Nanochem Res 9(3): 242-247, Summer 2024

RESEARCH PAPER

Investigation of Antimicrobial Potential of Silver Nanoparticles Synthesised from Vegetable Peel Extracts

Sheeba Daniel* *, Latha R. Gladis

Department of Chemistry, Holy Cross College (Autonomous), Nagercoil, Tamil Nadu, India.

ARTICLE INFO

Article History:
Received 30 Mar 2024
Accepted 13 May 2024
Published 01 Jun 2024

Keywords:
Vegetable Peel Extracts
Green Synthesis
Silver Nanoparticles
Antimicrobial Evaluation

ABSTRACT

The aim of the present study is to synthesise silver nanoparticles (AgNPs) from ash gourd and cucumber peel extracts and analyse their antimicrobial activities. The synthesised AgNPs are characterized by UV-Visible and FTIR spectral analysis. The synthesised AgNPs showed the corresponding surface plasmon resonance peak in the range of 440-459 nm. The absorption peaks indicated the poly dispersed nature of the AgNPs. The bioactive molecules present in the peel extracts not only reduced the Ag^{+} ions to AgNPs but also stabilized the synthesised AgNPs. The nature and the particle size of the synthesised AgNPs were determined using XRD analysis. The surface morphology of the synthesised AgNPs was analyzed by SEM analysis. The synthesised AgNPs exhibited antimicrobial activity on selected microorganisms taken in the present study. The synthesised AgNPs directly interacted with the outer membrane of the microorganism, causing the membrane to rupture and thus killing the microorganism. Hence, the AgNPs synthesised from ash gourd and cucumber peel extracts are used as drugs for microbial infection.

How to cite this article
Daniel Sh., R. Gladis L. Investigation of Antimicrobial Potential of Silver Nanoparticles Synthesised from Vegetable Peel Extracts. Nanochem Res, 2024; 9(3):242-247. DOI: 10.22036/ncr.2024.03.008

INTRODUCTION

Vegetables and fruits stand as the most commonly consumed agricultural produce; however, their peels create substantial waste, resulting in both nutritional and economic losses. The processing of vegetables and fruits generate significant waste such as peels, rind, seeds etc., leading to environmental problems. According to the FAO (Food and Agriculture Organization), food wastage is the second highest cause of greenhouse gas emission [1]. Vegetables and fruits waste consist of high amounts of bioactive compounds and these bioactive compounds exhibit strong antioxidant, antimicrobial, anticancer, antidiabetic and antihypocholesterolemic properties [2-5].

Nowadays, these vegetable and fruits wastes are utilized for the production of edible films, nanoparticles, and other valuable products [6]. The compounds found in vegetable peels serve as agents that reduce and stabilize nanoparticle formation during synthesis. Several researchers describe the process of creating nanoparticles using leftovers from food. Among the noble metal nanoparticles, silver nanoparticles (AgNPs) find a multitude of applications across various fields due to their unique properties [7]. Because of their distinct characteristics and applications, many researches have made considerable efforts towards synthesizing AgNPs using green synthetic approaches [8,9]. Deepa and co-workers synthesised AgNPs from vegetable waste of pea and bottle gourd and analyzed their antibacterial properties [10]. Jain and co-workers synthesised FeNPs from the peel extracts of *Artocarpus heterophyllus* [11]. Raul *et al.*, determined the larvicidal activity of silver nanohybrids synthesized from peel waste of some fruits and vegetables [12]. Surendra *et al.*, reported the toxicological and biological activities of zinc oxide nanoparticles synthesized from the peel extract of *Moringa oleifera* [13]. Sharma and

* Corresponding Author Email: *sheebadaniel@holycrossngl.edu.in*

co-workers described the antimicrobial efficacy of AgNPs synthesized by vegetable wastes [14].

According to the review of literature, this study concentrates on the creation of AgNPs using extracts obtained from the peels of ash gourd (*Benincasa Hispida*) and cucumber (*Cucumis sativus*). The peel extracts of ash gourd and cucumber consists of polyphenols, flavonoids, glycosides, proteins, vitamins, minerals, carbohydrates, beta-carotene, magnesium, potassium, manganese, calcium, iron, potassium and iodine [15-18]. The phytochemicals and nutrients present in the peel extracts are responsible for producing the AgNPs. The formation of AgNPs was confirmed by spectroscopic analysis. The particle nature and the particle size were determined by XRD and SEM analysis. The antimicrobial properties of AgNPs on certain microorganisms *Klebsiella pneumonia, Escherichia coli, Staphylococcus aureus*, *Pseudomonas aerogenisa*, *Candida albicans* and *Aspergillus* were evaluated.

EXPERIMENTAL

Materials

The peels of ash gourd and cucumber were collected from the kitchen waste. Silver nitrate (purity 99 %) was purchased from Merck. Deionized water was utilized for the experiments.

Preparation of Vegetable Peel Extracts

Vegetable peels of ash gourd and cucumber were washed with distilled water and 20 g of each were taken separately in a 250 mL conical flask. The contents were boiled using distilled water (100 mL) for 5 min. The corresponding peel extracts were collected, filtered, and centrifuged for 10 min at 8,000 rpm. The corresponding supernatant extracts were used as such for the preparation of AgNPs.

Synthesis of AgNPs

About 90 mL of aqueous $AgNO_3$ solution (1 mM) was added to 10 mL of the corresponding vegetable peel extracts taken in a 250 mL conical flask, incubated for 20 min. The preliminary detection of the resulting AgNPs was identified by the alteration in colour from colourless to brown. Thus, the AgNPs formed were centrifuged for 10 min and distributed in deionized water. The pellets of AgNPs formed was collected, dried at room temperature, and stored.

Characterization Techniques

The UV-Visible spectral analysis of AgNPs was carried out by Shimadzu UV-1800 spectrophotometer. FTIR spectral analysis of the synthesised AgNPs was conducted using Shimadzu IR Affinity-1 spectrophotometer using KBr pellet sampling technique. The particle nature and particle size of the synthesised AgNPs were determined via XRD pattern using X-ray diffractometer Ultima III, Rigaku, Tokyo. XRD analysis pattern of AgNPs on glass slides was recorded with Cu Kα radiation (λ = 1.5406 Å) source in the range of 2θ, 10°-80° with 4°/minute scanning rate. The morphology and the size of the AgNPs were determined utilizing Quanta 250 FEG scanning electron microscope.

Antimicrobial Activity of AgNPs

The antimicrobial properties of AgNPs with *Klebsiella pneumonia, Escherichia coli, Staphylococcus aureus, Pseudomonas aerogenisa, Candida albicans and Aspergillus* were analyzed by Kirby-Bauer discs diffusion method. The microbes taken in the present investigation were grownup in LB broth for 24 h. Approximately 20 mL of agar was transferred into the culture plate. The organisms under test were streaked across the agar, and disks containing AgNPs were placed on the medium using sterilized tongs. The antimicrobial effectiveness was assessed by measuring the inhibition zones.

RESULTS AND DISCUSSION

The current study reveals a cost-effective, eco-friendly approach for the mass production of AgNPs using extracts from ash gourd and cucumber peels. The initial detection of AgNPs derived from these peels was indicated by a change in colour. Furthermore, the colour of AgNPs varies based on the size of the nanoparticles.

UV-Visible Spectral Analysis

The UV-Visible spectra of AgNPs showed an absorbance at 440 - 459 nm. The uptake of AgNPs, produced through the reduction of Ag^+ ions in a water-based solution, occurred due to the synchronized movement of their conduction band electrons reacting to electromagnetic waves [18]. The broadening of the absorption spectrum of AgNPs indicated the poly dispersive nature of the materials (**Fig.1**).

FTIR Spectral Analysis

The FTIR spectra of AgNPs synthesized from ash gourd and cucumber demonstrate similar bands

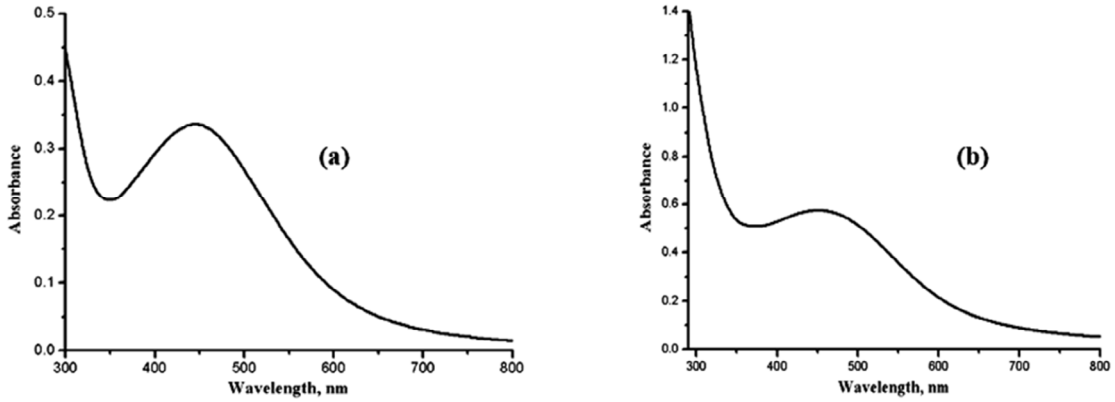

Fig. 1. Absorption spectrum of AgPNs formed from peel extract of (a) ash gourd (b) cucumber

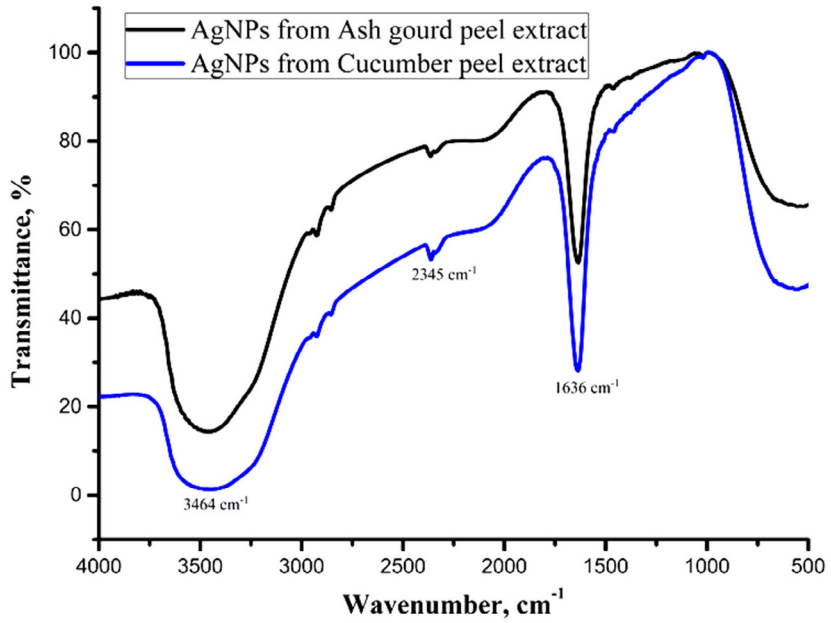

Fig. 2. FTIR spectra of AgNPs formed from vegetable peel extracts

at 3464, 2926, 2854, 2345, 1636, 1464, 1023 and 547 cm^{-1}, respectively (**Fig. 2**). The broad band at 3464 cm^{-1} represents the O-H stretching frequency of H-bonded alcohols or phenols. The presence of weak bands at 2926, 2854 and 1464 cm^{-1} indicate the C-H stretching of methyl and methylene groups. The band at 2345 cm^{-1} is due to the asymmetric stretching of C-H bond. The strong absorption band at 1636 cm^{-1} depicts the C=O stretching of an ester. The weak band at 1023 cm^{-1} is assigned to C-O stretching of primary alcohols. The FTIR spectral data confirm that the polyphenols present in the peel extracts of ash gourd and cucumber are responsible for the production of AgNPs at room temperature. Similar results are reported for the FTIR analysis of AgNPs synthesised from *Cucumis prophetarum* leaf extract [19].

XRD Analysis of AgNPs

XRD analysis is used for the determination of particle nature and size of AgNPs synthesized from vegetable peel extracts (**Fig. 3**). The diffractogram of synthesised AgNPs is in accordance with the diffraction pattern of JCPDS silver file No. 65-2871. The formation of AgNPs are confirmed from the diffraction pattern, the peaks at 2θ values 37.947, 44.219, 64.240 and 77.257 degree in the diffractogram indicates the presence of silver metal

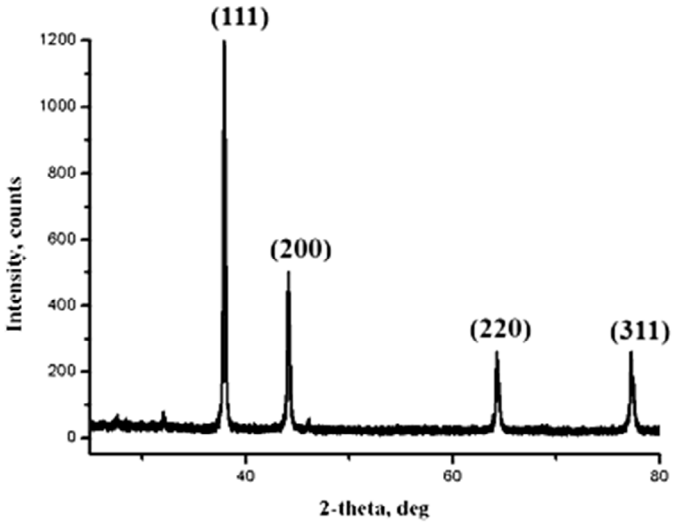

Fig. 3. XRD pattern of AgNPs

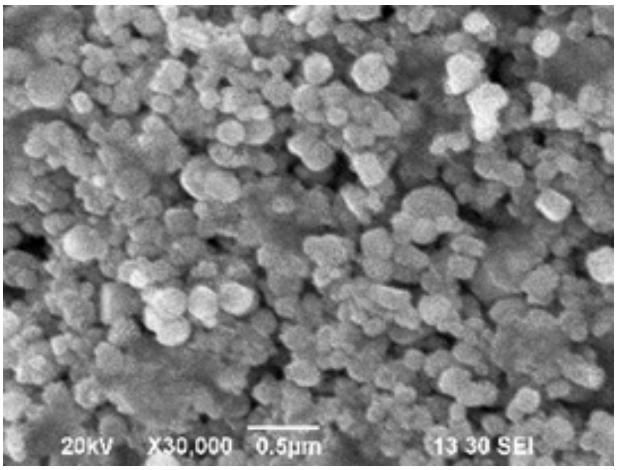

Fig. 4. SEM image of AgNPs

and the corresponding (hkl) values are (111), (200), (220) and (311). The crystalline size of the synthesised AgNPs determined from Scherrer formula is found to be 25 nm. The XRD data confirm the face centered cubic geometry of AgNPs which is in accordance with the face centered XRD pattern of AgNPs reported by Feng *et al*., [20].

SEM Analysis of AgNPs

The SEM image of the synthesized AgNPs shows that the particles are spherical and non-uniformly distributed with a diameter of 28 nm (**Fig. 4**). The SEM image shows that most of the AgNPs are aggregated and the result is in accordance with the SEM image of AgNPs synthesized from Taraxacum officinale [21].

Antimicrobial Activity of AgNPs

The synthesized AgNPs from the peel extracts of ash gourd and cucumber demonstrate antimicrobial properties on *Klebsiella pneumonia, Escherichia coli, Staphylococcus aureus, Pseudomonas aerogenisa, Candida albicans and Aspergillus.* The zone of inhibition of the synthesized AgNPs against the selected human pathogens taken in the present investigation is shown in **Fig. 5**. The AgNPs synthesized from ash gourd peel extract exhibit higher activity on *Candida albicans* than that of the other pathogens. The AgNPs from cucumber peel extract show higher activity on *Escherichia coli*

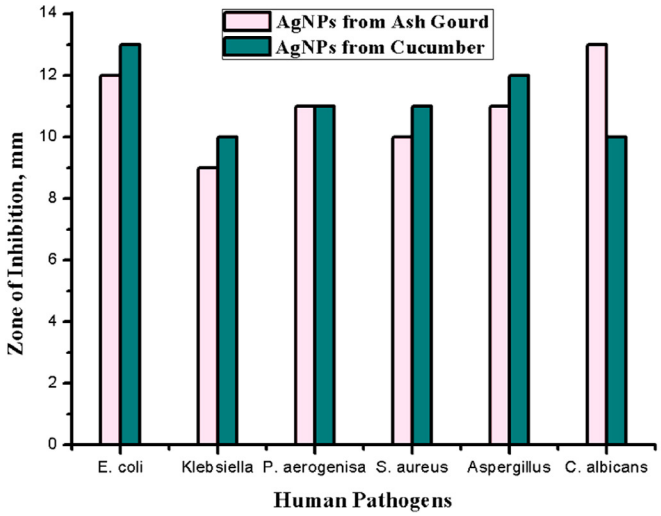

Fig. 5. Zone of inhibition of AgNPs synthesised from ash gourd and cucumber peel extracts against human pathogens

(gram-negative) than that of the other microbes. As per the literature, the antibacterial activity of AgNPs synthesized from vegetable peel extracts is higher in the case of the gram-negative bacteria [22,23]. Gram-negative bacteria possess a single peptidoglycan layer in their membrane, whereas gram-positive microorganism have numerous peptidoglycan layer. This structural difference makes gram-positive bacteria tougher and more resistant to rupture compared to their gram-negative counterparts.

Usually, gram-negative microorganism is more sensitive to silver ions because of the presence of various targets for interaction within the bacterial cell. The small size of AgNPs allows them to penetrate the bacterial cell walls more effectively. Their increased surface area enhances the contact between the nanoparticles and bacterial membranes. Another reason is that the negatively charged surface of gram-negative bacteria may facilitate electrostatic interactions with the positively charged AgNPs. This interaction can lead to adsorption and disruption of the bacterial cell membrane [24,25]. Thus, the gram-negative bacteria demonstrate higher zone of inhibition. The obtained results indicate that the AgNPs synthesized from the peel extract of ash gourd and cucumber exhibit antimicrobial activities. The synthesised AgNPs directly interact with the outer membrane of the microorganism, causing the membrane to rupture and thus obliterating the microorganism. Therefore, the synthesized AgNPs may be used as antimicrobial agents.

CONCLUSION

The present investigation reveals the production, analysis, and antimicrobial efficacy of AgNPs derived from ash gourd and cucumber peel extracts. The synthesized AgNPs show surface plasmon resonance peak in the region of 440 - 459 nm. The phytochemicals present in the extracts reduce Ag^+ ions to AgNPs. The synthesized AgNPs show antimicrobial activity on *Klebsiella pneumonia, Escherichia coli, Staphylococcus aureus, Pseudomonas aerogenisa, Candida albicans and Aspergillus*. Thus, the synthesised AgNPs may be used as antimicrobial drugs in the field of biomedicine.

CONFLICTS OF INTEREST

The authors declare that none of the authors have any competing interest.

REFERENCES

1. Lau KQ, Sabran MR, Shafie SR. Utilization of Vegetable and Fruit By-products as Functional Ingredient and Food. 2021;8:661-93. https://doi.org/10.3389/fnut.2021.661693

2. Chávez-Santoscoy RA, Gutiérrez-Uribe JA, Serna-Saldivar SO, Perez-Carrillo E. Production of maize tortillas and cookies from nixtamalized flour enriched with anthocyanins, flavonoids and saponins extracted from black bean (Phaseolus vulgaris) seed coats. Food Chemistry. 2016;192:90-7. https://doi.org/10.1016/j.foodchem.2015.06.113

3. Chávez-Santoscoy RA, Lazo-Vélez MA, Serna-Sáldivar SO, Gutiérrez-Uribe JA. Delivery of Flavonoids and Saponins from Black Bean (Phaseolus vulgaris) Seed Coats Incorporated into Whole Wheat Bread. International Journal of Molecular Sciences [Internet]. 2016; 17(2):[222 p.]. https://doi.org/10.3390/ijms17020222

4. Maner S, Sharma AK, Banerjee K. Wheat Flour Replacement by Wine Grape Pomace Powder Positively Affects Physical, Functional and Sensory Properties of Cookies. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. 2017;87(1):109-13. https://doi.org/10.1007/s40011-015-0570-5
5. Benítez V, Mollá E, Martín-Cabrejas MA, Aguilera Y, Esteban RM. Physicochemical properties and in vitro antidiabetic potential of fibre concentrates from onion by-products. Journal of Functional Foods. 2017;36:34-42. https://doi.org/10.1016/j.jff.2017.06.045
6. Kumar H, Bhardwaj K, Sharma R, Nepovimova E, Kuča K, Dhanjal DS, et al. Fruit and Vegetable Peels: Utilization of High Value Horticultural Waste in Novel Industrial Applications. Molecules [Internet]. 2020; 25(12). https://doi.org/10.3390/molecules25122812
7. Santhosh A, Theertha V, Prakash P, Smitha Chandran S. From waste to a value added product: Green synthesis of silver nanoparticles from onion peels together with its diverse applications. Materials Today: Proceedings. 2021;46:4460-3. https://doi.org/10.1016/j.matpr.2020.09.680
8. Atalar MN, Baran A, Baran MF, Keskin C, Aktepe N, Yavuz Ö, et al. Economic fast synthesis of olive leaf extract and silver nanoparticles and biomedical applications. Particulate Science and Technology. 2022;40(5):589-97. https://doi.org/10.1080/02726351.2021.1977443
9. Alwhibi MS, Soliman DA, Awad MA, Alangery AB, Al Dehaish H, Alwasel YA. Green synthesis of silver nanoparticles: Characterization and its potential biomedical applications. 2021;10(1):412-20. https://doi.org/10.1515/gps-2021-0039
10. Deepa, Ameen F, Amirul Islam M, Dhanker R. Green synthesis of silver nanoparticles from vegetable waste of pea Pisum sativum and bottle gourd Lagenaria siceraria: Characterization and antibacterial properties. 2022;10. https://doi.org/10.3389/fenvs.2022.941554
11. Jain R, Mendiratta S, Kumar L, Srivastava A. Green synthesis of iron nanoparticles using Artocarpus heterophyllus peel extract and their application as a heterogeneous Fenton-like catalyst for the degradation of Fuchsin Basic dye. Current Research in Green and Sustainable Chemistry. 2021;4:100086. https://doi.org/10.1016/j.crgsc.2021.100086
12. Raul PK, Santra P, Goswami D, Tyagi V, Yellappa C, Mauka V, et al. Green synthesis of carbon dot silver nanohybrids from fruits and vegetable's peel waste: Applications as potent mosquito larvicide. Current Research in Green and Sustainable Chemistry. 2021;4:100158. https://doi.org/10.1016/j.crgsc.2021.100158
13. Surendra TV, Roopan SM, Al-Dhabi NA, Arasu MV, Sarkar G, Suthindhiran K. Vegetable Peel Waste for the Production of ZnO Nanoparticles and its Toxicological Efficiency, Antifungal, Hemolytic, and Antibacterial Activities. Nanoscale Research Letters. 2016;11(1):546. https://doi.org/10.1186/s11671-016-1750-9
14. Sharma K, Kaushik S, Jyoti A. Green synthesis of silver nanoparticles by using waste vegetable peel and its antibacterial activities. Journal of Pharmaceutical Sciences Research. 2016;8(5):313.
15. Kumar C, Mythily R, Chandraju S. Extraction and mass characterization of sugars from ash gourd peels (Benincasa hispida). Rasayan Journal of Chemistry. 2012;5(3):280-5.
16. Babajide JM, Olaluwoye AA, Taofik Shittu TA, Adebisi MA. Physicochemical Properties and Phytochemical Components of Spiced Cucumber-Pineapple Fruit Drink. Nigerian Food Journal. 2013;31(1):40-52. https://doi.org/10.1016/S0189-7241(15)30055-2
17. Kim MY, Kim EJ, Kim YN, Choi C, Lee BH. Comparison of the chemical compositions and nutritive values of various pumpkin (Cucurbitaceae) species and parts. Nutrition research and practice. 2012;6(1):21-7. https://doi.org/10.4162/nrp.2012.6.1.21
18. Roy A, Bulut O, Some S, Mandal AK, Yilmaz MD. Green synthesis of silver nanoparticles: biomolecule-nanoparticle organizations targeting antimicrobial activity. RSC advances. 2019;9(5):2673-702. https://doi.org/10.1039/C8RA08982E
19. Hemlata, Meena PR, Singh AP, Tejavath KK. Biosynthesis of Silver Nanoparticles Using Cucumis prophetarum Aqueous Leaf Extract and Their Antibacterial and Antiproliferative Activity Against Cancer Cell Lines. ACS Omega. 2020;5(10):5520-8. https://doi.org/10.1021/acsomega.0c00155
20. Feng A, Cao J, Wei J, Chang F, Yang Y, Xiao Z. Facile Synthesis of Silver Nanoparticles with High Antibacterial Activity. Materials [Internet]. 2018; 11(12). https://doi.org/10.3390/ma11122498
21. Rasheed T, Bilal M, Li C, Iqbal H. Biomedical potentialities of Taraxacum officinale-based nanoparticles biosynthesized using methanolic leaf extract. Current pharmaceutical biotechnology. 2017;18(14):1116-23. https://doi.org/10.2174/1389201019666180214145421
22. Bilal M, Rasheed T, Iqbal HMN, Li C, Hu H, Zhang X. Development of silver nanoparticles loaded chitosan-alginate constructs with biomedical potentialities. International Journal of Biological Macromolecules. 2017;105:393-400. https://doi.org/10.1016/j.ijbiomac.2017.07.047
23. Netai M-M, Stephen N, Musekiwa C. Synthesis of silver nanoparticles using wild Cucumis anguria: Characterization and antibacterial activity. African journal of Biotechnology. 2017;16(38):1911-21. https://doi.org/10.5897/AJB2017.16076
24. Ahmed S, Ahmad M, Swami BL, Ikram S. A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise. Journal of Advanced Research. 2016;7(1):17-28. https://doi.org/10.1016/j.jare.2015.02.007
25. Murthy HCAA. Green Silver Nanoparticles Synthesised Using Medicinal plant Echinops sp. Root Extract for Antimicrobial Applications. Nanochemistry Research. 2020;5(2):128-40.