synthesized AgNPs were carried to centrifugation at 12,000 rpm (rounds per minute) for 10 min. Supernatant was poured out and the AgNPs pellets were re-suspended in deionized water. The procedure was repeatedthree times to purify the AgNPs and then dried in oven. The resultant AgNPs were further analyzed through spectrochemical characterization techniques.[25]

Phytochemical screening of leaf extract

Various qualitative tests were carried out to analyze phytochemicals in leaf extract of *A. oleracea*. Several secondary metabolites or phytochemicals extant in the extract helps in stabilizing the NPs. Such phytochemical constituents were screened through standard protocol.[26] The plant extract formulated in acetonitrile (50 mg/3 mL) was analyzed using GC-MS Thermo Scientific (TRACETM 1300 ISQTM LT). The chromatogram was generated using Thermo Scientific™ Xcalibur™ tools and the compounds were classified from the standards database.

Spectrochemicalcharacterization

Spectrochemical characterization of synthesized AgNPs was carried out using UV-Vis, FTIR, and FESEM. The absorption spectra of AgNPs were achieved by Agilent Cary 60 UV-Vis Spectrophotometer in the range of 300–700 nm of wavelength. The possible functional groups in leaf extract as well as in synthesized NPs were identified through Fourier transform inferred spectrometer (Thermo Scientific NICOLET 1S50) at the registered amplitude waves ranging from 450 to 4000 cm^{-1}. Morphology of nanoparticles was examined by FESEM (JEOL JSM-6100 [Jeol] machine).

Spectrochemical characterization

Spectrochemical characterization of synthesized AgNPs was performed to ascertain the chemical and morphological characteristics. The absorption spectra (300–700 nm) of AgNPs were attained by UV-Vis Spectrophotometer (Agilent Cary 60). The probable functionalities in leaf extract as well as in synthesized NPs were identified through Fourier transform inferred spectrometer (Thermo Scientific NICOLET 1S50) at the registered amplitude waves ranging from 450 to 4000 cm^{-1}. Morphological features of NPs were scrutinized by FESEM (JEOL JSM-6100 [Jeol] machine).

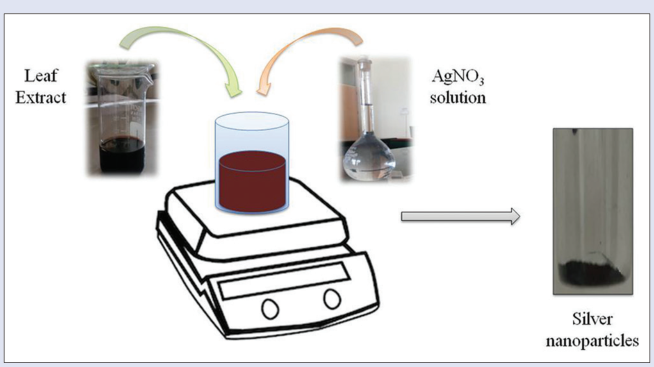


Figure 2: Diagrammatic representation of extract-mediated synthesis of silver nanoparticles

Antioxidant property

The quantitative investigation of the antioxidant potential of AgNPs was carried out with the aid of *in-vitro* 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay. The radical scavenging activity was estimated as per the scheme given by Jokar *et al*. with slight modifications.[11] Briefly, the sample solution of AgNPs was prepared as 100, 200, 300, 400, 500 µg/mL equal volume (1.5 mL) of various concentrations of the sample was mixed freshly prepared DPPH reagent in methanol (with the final concentration of 0.1 mM). The mixture was blended thoroughly and was subjected to unilluminated incubation for 40 min. The reduction in the absorption peak of the DPPH solution, at 517 nm, due to the incorporation of the antioxidant was assessed. The assay was triply executed while using ascorbic acid as a reference. The percentage scavenging effect of DPPH free radical was computed as per equation (1):

$$\text{percentage scavenging effect}(\%) = \left(1 - \frac{\text{Absorbance}_{\text{sample}}}{\text{Absorbance}_{\text{control}}}\right) \times 100 \quad (1)$$

where $\text{Absorbance}_{\text{control}}$ and $\text{Absorbance}_{\text{sample}}$ is the absorbance of DPPH + methanol and DPPH + sample, respectively. The concentration of the sample solution entailed to scavenge 50% of DDPH free radical known as IC_{50} can also be estimated from the graph plotted between the percentage of inhibition (%) versus concentrations of the sample (µg/mL) using linear regression statistical data analysis.

Catalytic activity

The catalytic activity is the other potential application of the extract-mediated synthesized AgNPs that was investigated in the current work. The catalytic property of AgNPs was examined for NP reduction to 4-aminophenol (AP) freshly prepared $NaBH_4$ solution that acts as a reductant. 1.9 ml of NP (0.2 mM) was poured into 1 mL of $NaBH_4$ solution (0.2 M) in a quartz cuvette. The UV-Visible spectra (200–700 nm) were noted after the addition of AgNPs (0.1 mL, 0.1%) solution for the completion of the reaction. The decrease in absorption peak at 400 nm of 4-nitrophenolate ion was monitored at various time intervals.[21]

RESULTS AND DISCUSSION

Phytochemical screening of *Acmella oleracea* leaf extract

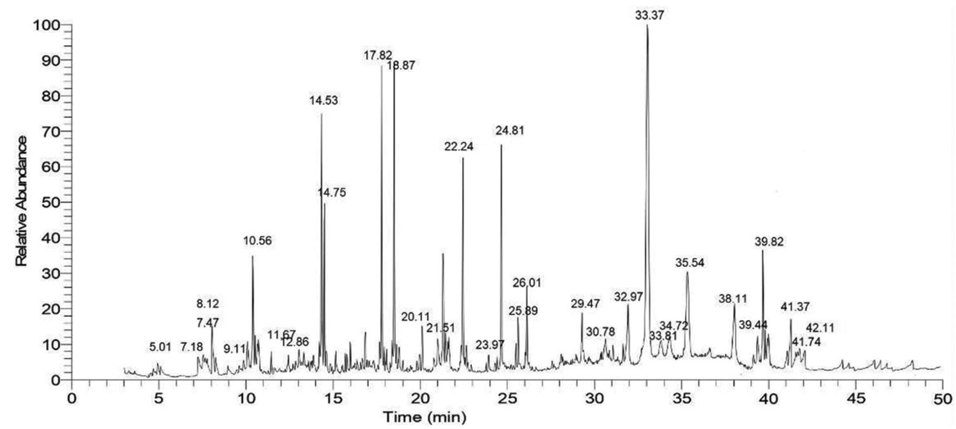
From the phytochemical screening of aqueous leaf extract of *A. oleracea*, it was found to be a fine source of phytochemicals (secondary metabolites) such as glycosides, flavonoids, phenolic compounds, alkaloids, amino acids, tannins, terpenoids, saponins, and steroids as shown in Table 1.

The gas chromatogram of the extract is illustrated in Figure 3 and also shows the list of the identified phytochemical compounds. Such

Table 1: Qualitative phytochemical screening of *Acmella oleracea* leaf extract*

Phytochemicals	Observation
Flavonoids	+
Alkaloids	+
Amino acid	+
Tannins	+
Triterpenoids	+
Phenolic compound	+
Glycosides	+
Saponins	+
Steroid	+

*Present (+)/Absent (−)



S. No.	Retention time (minute)	Compound
1	5.01	5,9-Dimethyl-1-decanol
2	7.18	9-Octadecenamide
3	7.47	1-Butanol, 3-methyl-, acetate
4	8.12	o-Xylene
5	9.11	2,5-Dimethyl-1,5-heptadiene-3,4-diol
6	10.56	(E)-4,4-Dimethyl-2-pentene
7	11.67	Glycerin
8	12.86	2,5-Dimethyl-5-hexen-3-ol
9	14.53	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-
10	14.75	Pentanoic acid, isobutyl 3-hydroxy-2,2,4-trimethylpentanoate
11	17.82	Propanoic acid, 2-methyl,3-hydroxy-2,2,4-trimethylpentyl ester
12	18.87	(9Z)-9-Hexadecen-1-ol
13	20.11	2-Methoxy-4-vinylphenol
14	21.51	7-Hydroxy-6, 9a-dimethyl-3-methylene-decahydro-azuleno[4,5-b] furan-2,9-dione
15	22.24	6,10,14-Trimethylpentadecan-2-one
16	24.81	Spiro[tricyclo[4.4.0.0(5,9)]decane-10,2-oxirane] 1-methyl-4-isopropyl-7,8-dihydroxy-, 8(S)-
17	25.89	Caryophyllene
18	23.97	8-Acetyl-5,5-dimethyl-nona-2,3,8-trienoic acid, methyl ester
19	26.01	1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-
20	29.47	Butyl 4,7,10,13,16,19-docosahexaenoate
21	30.78	Cyclooctane, 1,2-dimethyl-
22	32.97	1H-Cyclopenta[1,3]cyclopropa[1,2]benzene, octahydro-7-methyl-3-methylene-4-(1-methylethyl)-, [3aS-(3a.alpha.,3b.beta.,4.beta.,7.alpha.,7aS*)]-
23	33.37	1-Pentadecene
24	33.81	3,7,11,15-Tetramethylhexadec-2-en-1-ol
25	34.72	N-Isobutyl-(2E,4Z,8Z,10E)-dodecatetraenamide
26	35.54	Caryophyllene oxide
27	38.11	Diethyl Phthalate
28	39.44	Bufa-20,22-dienolide, 14,15, -epoxy-3,11-dihydroxy-, (3a,5a,11a,15a)
29	39.82	2-Propenoic acid, pentadecyl ester
30	41.37	9-Desoxo-9-x-acetoxy-3,8,12-tri-O-acetylingol
31	41.74	(3Î²)-Lup-20(29)-en-3-yl acetate
32	42.11	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-

Figure 3: Chromatogram of *Acmella oleracea* leaf extract (retention time 50 min)

phytochemical constituents prevent the aggregation of the nanoparticles and are eventually accountable for the stability of the AgNPs. Mohanta *et al*. have highlighted that among these phytochemicals, the phenolic compounds and flavonoids are mainly accountable for the Ag^+ ions reduction to AgNPs.[27] The hydroxyl and carboxylic functionalities of phenolic compounds and flavonoids bind with the metal ion and thus act as good reducing agents. Besides flavonoids, tannins and glycosides may also help in the bio-reduction of Ag^+ ions to AgNPs and can act as capping agents thus preventing the agglomeration.[2] Saponins also assist the stabilization of the synthesized NPs. The secondary metabolites namely flavonoids and phenolic compounds can also serve as free radical scavengers as discussed in the application section of the present study.[23]

Ultraviolet-visible absorption studies

UV-Vis absorption spectroscopy is an imperative tool to observe the emergence as well as stability of the synthesized metal NPs. The absorption peak can be recorded and screened through the UV-Vis technique due to the surface plasmon phenomenon for various metal nanoparticles whose particle size varies within the nanometric range (<100 nm).[8] In the present study, the absorption spectra of bio-synthesized AgNPs were recorded in aqueous solution at the wavelength range of 300–700 nm.[13] Figure 4 shows the UV-Vis absorption spectra of AgNPs synthesized using *A. oleracea* leaf extract that was observed to be around 435 nm. Besides the absorption peak, the change in color from greenish-yellow to blackish-brown was also an indication of the formation of AgNPs confirming the surface plasmon resonance [In set Figure 4]. The formation of the NPs was also monitored through absorption spectra

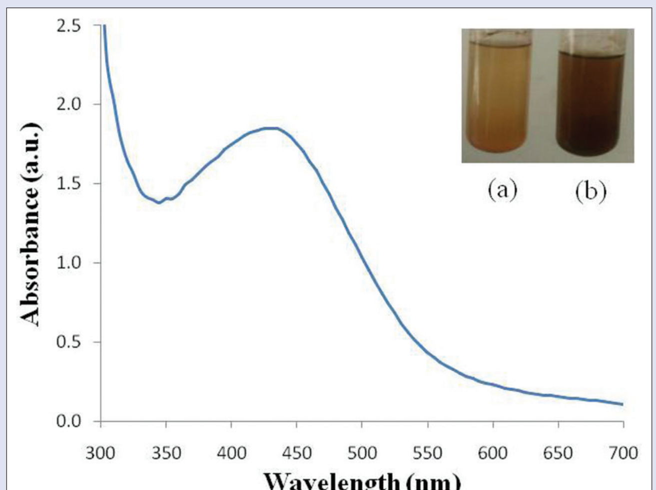


Figure 4: Ultraviolet-visible spectra of silver nanoparticles (AgNPs) synthesized form *Acmella oleracea* leaf extract. In set, color changes from (a) greenish-yellow to (b) blackish-brown upon synthesis of AgNPs

as a function of time [Figure 5]. The intensity of the absorbance peak amplified with reaction time (from 5 to 30 min). The temperature was kept near about 60°C of temperature during the study. No further increase in absorption peak was observed after 30 min thus considering half an hour to be the optimum reaction time.

Fourier transform infrared spectroscopy

FTIR spectroscopy was availed to analyze the functionalities of secondary metabolites that were accountable for capping as well as efficient stabilization of AgNPs.[8] FTIR spectrum of synthesized AgNPs was observed with many frequency bands at the range in between 3300 and 1000 cm^{-1} as shown in Figure 6.

The spectral band range between 3500 and 3100 cm^{-1} consigned the stretching vibrations of O-H group or N-H group, therefore, the band at 3275 cm^{-1} perhaps due to either stretching of O-H as alcohol intermolecular bond of the phenolic compound or N-H stretching of primary or secondary amine/amide [Figure 6a]. The band at 1605 cm^{-1} was observed to associate with C = O stretching of amide bond of protein and that at 1312 cm^{-1} indicate the presence of C-N stretching bond of amines.[8] The absorption bands at 1007 cm^{-1} can be ascribed to the vibration of the C = C bending of alkene. The shift in the frequency bands (for instance, the absorption peak shifts from 3275 to 3351 cm^{-1} whereas 1605 to 1653 cm^{-1}) as shown in Figure 6b and reduction in the number of peaks is a clear manifestation of some sort of interaction taking place between the synthesized AgNPs and the biomolecules at the interface.[24,25] The FTIR analysis in the present study have shown the active functional groups associated with various phytochemicals such as proteins, amino acids, flavonoids, phenolic acid, saponins, that are adequately existing in the leaf extract and assist the formation as well as the stability of AgNPs in consistence with literature reports.[8]

Field emission scanning electron microscope

The FESEM micrograph [Figure 7] displays the presence of bio-synthesized AgNPs. The FESEM analysis verified the data about the nature, dispersity, shape, and size of particles.[27] The micrograph depicts that the prepared AgNPs having a spherical shape, smooth surfaces, uniform, homogeneous, dispersed, and low levels of agglomeration with the average particle size of NPs ranging as 45–60 nm [Figure 7].

Antioxidant property and catalytic activity of silver nanoparticles

Antioxidant property

Potential antioxidant property of *A. oleracea* synthesized AgNPs was examined through DPPH assay.[11] DPPH is a stable free radical and its free radical scavenging is noticeable and can be assessed through visual color change from purple to greenish-yellow indicative of the reaction between methanolic DPPH solution and the antioxidant [Figure 8]. The decrease in absorption peak can be observed at 517 nm. However, it was detected that the decrease, as well as the color change, was solely depended on the concentration of the sample solution. Further, increased concentration has improved the free radical scavenging action of the AgNPs [Figure 8b]. The IC$_{50}$ value calculated from the graph was found to be 298.69 µg/mL [Figure 8c]. The antioxidant efficacy of AgNPs could be attributed to phytochemicals such as flavonoids and phenolic compounds (from leaf extract) adhered to them that act as hydrogen or electron donor to DPPH.[28] The DPPH radical acquires the electron/hydrogen to form a stable compound. The free radical generated in the first step can undergo several other chemical reactions to control the overall stoichiometry.[27]

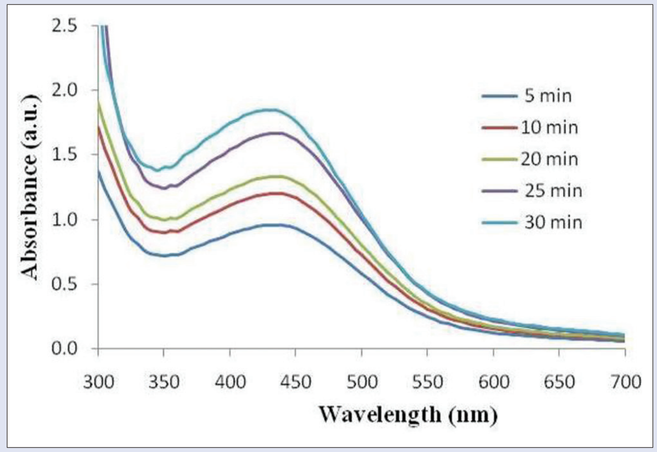


Figure 5: Ultraviolet-visible spectra of bio-synthesized silver nanoparticles at different time intervals (from 5 to 30 min)

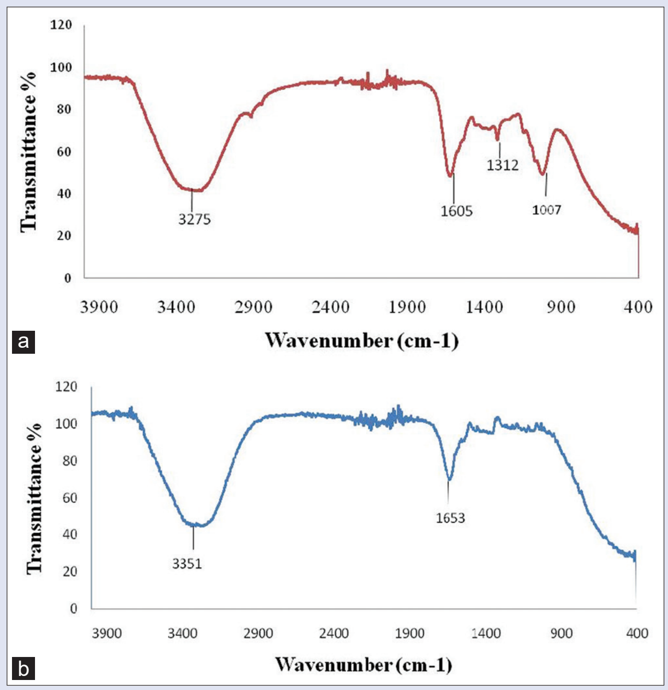


Figure 6: Fourier transform infrared spectra of (a) leaf extract and (b) silver nanoparticles

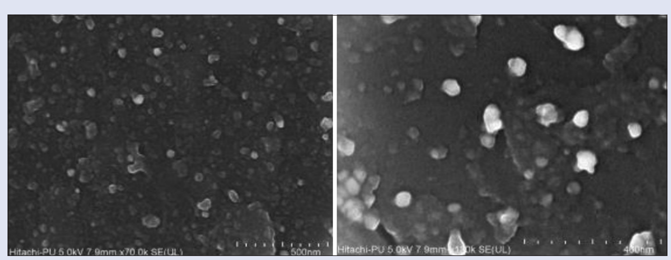


Figure 7: Field emission scanning electron microscope analysis of *Acmella oleracea* leaf extract-mediated silver nanoparticles

Catalytic activity

As another potential application, the catalytic activity of AgNPs [Figure 9a] was analyzed through UV-Vis absorption spectra of NP in an aqueous $NaBH_4$ solution. The reduction of NP to AP emerges as thermodynamically favorable, however, the kinetic barrier restricts the spontaneity of the reaction. Such a high energy barrier can be abridged in presence of AgNPs that act as good catalysts.[21] The reaction shows absorption maximum at 400 nm in absence of AgNPs and no reduction is observed even after 24 h or more. However, in the presence of AgNPs color of the solution mixture gradually changes and peak intensity at 400 nm gradually decreases [Figure 9b]. The decrease in peak intensity perhaps is due to a decrease in the concentration of the intermediate (4-nitrophenolate ion). A new peak appears around 293 nm demonstrating the formation of AP [Figure 9c]. The increase in the speed of reaction can be attributed to the adhering hydrogen to AgNPs and providing it from the reducing agent to the reaction intermediate or perhaps facilitating the transfer of electrons.[17]

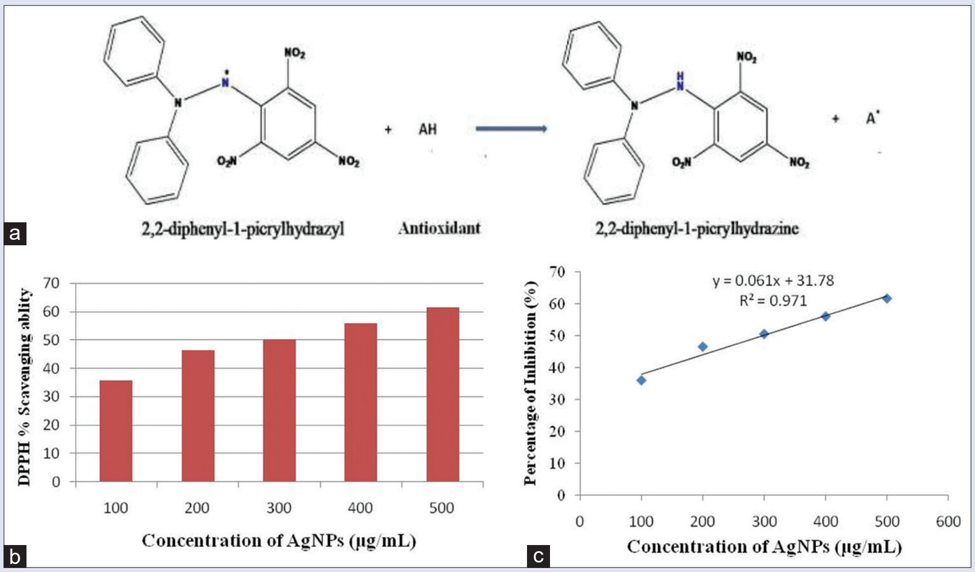


Figure 8: 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay: (a) The reaction shows the transfer of the electron/hydrogen from antioxidant to DPPH free radical, (b) Concentration dependent antioxidant efficacy of silver nanoparticles (AgNPs) solution, (c) Increase in percentage of inhibition with increase in concentration AgNPs solution

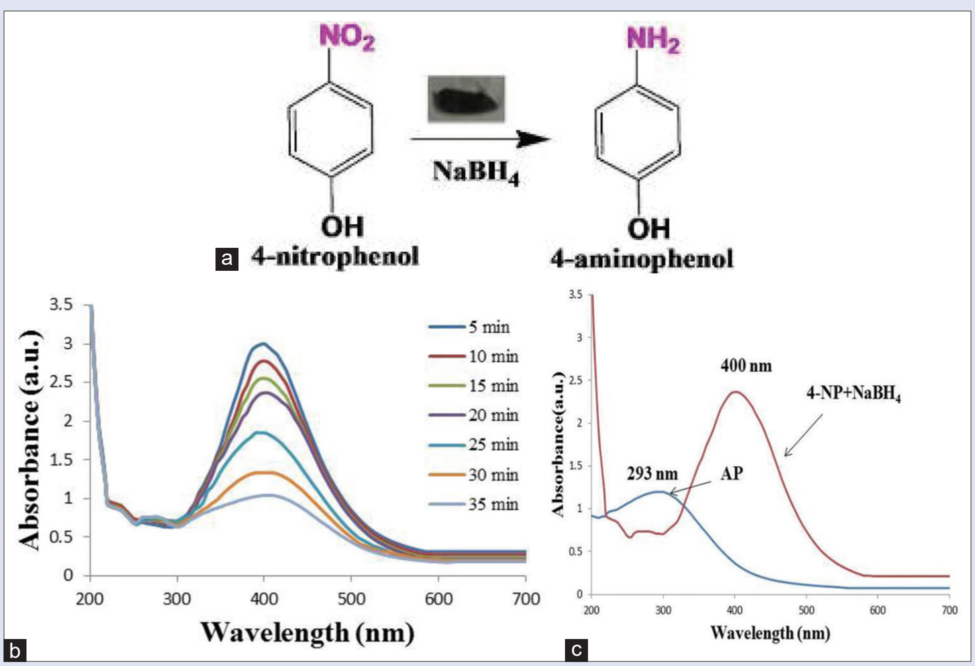


Figure 9: Catalytic activity of silver nanoparticles (AgNPs): (a) Reduction in the presence of AgNPs, (b) Ultraviolet-visible (UV-Vis) spectra of time-dependent reduction (c) UV-Vis peak for the formation of 4-aminophenol

CONCLUSION

In this research, the phyto-mediated synthesis of AgNPs using *A. oleracea* leaf extract has been developed. *A. oleracea*, as per knowledge, has not been reported so far for green synthesis of AgNPs, therefore, provides exclusivity to the present work. The confirmation of the bio-synthesized AgNPs was carried through color change as well through other characterization tools, namely UV-Vis, FTIR, and FESEM. The spherical morphology having an average size in between 45 and 60 nm of AgNPs was identified from the FESEM micrograph. The green synthesized AgNPs have shown potential free radical scavenging activity, as well as catalytic activity thus, may be introduced as promising applications in the biomedical field, and in environmental remediation.

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Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Ghosh PR, Fawcett D, Sharma SB, Poinern GE. Production of high-value nanoparticles via biogenic processes using aquacultural and horticultural food waste. Materials (Basel) 2017;10:E852.
2. Sharma R, Garg R, Kumari A. A review on biogenic synthesis, applications and toxicity aspects of zinc oxide nanoparticles. EXCLI J 2020;19:1325-40.
3. Devi M, Devi S, Sharma V, Rana N, Bhatia RK, Bhatt AK. Green synthesis of silver nanoparticles using methanolic fruit extract of *Aegle marmelos* and their antimicrobial potential against human bacterial pathogens. J Tradit Complement Med 2020;10:158-65.
4. Rokade SS, Joshi KA, Mahajan K, Patil S, Tomar G, Dubal DS, *et al*. *Gloriosa superba* mediated synthesis of platinum and palladium nanoparticles for induction of apoptosis in breast cancer. Bioinorg Chem Appl 2018;2018:4924186.
5. Yallappa S, Manjanna J, Dhananjaya BL. Phytosynthesis of stable Au, Ag and Au-Ag alloy nanoparticles using J. Sambac leaves extract, and their enhanced antimicrobial activity in presence of organic antimicrobials. Spectrochim Acta Part A Mol Biomol Spectrosc 2015;137:236-43.
6. Karnan T, Selvakumar SA. Biosynthesis of ZnO nanoparticles using rambutan (*Nephelium lappaceum L.*) peel extract and their photocatalytic activity on methyl orange dye. J Mol Struct 2016;1125:358-65.
7. Filip GA, Moldovan B, Baldea I, Olteanu D, Suharoschi R, Decea N, *et al*. UV-light mediated green synthesis of silver and gold nanoparticles using Cornelian cherry fruit extract and their comparative effects in experimental inflammation. J Photochem Photobiol B Biol 2019;191:26-37.
8. Moodley JS, Krishna SB, Pillay K, Sershen P, Govender P. Green synthesis of silver nanoparticles from *Moringa oleifera* leaf extracts and its antimicrobial potential. Adv Nat Sci Nanosci Nanotechnol 2018;9:1-9.
9. Venkatesh N. Metallic nanoparticle: A review. Biomed J Sci Tech Res 2018;4:3765-75.
10. Basavegowda N, Mandal TK, Baek KH. Bimetallic and trimetallic nanoparticles for active food packaging applications: A review. Food Bioprocess Technol 2020;13:30-44.
11. Jokar M, Rahman RA, Ibrahim NA, Abdullah LC, Ping TC. Characterization and biocompatibility properties of silver nanoparticles produced using short chain polyethylene glycol. J Nano Res 2010;10:29-37.
12. Khodadadi B, Bordbar M, Yeganeh-Faal A, Nasrollahzadeh M. Green synthesis of Ag nanoparticles/clinoptilolite using *Vaccinium macrocarpon* fruit extract and its excellent catalytic activity for reduction of organic dyes. J Alloys Compd 2017;719:82-8.
13. Edison TJ, Sethuraman MG. Instant green synthesis of silver nanoparticles using *Terminalia chebula* fruit extract and evaluation of their catalytic activity on reduction of methylene blue. Process Biochem 2012;47:1351-7.
14. He Y, Xu B, Li W, Yu H. Silver nanoparticle-based chemiluminescent sensor array for pesticide discrimination. J Agric Food Chem 2015;63:2930-4.
15. Chokkalingam M, Singh P, Huo Y, Soshnikova V, Ahn S, Kang J, *et al*. Facile synthesis of Au and Ag nanoparticles using fruit extract of Lycium chinense and their anticancer activity. J Drug Deliv Sci Technol 2019;49:308-15.
16. Ansar S, Tabassum H, Aladwan NSM, Naiman Ali M, Almaarik B, AlMahrouqi S, *et al*. Eco friendly silver nanoparticles synthesis by *Brassica oleracea* and its antibacterial, anticancer and antioxidant properties. Sci Rep 2020;10:18564.
17. Albukhari SM, Ismail M, Akhtar K, Danish EY. Catalytic reduction of nitrophenols and dyes using silver nanoparticles @ cellulose polymer paper for the resolution of waste water treatment challenges. Colloids Surfaces A Physicochem Eng Asp 2019;577:548-61.
18. Filip GA, Moldovan B, Baldea I, Olteanu D, Suharoschi R, Decea N, *et al*. UV-light mediated green synthesis of silver and gold nanoparticles using Cornelian cherry fruit extract and their comparative effects in experimental inflammation. J Photochem Photobiol B 2019;191:26-37.
19. Kumar B, Vizuete KS, Sharma V, Debut A, Cumbal L. Ecofriendly synthesis of monodispersed silver nanoparticles using Andean Mortiño berry as reductant and its photocatalytic activity. Vacuum 2019;160:272-8.
20. Alamelu K, Jaffar Ali BM. Ag nanoparticle-impregnated sulfonated graphene/TiO2 composite for the photocatalytic removal of organic pollutants. Appl Surf Sci 2020;512:145629.
21. Zaheer Z. Biogenic synthesis, optical, catalytic, and *in vitro* antimicrobial potential of Ag-nanoparticles prepared using Palm date fruit extract. J Photochem Photobiol B Biol 2018;178:584-92.
22. Qu LL, Geng ZQ, Wang W, Yang KC, Wang WP, Han CQ, *et al*. Recyclable three-dimensional Ag nanorod arrays decorated with O-g-C3N4 for highly sensitive SERS sensing of organic pollutants. Hazard Mater 2019;379:120823.
23. Abeysiri GR, Dharmadasa RM, Abeysinghe DC, Samarasinghe K. Screening of phytochemical, physico-chemical and bioactivity of different parts of *Acmella oleraceae* Murr. (Asteraceae), a natural remedy for toothache. Ind Crops Prod 2013;50:852-6.
24. Ebrahimzadeh MA, Naghizadeh A, Amiri O, Shirzadi-Ahodashti M, Mortazavi-Derazkola S. Green and facile synthesis of Ag nanoparticles using *Crataegus pentagyna* fruit extract (CP-AgNPs) for organic pollution dyes degradation and antibacterial application. Bioorg Chem 2020;94:103425.
25. Mohseni MS, Khalilzadeh MA, Mohseni M, Hargalani FZ, Getso MI, Raissi V, *et al*. Green synthesis of Ag nanoparticles from pomegranate seeds extract and synthesis of Ag-Starch nanocomposite and characterization of mechanical properties of the films. Biocatal Agric Biotechnol 2020;25:101569.
26. Aziz MA. Qualitative phytochemical screening and evaluation of anti-inflammatory, analgesic and antipyretic activities of *Microcos paniculata* barks and fruits. J Integr Med 2015;13:173-84.
27. Mohanta YK, Panda SK, Bastia AK, Mohanta TK. Biosynthesis of silver nanoparticles from *Protium serratum* and investigation of their potential impacts on food safety and control. Front Microbiol 2017;8:1-10.
28. Abdel-Aziz MS, Shaheen MS, El-Nekeety AA, Abdel-Wahhab MA. Antioxidant and antibacterial activity of silver nanoparticles biosynthesized using *Chenopodium murale* leaf extract. J Saudi Chem Soc 2014;18:356-63.