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Cytotoxic and antimicrobial analysis of biosynthesized selenium nanoparticles from *Solanum tuberosum* peels

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Abstract

In recent years, interest in the eco-friendly manufacturing of metal nanoparticles from plant extracts has surged. Nonetheless, no research has examined the combined antibacterial and anticancer properties of SeNPs synthesized with *Solanum tuberosum* (*S. tuberosum*) extract. This study involved the synthesis of selenium nanoparticles (ST-SeNPs) utilizing phytochemicals with reducing and capturing properties derived from the aqueous extract of *S. tuberosum* shell through a green synthesis approach. To determine the unique characteristics of ST-SeNPs nanoparticles, a variety of techniques were used, including scanning electron microscopy (SEM), zeta potential analysis, transmission electron microscopy (TEM), dynamic light scattering (DLS), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), UV-visible (UV-Vis) spectroscopy, and energy dispersive X-ray spectrometry (EDX). The optical characteristics of ST-SeNPs were validated using UV-Vis measurement, revealing the peak absorbance at 350 nm. FTIR examination verified the presence of functional groups on the surface of the produced ST-SeNPs nanoparticles. Upon examination of the SEM results, it was concluded that the synthesized SeNPs exhibited uniform distribution and possessed a round morphology. The anticancer efficacy of the produced nanoparticles on the A549 lung cancer cell line and OVCAR-3 ovarian cancer cell line after 24 and 48 hours of exposure was assessed using the MTT test. It was established that elevated concentration inhibited cell growth. The inhibitory efficacy of SeNPs against the proliferation of *Escherichia coli* (*E. coli*), *Staphylococcus aureus* (*S. aureus*), and *Candida albicans* (C. albicans) was assessed using the disk diffusion agar technique. The evaluated SeNPs exhibited antibacterial efficacy against bacterial and yeast cells. The results indicate that ST-SeNPs produced via green synthesis can serve as anticancer and antibacterial agents.

Keywords: *Solanum tuberosum* peels, Selenium nanoparticle, Anticancer, Antimicrobial

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INTRODUCTION

Nanotechnology is the name given to the entirety of scientific studies conducted in interdisciplinary technologies such as physics, chemistry, biology, materials science, electronics, and medicine with dimensions ranging from 1 to 100 nanometers. We can also say that this field is a set of studies conducted on a very small scale (Zambonino et al., 2021). Nanoparticles (NPs) used in the field of nanotechnology and nanoscience are unique due to their ultra-small sizes and offer significant advantages over materials such as better physical, chemical, and biological properties, larger surface area, spatial confinement, reduced defects, and higher surface energy (Chaudhary et al., 2016). The dimensions of these particles significantly influence their prospective applications across various domains, including biomedicine, nanobiotechnology, agriculture, pharmacology, and optoelectronics, owing to attributes such as surface functionality, chemical composition, morphology, and crystallinity (Rasouli, 2019; Elahian et al., 2017). Nanoparticles can be of different types depending on their areas of use. Nanomaterials derived from metals, including silver, gold, selenium, copper, zinc, and tellurium, are referred to as metallic nanoparticles. Metallic nanoparticles can be produced by several synthesis processes, and these nanoparticles have garnered interest from researchers due to their significant attributes, including their characteristics and size specificity, particularly when made using plant extracts. The method of using plants or their parts is safe, economical, and environmentally friendly. In this method, no harmful chemicals or reducing agents are used, and the plant extract obtained here acts as a reducing agent, reducing metal ions, and thus NPs are synthesized. Synthesized NPs such as silver, selenium, copper, gold, and zinc contain many functional properties such as anti-tumor, antimicrobial, and antioxidant roles (Burlec et al. 2023).

Selenium (Se) is a crucial element utilized in medical applications due to its antioxidant, immune-modulating, antibacterial, and antifungal properties, as well as its roles in cancer prevention, growth enhancement, and reproductive improvement. Additionally, it is employed in various industrial sectors, including electronic components, solar cells, sensors, biological imaging, metallurgy, glass manufacturing, and pigment production (He et al., 2025). Nanoparticles of selenium are significant for study due to their elevated absorption rate and reduced toxicity relative to their organic and inorganic counterparts. Because of its special qualities, such as high biological activity, bioavailability, low toxicity, good particle dispersion, and large surface area, selenium nanoparticles are thought to be a promising material for many applications (Kumar and Prasad, 2021). Experimental studies have shown that SeNP can stop cancer cell proliferation and even lead to apoptosis. This effect has been shown to induce ROS-mediated necrosis in prostate cancer (Sonkusre and Cameotra, 2017), by inducing autophagy in colorectal cancer (Huang et al., 2019), and by increasing apoptosis in skin, breast, and liver cancer (Chen and Wong, 2009). Due to their low toxicity, Se-NPs have recently attracted much more attention as a promising candidate in medical diagnostics, especially in addition to anti-cancer therapy in medical applications, with their excellent antioxidant, antibacterial, antiviral, antifungal, sensor, and anti-inflammatory biological properties. SeNPs have proven to be effective against a variety of bacteria and dangerous fungi (Lin et al., 2021; Abbas et al., 2021). Moreover, Se-NPs exhibit physical, chemical, electrical, optical, magnetic, semiconducting, catalytic, and biological properties (Ansari et al., 2024).

SeNPs have attracted great attention worldwide due to their wide applications in therapeutics (Park et al., 2025). The promising role of SeNPs in the stabilization of the immune system and the activation of the defense response makes this nanomaterial advantageous. Green synthesis applications, which are easy to synthesize, lower cost, have a wide spectrum of materials (organisms) used, and are an environmentally friendly method for obtaining SeNPs, have become more preferred (Roy et al., 2025). SeNPs synthesized by the green synthesis method are attracting great interest from scientists with their current studies due to their biocompatibility, low toxicity, and strong biological activities, including antitumor and antimicrobial effects (Chen et al., 2025).

Potatoes is one of the most consumed products worldwide. Potato peels are generally considered waste, which constitutes a significant portion of kitchen waste. Potato peels can also be an important food in animal nutrition (Kowalczewski et al., 2022). The extract of potato peels contains a large amount of components with anticancer, antioxidant, antibacterial, anti-inflammatory, antiseptic, and antiapoptotic properties. The extract of potato peels contains bioactive components such as gallic acid, caffeic acid, chlorogenic acid, and neochlorogenic acid, which help in anticancer, antioxidant, and antibacterial activities (Jimenez-Champi et al., 2023).

This study aims to contribute to the waste management system by using potato peels, which are considered agricultural waste. In the present study, environmentally friendly SeNPs were synthesized from waste potato peels, and the characterization of SeNPs and their antimicrobial and antiproliferative effects on cancerous cells were investigated. For this purpose, SeNPs, which have low cost, easy synthesis, biocatalytic, and photocatalytic advantages, were used on A549 (human lung carcinoma cell line) and OVCAR-3 (human ovarian carcinoma cell line) cells and human pathogenic bacterial strains (*S. aureus* and *E. coli*) and yeast (*C. albicans*).

MATERIALS AND METHODS

Since the manuscript is an experimental study, it does not require any ethical committee decision.

Material

S. tuberosum was collected from kitchen waste. To remove the contamination on the collected potato waste, it was first washed thoroughly with tap water and then with pure water. The cleaned waste potatoes were dried in the shade in the laboratory.

Preparation of Potato Peels Aqueous Extract

After the dried potato waste was ground into powder in a grinder, it was stored in suitable containers for both synthesis and characterization studies. To prepare the extract from 30 g of powdered potato waste, it was boiled in 500 mL of deionized water at 85 °C on a magnetic stirrer for 60 minutes and obtained. The acquired aqueous extract was stored in a cool, dark location for three hours. The aqueous potato waste was separated from the extract by filtering the liquid with Whatman filter paper no. 1. The extract derived from the trash was preserved in bottles within a refrigerator maintained at 4 °C for subsequent utilization.

Synthesis of ST-SE-NPs

For the preparation of SeNPs from *S. tuberosum* shell aqueous extract, the green synthesis method was used to prepare a mixture by taking 1 mL of the solution containing 10 mM selenium and 9 mL of the potato extract. The pH of the combination was subsequently measured and recorded. The reaction mixture was maintained in a dark environment using a rotary shaker at 75 °C for 3 hours at 200 rpm. The alteration in the color of the reaction mixture was noted. The reaction mixture was thereafter incubated at 37 °C for 96 hours. The complete color change of the reaction mixture at the end of the interval indicated the formation of nanoparticles.

Characterization of Biosynthesised Nanoparticles

SeNPs were studied by UV-Vis spectrophotometry, Fourier Transform Infrared Spectroscopy, zeta potential analysis, X-ray Diffraction (XRD), Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), and Energy Dispersive X-ray Spectrometry (EDX).

Determination of Cytotoxic Activity

The cytotoxic activities of SeNPs were applied to A549 and ovarian carcinoma OVCAR-3 cancer cell lines by modifying the MTT method (Mosmann, 1983). Cisplatin was used as a positive control in cytotoxicity experiments. Cisplatin was dissolved with DMSO, and intermediate stock solutions were prepared with cell culture media. Cell lines (A549) were cultured in Dulbecco's modified medium (DMEM), 10% fetal bovine serum (FBS), 1% glutamax, and 1% penicillin-streptomycin medium. Cells were seeded at a density of 5 x 10^3 cells/well in 96-well plates containing 90 µL of medium per sterile well. Two separate microplates were used to facilitate two separate incubation periods of 24 and 48 hours for both cell lines. Cells were allowed to adhere to the bottom of the microplates for 24 hours. Plates were incubated for 24 hours in a humidified environment containing 37°C and 5% carbon dioxide (CO_2), and the cells were given the drug candidate compound ML-SeNP (600, 300, and 100 g/mL). When the cells reached approximately 80-90% confluence, they were removed from the flasks and counted by the hemocytometric method. For A549 and OVCAR-3 cell lines (5×10^3) and RPE-1 (10×10^3) cell lines, they were injected in triplicate into 96-well plates, and various doses were applied to the seeded plates the next day. Ultrapure water was added to the control group cells. MTT assay determined changes in cell viability 24 and 48 hours after this application. 10 µL of the MTT (5 mg/mL) solution we prepared was applied to each well-containing cell and then incubated for exactly 3 hours at 37 ºC in a 5% CO_2 humidified environment. After the time was up, it was removed, and 100 microliters of DMSO was added to each well. It was then shaken gently and then left for 20 minutes. Subsequently, the optical density (OD) values in the wells were measured using a UV-vis spectrophotometer (Multiskan GO, Thermofisher, USA) as applied by İpek et al. (2023). The absorbance values from the control wells were determined as the average. Then, the cells were evaluated according to the 100% viability principle. The absorbance values obtained from the wells treated with ML-SeNP were normalized to the control absorbance value. This value was accepted as % viability. MTT analysis was performed at three different times. Statistical evaluation of viability data was performed using the GraphPad Prism 8 package program. Two-way analysis of variance was applied in repeated measurements to evaluate the effect of the applied tests on cell viability.

Antimicrobial Activity

E. coli, *S. aureus*, and *C. albicans* were chosen for antimicrobial evaluation. Cultures were acquired from the Microbiology Laboratory of Inonu University Medical Faculty Hospital. These bacteria and fungi were selected due to their propensity to induce common diseases in people and their resistance to current antibiotics.

RESULTS AND DISCUSSION

UV-visible spectroscopy of SeNPs was measured between 300 and 800 nm (Figure 1). Strong absorption peaks were observed approximately in the 330 nm region, indicating that selenite was reduced to SeNPs with the potato extract. When the obtained graph was examined, it was consistent with the UV-visible spectroscopic results of SeNPs in the literature (Baran et al., 2024).

The FTIR spectrum of potato (*S. tuberosum*) displayed a broad OH band at 3280 cm^{-1} (Akpomie, 2021). The infrared absorption bands for C–H stretching in alkenes and alkanes were observed at 2914 and 2847 cm^{-1}, respectively, whereas the C≡C group displayed absorption bands at 2113 and 1990 cm^{-1} (Ezekoye et al., 2020; Akpomie, 2021). The absorption peak at 1636 cm^{-1} is ascribed to the carbonyl C=O stretching (Akpomie, 2021; Trinh, 2020). The absorption band at 1013 cm^{-1} is attributed to the C–O stretching vibration (Figure 2) (Chukwuemeka-Okorie et al., 2018). The peaks at 1509 and 1364 cm^{-1} are attributed to the O-H bending of the carboxylate group. The peak at 987 cm^{-1} signifies the C-N stretching associated with the amine functional group. The absorption peaks of SeNPs correspond to the stretching, bending, and vibration frequencies of specific organic functional groups, such as NH_2, COOH, CH_2, and CO, as documented in previous studies (Ullah et al., 2021). Ren et al. (2013); Liu et al. (2012).

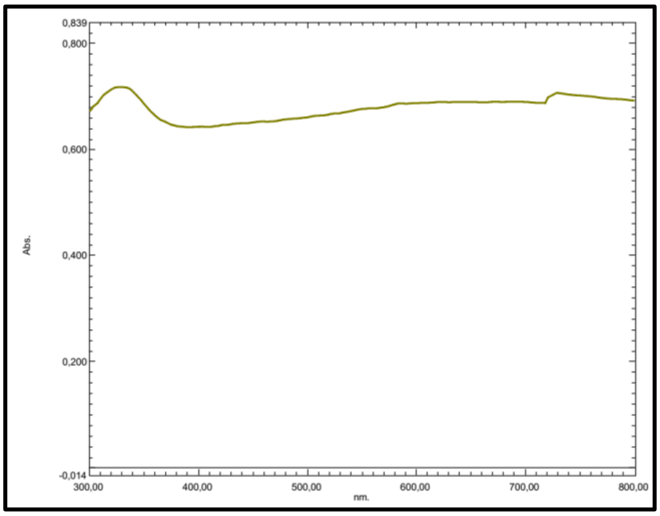

Figure 1. UV-visible spectroscopic results of ST-SeNP nanoparticles

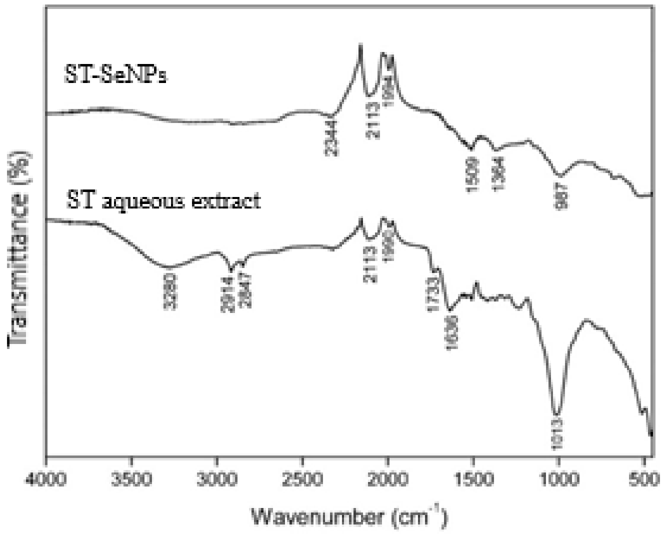

Figure 2. FTIR spectrum of synthesized ST-SeNPs and potato aqueous peel extract

The SEM image of the synthesized ST-SeNPs (Figure 3) was captured at a power setting of 20 kV and a magnification of 20.000X in high vacuum mode, with a scale of 1000 nm. The synthesized selenium nanoparticles exhibited uniformity and smoothness, with an average particle size ranging from 30 to 100 nm. Selenium nanoparticles exhibit a hexagonal structure. The average size of green synthesis selenium nanoparticles (SeNPs) is marginally larger than that produced by chemical methods (Ramamurthy et al. 2013).

Figure 4 illustrates the detection of selenium (Se) peak at approximately 1.5 and 11.2 keV, confirming the reduction of sodium selenite to selenium nanoparticles as indicated by EDX analysis. Upon examination of the figure, the elemental analysis reveals that the Se element occupies the highest rank, with a weight percentage of 88.43% (Baskar et al., 2019).

The XRD examination of selenium in the produced SeNPs reveals three prominent peaks across the spectrum at 2θ values between 5 and 80 (Figure 6). The diffraction at 2θ values of 23.460, 29.661, and 43.620 corresponds to the (100), (101), and (102) planes of the face-centered cubic selenium structure, respectively (Khiralla and El-Deeb 2015).

The synthesis of selenium nanoparticles, as analyzed in Figure 5 via TEM, indicates that Se-NPs exhibit a nearly spherical morphology at the nanometer scale, with an average diameter of 32.97 ± 15.77 nm (Boroumand et al., 2019).

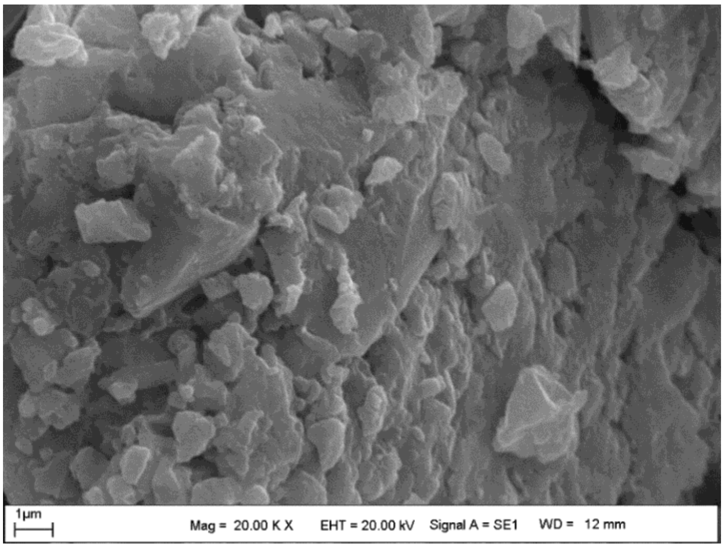

Figure 3. SEM image of synthesized selenium nanoparticles

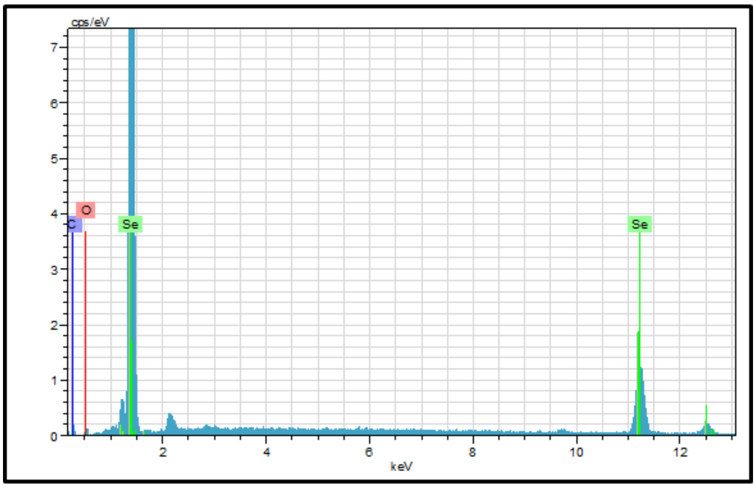

Figure 4. EDX spectrum of selenium nanoparticles.

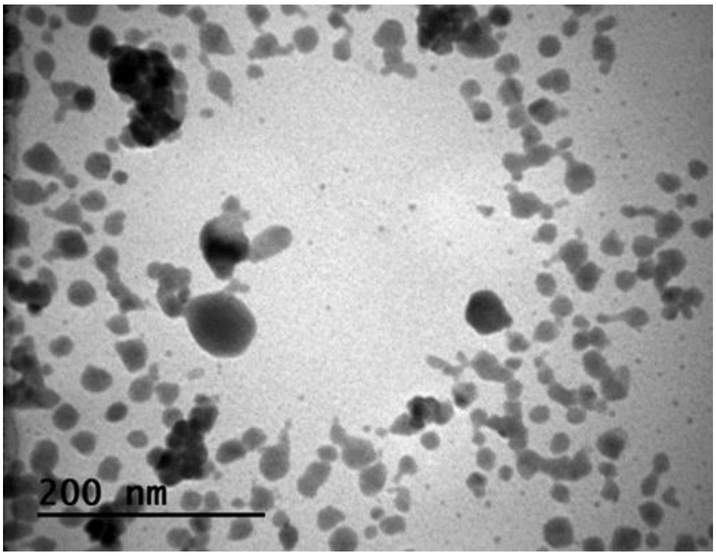

Figure 5. TEM image of SeNPs at 200 nm

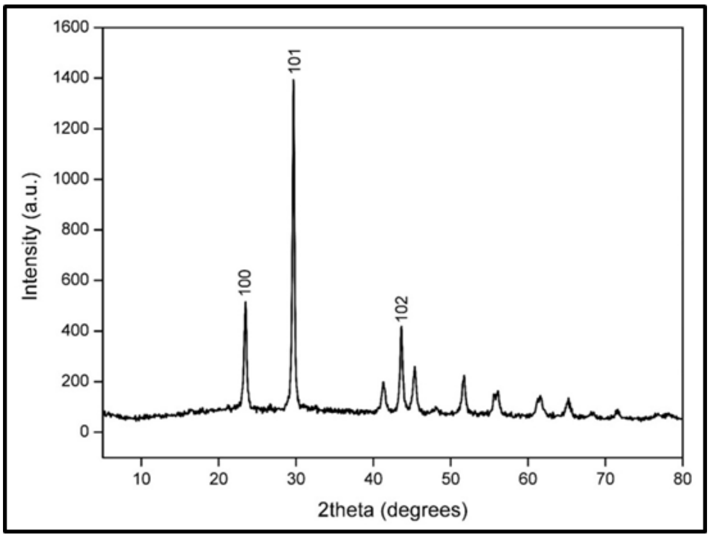

Figure 6. XRD spectrum of selenium nanoparticles

Figure 7 illustrates that the average hydrodynamic diameter of Se-NPs, as measured by DLS, was approximately 98 nm. The size distributions of SeNPs were assessed through dynamic light scattering, with results presented in Figure 7. The average particle size of SeNPs was approximately 98 nm, suggesting a homogeneous particle size distribution in the synthesized SeNPs.

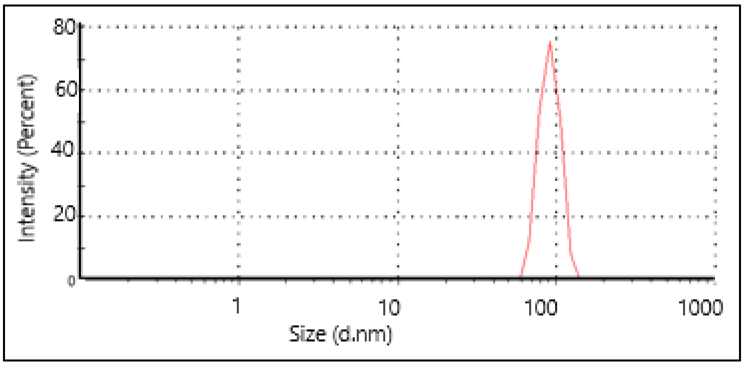

Figure 7. DLS images of synthesized SeNPs.

Anticancer Effect of ST-SENPs

Figure 8 illustrates the in vitro cytotoxicity of SeNPs at various doses and their impact on the growth of A549 and OVCAR-3 cells, as assessed by the MTT assay. The potential mechanism of SeNPs' anti-proliferative activity involves the induction of oxidative stress by the generation of reactive oxygen species (ROS), resulting in DNA damage or apoptosis via the activation of caspases or apoptotic proteins, and may potentially induce cell cycle arrest. This claim is also supported by the research of Menon and Shanmugam (2020). SeNPs were used at varying concentrations (1, 31.25, 62.5, 125, 250, 500, 1000 and 2000 µg/mL) to treat A549 and OVCAR-3 cells at 24 and 48 hours. The inhibitory concentration (IC50) value for 50% cell death of biosynthesized SeNPs against A549 cells was determined to be 2000 µg/mL at both 24 and 48 hours. The inhibitory concentration (IC_{50}) of the produced SeNPs against OVCAR-3 cells, indicating 50% cell mortality, was established at 2000 µg/mL at both 24 and 48 hours. However, the cytotoxicity test of the synthesized SeNPs against A549 and OVCAR-3 cells did not show significant cytotoxicity at low concentrations, and as the concentration increased at 24 and 48 hours, cytotoxicity also increased (Rajasekar and Kuppusamy, 2021). We obtained the most effective cytotoxicity in the OVCAR-3 cell line with a concentration of 2000 µg/mL after 24 hours, and in the A549 cell line, we obtained a concentration of 2000 µg/mL again after 48 hours of incubation. Menon and Shanmugam (2020) conducted an experimental study with SeNPs in the A549 cell line, and Toubhans et al. (2020) Their experimental research on OVCAR-3 cell line cytotoxicity supports our study.

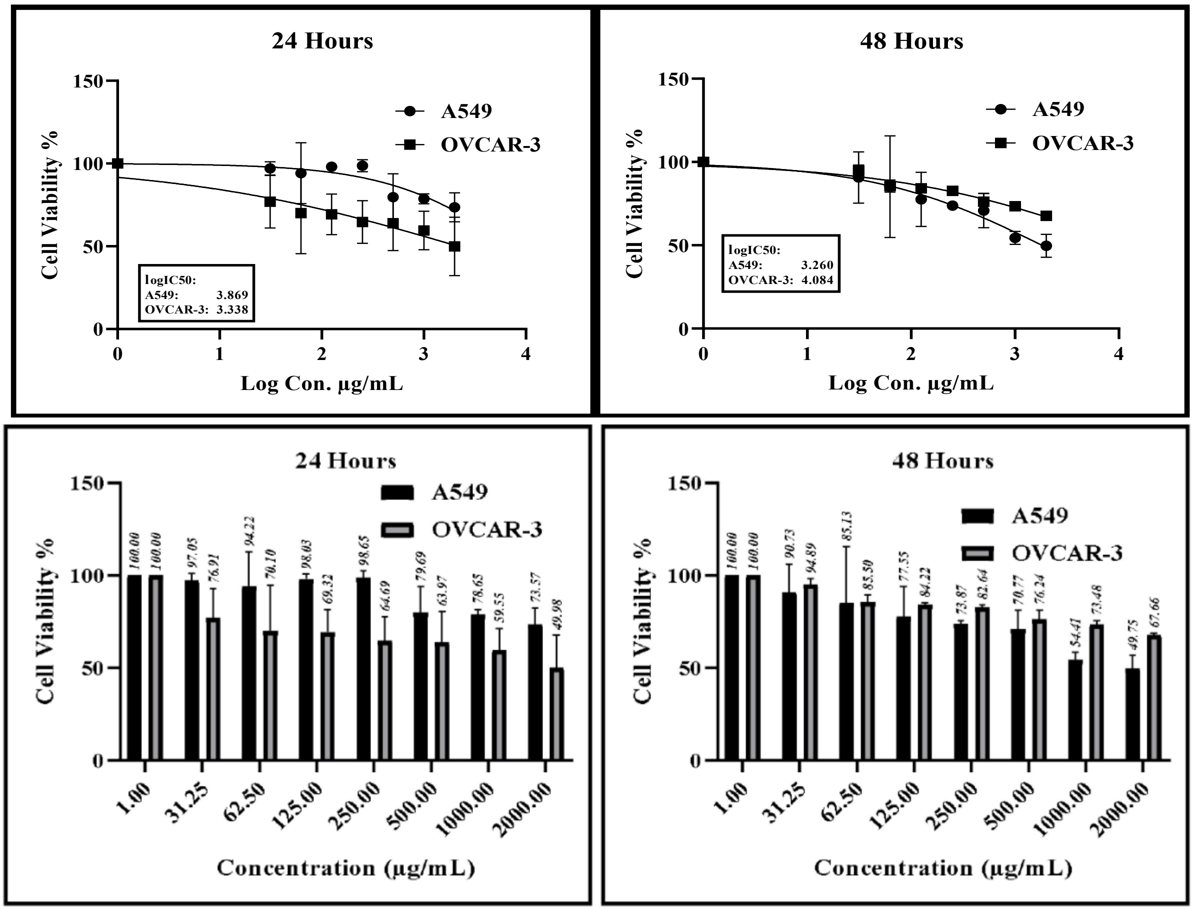

Figure 8. MTT assay for relative cell viabilities of A549 cells and OVCAR-3 cells incubated with biosynthesized ST-SeNPs for 24 and 48 h.

Numerous studies have shown that the generation of reactive oxygen species (ROS) plays a role in the apoptotic process and is strongly associated with the mitochondrial electron transport chain. Typically, selenium nanoparticles (Se-NPs) produce excessive reactive oxygen species (ROS) to induce apoptosis by inhibiting the electron transport chain. As a result, high intracellular ROS production triggered by Se-NPs can induce apoptosis and cell cycle arrest, thereby promoting cancer cell death. Moreover, apoptosis may exert cytotoxic effects on cancer cells via extrinsic or intrinsic pathways (Menon et al., 2018).

In general, cancer is one of the deadly diseases that requires careful and selective treatment planned after a meticulous diagnosis. There are common treatment methods for cancer, such as chemotherapy, radiotherapy, and immunotherapy. However, these methods can also create a lot of exposure, especially in terms of resistance to radiotherapy and chemotherapy options and toxic side effects. For these reasons, there is a need to develop new cancer treatments. (Xia et al. 2024). Selenium nanoparticles increase cell apoptosis, and when used together with anticancer drugs, they increase the effectiveness of the drugs and show an anticancer effect (Kumar and Prasad, 2021). Various anticancer agents, including metals, polymers, biomolecular materials, and semiconductors, have been used for cancer treatment. Among these functional anticancer agents, selenium nanoparticles have also gained great importance as anticancer biomaterials. SeNPs have less toxicity than organic and inorganic selenium compounds, and the high activity of bio-SeNPs has been used in many therapeutic applications, such as anticancer (Xiao et al., 2023).

Antimicrobial Activity of ST-SENPs

Selenium atom is an element recognized for its exceptional antioxidant properties. This property influences cellular function in both adaptive and innate immunity and demonstrates selenium's ability to regulate bacterial infections. Selenium compounds exhibit notable antibacterial activity against various bacterial infections. (Medina and Webster 2018, Tran et al. 2015). As a new type of selenium that shows improved biological activities compared to traditional selenium compounds, SeNPs have been extensively demonstrated to have broad-spectrum antibacterial properties. In our analysis, SeNPs demonstrated antimicrobial activity against gram-positive bacteria, gram-negative bacteria, and fungi (Figure 9). The disk diffusion method demonstrated that SeNPs exhibited greater antimicrobial activity against *E. coli* (5 mm) and *C. albicans* compared to *S. aureus*

(8 mm) (Figure 9). The microorganism to which sensitivity was highest was identified as *C. albicans*. In some studies, conducted with SeNPs, similar to our study, it has shown antibacterial activity in S. aureus and E. coli bacteria (Vahdati and Tohidi Moghadam 2020, Tran et al., 2016). Similarly, in their study with *C. albicans*, Safaei et al. (2022) showed that the produced nanoparticles significantly prevented fungal growth under optimum conditions.

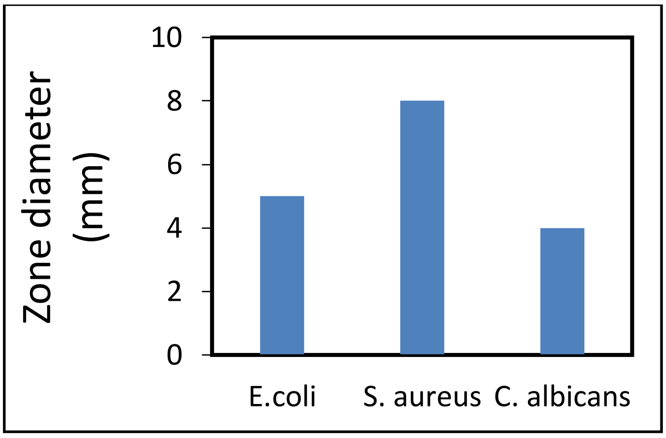

Figure 9. Antimicrobial activity of Se-NPs against *E. coli*, *S. aureus*, and *C. albicans*.

Metal nanoparticles demonstrate antimicrobial properties due to their distinctive characteristics, such as a high surface-to-volume ratio, specific surface area, quantum effects, enhanced surface reactivity, and unique chemical and physical properties. Research indicates that nanoparticles can eliminate resistant infections via interactions with the thiol (-SH) protein group. This interaction alters cell morphology and gene expression, influences membrane permeability, disrupts mitochondrial membrane integrity, induces DNA damage, and generates oxidative stress (Safaei et al. 2022, Truong et al. 2021).

CONCLUSION

In this study, the cytotoxic activity of SeNPs synthesized with potato peels on A549 cells and OVCAR-3 cell lines, as well as their antimicrobial effects against gram-negative *E. coli*, gram-positive *S. aureus* bacteria, and *C. albicans* yeast, were analyzed. ST-SeNPs showed potential as anticancer and antimicrobial agents and could serve as alternative treatments or adjuvants for bacterial infections, thus reducing the burden on current antibiotics and their applications. Consequently, it was concluded that reducing exposure to conventional antibiotics could help reduce rapid antimicrobial resistance, which is a significant effort considering that the resistance rate currently exceeds the rate of new drug development. The obtained findings encourage the use of metal nanoparticle systems exhibiting cytotoxic and antimicrobial properties. Further studies are required to comprehensively elucidate the mechanisms and effects of cytotoxicity and antibacterial properties associated with these metal nanoparticle systems.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Conflict of interest

The authors declare that they have no competing, actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text and Table are original and that they have not been published before.

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REFERENCES

Abbas, H. S., Abou Baker, D. H., & Ahmed, E. A. (2021). Cytotoxicity and antimicrobial efficiency of selenium nanoparticles biosynthesized by *Spirulina platensis*. Archives of Microbiology, 203(2), 523-532. https://doi.org/10.1007/s00203-020-02042-3

Akpomie, K. G., & Conradie, J. (2021). Biosorption and regeneration potentials of magnetite nanoparticle loaded *Solanum tuberosum* peel for celestine blue dye. International Journal of Phytoremediation, 23(4), 347-361. https://doi.org/10.1080/15226514.2020.1814198

Ansari, J. A., Malik, J. A., Ahmed, S., Manzoor, M., Ahemad, N., & Anwar, S. (2024). Recent advances in the therapeutic applications of selenium nanoparticles. Molecular biology reports, 51(1), 688. https://doi.org/10.1007/s11033-024-09598-z

Baran, M. F., Keskin, C., Baran, A., Kurt, K., İpek, P., Eftekhari, A., ... & Cho, W. C. (2024). Green synthesis and characterization of selenium nanoparticles (Se NPs) from the skin (testa) of *Pistacia vera* L.(Siirt pistachio) and investigation of antimicrobial and anticancer potentials. Biomass Conversion and Biorefinery, 14(19), 23623-23633. http://dx.doi.org/10.1007/s13399-023-04366-8

Baskar, G., Lalitha, K., & Bikku George, G. (2019). Synthesis, characterization and anticancer activity of selenium nanobiocomposite of L-asparaginase. Bulletin of Materials Science, 42, 1-7. https://doi.org/10.1016/j.msec.2018.08.051

Boroumand, S., Safari, M., Shaabani, E., Shirzad, M., & Faridi-Majidi, R. (2019). Selenium nanoparticles: synthesis, characterization and study of their cytotoxicity, antioxidant and antibacterial activity. Materials Research Express, 6(8), 0850d8. https://ui.adsabs.harvard.edu/link_gateway/2019MRE.....6h50d8B/doi:10.1088/2053-1591/ab2558

Burlec, A. F., Corciova, A., Boev, M., Batir-Marin, D., Mircea, C., Cioanca, O., ... & Hancianu, M. (2023). Current overview of metal nanoparticles' synthesis, characterization, and biomedical applications, with a focus on silver and gold nanoparticles. Pharmaceuticals, 16(10), 1410. https://doi.org/10.3390/ph16101410

Chaudhary, S., Umar, A., & Mehta, S. K. (2016). Selenium nanomaterials: an overview of recent developments in synthesis, properties and potential applications. Progress in Materials Science, 83, 270-329. https://doi.org/10.1016/j.pmatsci.2016.07.001

Chen, Y., Liu, W., Liu, Y., Li, S., Liu, H., Li, S., ... & Chen, T. (2025). Synergistic convergence of selenium and nanotechnology in dermatological therapeutics: Mechanistic insights and clinical prospects. Chinese Chemical Letters, 111298. https://doi.org/10.1016/j.cclet.2025.111298

Chen, T., & Wong, Y. S. (2009). Selenocystine induces reactive oxygen species–mediated apoptosis in human cancer cells. Biomedicine & Pharmacotherapy, 63(2), 105-113. https://doi.org/10.1016/j.biopha.2008.03.009

Chukwuemeka-Okorie, H. O., Ekemezie, P. N., Akpomie, K. G., & Olikagu, C. S. (2018). Calcined corncob-kaolinite Combo as new sorbent for sequestration of toxic metal ions from polluted aqua media and desorption. Frontiers in chemistry, 6, 273. https://doi.org/10.3389/fchem.2018.00273

Elahian, F., Reiisi, S., Shahidi, A., & Mirzaei, S. A. (2017). High-throughput bioaccumulation, biotransformation, and production of silver and selenium nanoparticles using genetically engineered *Pichia pastoris*. Nanomedicine: Nanotechnology, Biology and Medicine, 13(3), 853-861. https://doi.org/10.1016/j.nano.2016.10.009

Ezekoye, O. M., Akpomie, K. G., Eze, S. I., Chukwujindu, C. N., Ani, J. U., & Ujam, O. T. (2020). Biosorptive interaction of alkaline modified Dialium guineense seed powders with ciprofloxacin in contaminated solution: central composite, kinetics, isotherm, thermodynamics, and desorption. International journal of phytoremediation, 22(10), 1028-1037. https://doi.org/10.1080/15226514.2020.1725869

He, L., Zhang, L., Peng, Y., & He, Z. (2025). Selenium in cancer management: exploring the therapeutic potential. Frontiers in Oncology, 14, 1490740. https://doi.org/10.3389/fonc.2024.1490740

Huang, G., Liu, Z., He, L., Luk, K. H., Cheung, S. T., Wong, K. H., & Chen, T. (2018). Autophagy is an important action mode for functionalized selenium nanoparticles to exhibit anti-colorectal cancer activity. Biomaterials science, 6(9), 2508-2517. http://dx.doi.org/10.1039/C8BM00670A

İpek, P., Baran, A., Hatipoğlu, A., & Baran, M. F. (2024). Cytotoxic potential of selenium nanoparticles (SeNPs) derived from leaf extract of Mentha longifolia L. International Journal of Agriculture Environment and Food Sciences, 8(1), 169-175. https://doi.org/10.31015/jaefs.2024.1.17

Jimenez-Champi, D., Romero-Orejon, F. L., Moran-Reyes, A., Muñoz, A. M., & Ramos-Escudero, F. (2023). Bioactive compounds in potato peels, extraction methods, and their applications in the food industry: a review. Cyta-journal of Food, 21(1), 418-432. https://doi.org/10.1080/19476337.2023.2213746

Khiralla, G. M., & El-Deeb, B. A. (2015). Antimicrobial and antibiofilm effects of selenium nanoparticles on some foodborne pathogens. LWT-Food Science and Technology, 63(2), 1001-1007. https://doi.org/10.1016/j.lwt.2015.03.086

Kowalczewski, P. Ł., Olejnik, A., Świtek, S., Bzducha-Wróbel, A., Kubiak, P., Kujawska, M., & Lewandowicz, G. (2022). Bioactive compounds of potato (*Solanum tuberosum* L.) juice: From industry waste to food and medical applications. Critical Reviews in Plant Sciences, 41(1), 52-89. https://doi.org/10.1080/07352689.2022.2057749

Kumar, A., & Prasad, K. S. (2021). Role of nano-selenium in health and environment. Journal of Biotechnology, 325, 152-163. https://doi.org/10.1016/j.jbiotec.2020.11.004

Lin, W., Zhang, J., Xu, J. F., & Pi, J. (2021). The advancing of selenium nanoparticles against infectious diseases. Frontiers in Pharmacology, 12, 682284. https://doi.org/10.3389/fphar.2021.682284

Liu, W., Li, X., Wong, Y. S., Zheng, W., Zhang, Y., Cao, W., & Chen, T. (2012). Selenium nanoparticles as a carrier of 5-fluorouracil to achieve anticancer synergism. ACS nano, 6(8), 6578-6591. https://doi.org/10.1021/nn202452c

Medina Cruz, D., Mi, G., & Webster, T. J. (2018). Synthesis and characterization of biogenic selenium nanoparticles with antimicrobial properties made by *Staphylococcus aureus*, methicillin-resistant *Staphylococcus aureus* (MRSA), *Escherichia coli*, and *Pseudomonas aeruginosa*. Journal of Biomedical Materials Research Part A, 106(5), 1400-1412. https://doi.org/10.1002/jbm.a.36347

Menon, S., & Shanmugam, V. (2020). Cytotoxicity analysis of biosynthesized selenium nanoparticles towards A549 lung cancer cell line. Journal of Inorganic and Organometallic Polymers and Materials, 30(5), 1852-1864. https://link.springer.com/article/10.1007/s10904-019-01409-4

Menon, S., Ks, S. D., Santhiya, R., Rajeshkumar, S., & Kumar, V. (2018). Selenium nanoparticles: A potent chemotherapeutic agent and an elucidation of its mechanism. Colloids and Surfaces B: Biointerfaces, 170, 280-292. https://doi.org/10.1016/j.colsurfb.2018.06.006

Mosmann, T. (1983). Rapid colorimetric assay for cellular growth and survival: application to proliferation and cytotoxicity assays. Journal of immunological methods, 65(1-2), 55-63. https://doi.org/10.1016/0022-1759(83)90303-4.

Park, K. C., Choi, J., Choi, S., Lee, G., An, H. J., Yun, H., & Lee, S. (2025). Therapeutic potential of Polydopamine-Coated selenium nanoparticles in Osteoarthritis treatment. International Journal of Pharmaceutics, 675, 125568. https://doi.org/10.1007/s11033-024-09598-z

Rajasekar, S., & Kuppusamy, S. (2021). Eco-friendly formulation of selenium nanoparticles and its functional characterization against breast cancer and normal cells. Journal of Cluster Science, 32(4), 907-915. https://doi.org/10.1007/s10876-020-01856-x

Ramamurthy, C. H., Sampath, K. S., Arunkumar, P., Kumar, M. S., Sujatha, V., Premkumar, K., & Thirunavukkarasu, C. (2013). Green synthesis and characterization of selenium nanoparticles and its augmented cytotoxicity with doxorubicin on cancer cells. Bioprocess and biosystems engineering, 36, 1131-1139. https://doi.org/10.1007/s00449-012-0867-1

Rasouli, M. (2019). Biosynthesis of selenium nanoparticles using yeast Nematospora coryli and examination of their anti-candida and anti-oxidant activities. IET nanobiotechnology, 13(2), 214-218. https://doi.org/10.1049/iet-nbt.2018.5187

Ren, Y., Zhao, T., Mao, G., Zhang, M., Li, F., Zou, Y., ... & Wu, X. (2013). Antitumor activity of hyaluronic acid–selenium nanoparticles in Heps tumor mice models. International journal of biological macromolecules, 57, 57-62. https://doi.org/10.1016/j.ijbiomac.2013.03.014

Roy, N., Nivedya, T., Paira, P., & Chakrabarty, R. (2025). Selenium-based nanomaterials: green and conventional synthesis methods, applications, and advances in dye degradation. RSC advances, 15(4), 3008-3025. https://doi.org/10.1039/D4RA07604D

Safaei, M., Mozaffari, H. R., Moradpoor, H., Imani, M. M., Sharifi, R., & Golshah, A. (2022). Optimization of green synthesis of selenium nanoparticles and evaluation of their antifungal activity against oral *Candida albicans* infection. Advances in Materials Science and Engineering, 2022(1), 1376998. https://doi.org/10.1155/2022/1376998

Sonkusre, P., & Cameotra, S. S. (2017). Biogenic selenium nanoparticles induce ROS-mediated necroptosis in PC-3 cancer cells through TNF activation. Journal of nanobiotechnology, 15, 1-12. https://jnanobiotechnology.biomedcentral.com/articles/10.1186/s12951-017-0276-3

Tran, P. A., O'Brien-Simpson, N., Reynolds, E. C., Pantarat, N., Biswas, D. P., & O'Connor, A. J. (2015). Low cytotoxic trace element selenium nanoparticles and their differential antimicrobial properties against S. aureus and E. coli. Nanotechnology, 27(4), 045101. https://doi.org/10.1088/0957-4484/27/4/045101

Trinh, V. T., Nguyen, T. M. P., Van, H. T., Hoang, L. P., Nguyen, T. V., Ha, L. T., ... & Nguyen, X. C. (2020). Phosphate adsorption by silver nanoparticles-loaded activated carbon derived from tea residue. Scientific reports, 10(1), 3634. https://doi.org/10.1038/s41598-020-60542-0

Truong, L. B., Medina-Cruz, D., Mostafavi, E., & Rabiee, N. (2021). Selenium nanomaterials to combat antimicrobial resistance. Molecules, 26(12), 3611. https://doi.org/10.3390/molecules26123611

Toubhans, B. (2020). Bio-Geochemistry of ovarian cancer: Role of selenium nanoparticles in treatment and copper isotopes in detection of ovarian cancer (Doctoral dissertation, Université Grenoble Alpes [2020-....]; University of Swansea (Swansea (GB))).

Ullah, A., Yin, X., Wang, F., Xu, B., Mirani, Z. A., Xu, B., ... & Naveed, M. (2021). Biosynthesis of selenium nanoparticles (via Bacillus subtilis BSN313), and their isolation, characterization, and bioactivities. Molecules, 26(18), 5559. https://doi.org/10.3390/molecules26185559

Vahdati, M., & Tohidi Moghadam, T. (2020). Synthesis and characterization of selenium nanoparticles-lysozyme nanohybrid system with synergistic antibacterial properties. Scientific reports, 10(1), 510. https://doi.org/10.1038/s41598-019-57333-7

Xia, Y., Sun, M., Huang, H., & Jin, W. L. (2024). Drug repurposing for cancer therapy. Signal transduction and targeted therapy, 9(1), 92. https://doi.org/10.1038/s41392-024-01808-1

Xiao, X., Deng, H., Lin, X., Ali, A. S. M., Viscardi, A., Guo, Z., ... & Han, J. (2023). Selenium nanoparticles: Properties, preparation methods, and therapeutic applications. Chemico-biological interactions, 378, 110483. https://doi.org/10.1016/j.cbi.2023.110483

Zambonino, M. C., Quizhpe, E. M., Jaramillo, F. E., Rahman, A., Santiago Vispo, N., Jeffryes, C., & Dahoumane, S. A. (2021). Green synthesis of selenium and tellurium nanoparticles: current trends, biological properties and biomedical applications. International journal of molecular sciences, 22(3), 989. https://doi.org/10.3