Jurnal MIPA dan Pembelajarannya
e-issn: 2798-0634, email: jmipap.journal@um.ac.id

VOL	ISS	YEAR	DOI
6	2	2026	10.17977/um067.v6.i2.2026.3

COMPARATIVE EVALUATION OF CLOVE EXTRACT AND GREEN-SYNTHESIZED SELENIUM OXIDE NANOPARTICLES FOR PROTECTION AGAINST UV-B INDUCED DNA DAMAGE: A COMET ASSAY-BASED STUDY

Kawther Y. Mashjal[a*], Hussain S. Hasan[a**], Labeeb Ahmed Alzubaidi[b***]

[a] Physiology and Medical Physics Department, College of Medicine, Al-Nahrain University, Baghdad, Iraq

[b] Research & Technology Center of Environment, Water & Renewable Energy/ Scientific Research commission. Baghdad. Iraq

[*]Corresponding author, email: kwthryasrmshjl@gmail.com[*], altai1965@yahoo.com[**], labeeb.a.alzubadi@src.edu.iq[***]

Keywords
Biosynthesis
Nano Selenium
Clove
Ultraviolet Array
Antigenotoxicity
Comet Assay

Abstract
Ultraviolet (UV) radiation is one of the major environmental factors which can be harmful for cellular DNA. It can lead to genetic mutations and damage to DNA, which can increase the risk of a variety of diseases, including cancer. The objective of the present study was to evaluate the therapeutic effects of clove extract (Syzygium aromaticum), clove-mediated selenium nanoparticles (SeNPs) and clove extract alone on UVB-induced DNA damage in mice. UVB exposure resulted in a significant increase in DNA damage as measured by the Olive Tail Moment in the Comet assay. Post-treatment with clove extracts reduced DNA damage however, the clove mediated selenium nanoparticles showed a stronger therapeutic effect. The SeNP-treated groups, especially after 15 min exposure, showed the lowest Olive Tail Moment values, indicating a significant reduction in genotoxicity. This suggests that clove mediated selenium nanoparticles have great therapeutic potential in repairing UV induced DNA damage and improving genome stability.

1. Introduction

The electromagnetic spectrum (100–400 nm) includes ultraviolet (UV) radiation, which has been linked to the development of cancer through mechanisms such immunosuppression, inflammation, and DNA damage (Talaie & Moussavi, 2025; Pfeifer, 2020). Over the past few years, the steady thinning of the atmospheric ozone layer has increased the incidence of solar UV radiation, especially UV-C, on Earth's surface. UV-C radiation is one of the primary environmental problems since it is harmful to all life forms. Solar UV light, especially the dangerous UV-B wavelength range of 280–320 nm, Various scientific sources confirm that UVB radiation can cause large DNA damages, particularly in the form of DNA lesions, such as cyclobutane pyrimidine dimers, which are associated with aging and disease. In particular, exposure to UVB causes oxidative stress, which leads to premature skin aging and an increased risk of cancer. These sources also point out that the DNA repair mechanisms in the body decline with age making the effects of UVB even more acute.

UV-B light damages DNA and produces reactive oxygen species in the skin, which can result in cellular mutations and genotoxic stress and genomic instability. Although UV radiation is hazardous, it has significant medical applications, such as the therapy of some cancers, inflammatory illnesses, and other ailments (Roy, 2017). The study's objective is to prevent or lessen the impact of UV arrays on mouse cells by employing the secondary generation of clove extract (eugenol and its derivatives). One significant environmental element that causes oxidative stress and DNA damage in biological systems is the ultraviolet (UV) spectrum. UV radiation has a wide range of biological effects on human health, with an emphasis on the integumentary system and ocular organs. Numerous detrimental skin conditions, such as erythema solar (sunburn), premature cutaneous senescence (aging), and an elevated risk of malignant skin neoplasms (cancer), can result from prolonged exposure to UV

radiation. Ultraviolet (UV) light has a major impact on several aspects, and these impacts are often measured in physical terms. (UV), particularly UV-B and UV-C, damages DNA primarily through photoproducts such 6–4 photoproducts between two neighboring pyrimidine bases and cyclobutane pyrimidine dimers (CPDs). These lesions disrupt the transcription and replication processes and warp the DNA helix. Such damage can result in distinctive mutations, particularly C->T transitions, which are closely associated with carcinogenesis if it is not fixed (by nucleotide excision repair, or NER) (Cadet & Douki, 2018). Bioactive chemicals, such as cloves and their component eugenol, which has anti-inflammatory and antioxidant qualities, are derived from medicinal plants (Atanasov et al., 2021; Barboza et al., 2018). Particularly in nanoparticles, which are influenced by size, shape, and composition, nanotechnology aids in improving material qualities at sizes smaller than 100 nanometers (Abid et al., 2022). Selenium at the nanoscale is a potential substance with low toxicity and biological activity. The comet assay is one of the most sensitive techniques for detecting DNA damage at the single-cell level (Jackson & Bartek, 2009). DNA is a double helix that contains genetic information. If DNA is broken, it can result in mutations or cell death, but there are complex repair mechanisms.

2. Materials and Methods

2.1 Flower buds of syzygium aromaticum preparation

Syzygium aromaticum flower buds were gain from Baghdad local market, Iraq. Were dried and crushed by using the electric grinder. In other hand the flower buds were identified as Syzygium aromaticumat the Herbarium of the Department of Biology, College of Science, University of Baghdad No. 4390 issued on April 13/ 2026.

2.2 Preparation of alcoholic clove extract

Using a Soxhlet apparatus, the 150 g were extracted through eight hours using methanol 80% v/v. The extracts were concentrated and dried were carried according (Zhang et al., 2020).

2.3 Phytochemical qualitative screening in the clove extract

Unless otherwise specified, phytochemicals in clove extract can be qualitatively screened.

2.3.1 Test for flavonoids

A few drops of 2% NaOH and a few drops of dilute HCl was added to 1ml of the extract; the disappeared of yellow color indicating the presence of flavonoids

2.3.2 Test for alkaloid (Wagner’s Test)

From S. aromaticum extract 1 ml was combined with 1 ml of Wagner's reagent The presence of alkaloids is indicated by the formation of a reddish-brown precipitate.

2.3.3 Test for Terpenoids and steroids (Salkowski's test)

From extracted clove sample 1ml was mixed with 0.5 ml of chloroform after that 0.5 ml of concentrated H2SO4 was added to form a layer. The presence of terpenoids is indicated by a reddish-brown precipitate near the interface, A dark blue coloration after a while indicates the presence of steroids.

2.3.4 Test for phenols

The presence of phenols was determined by treating 1ml of the extract with a few drops of 5% ferric chloride solution the production of a blue-black color indicates the presence of phenols.

2.3.5 Test for glycosides

Clove extract (2 ml) was treated with a few drops of glacial acetic acid and 1% ferric chloride solution and mixed, concentrated Sulfuric acid was added and observed for the formation of two layers; lower reddish-brown and upper acetic acid layer which turns bluish-green indicating a positive test for glycosides.

2.4 Selenium nanoparticle biosynthesis

Ten milliliters of alcoholic clove extract were added to 90 milliliters of 2 mM Na2SeO3 in order to biosynthesize Se-NPs. We combined 10 ml of D.W. and 90 ml of 2 mM Na2SeO3 for the control sample. Both flasks were placed on the rotary shaker for eight hours in the dark to achieve

homogeneous mixing. The produced Se-NPs were subsequently separated and purified using centrifugation and deionized water. We kept the dried Se-NPs at room temperature so they could be examined later (Cruz et al., 2019).

2.5 Clove Extract/ SeO NPs concentration determination by Atomic Absorption Spectrophotometer.

Estimation of selenium ions' concentration of prepared green synthesis clove extract /SeO NPs. were measured with an atomic absorption spectrophotometer (AAS) after the color shift of the green selenium oxide nanoparticles solutions had stabilized according method as described in Choudhary (2015)

2.6 Characterization of clove extract/selenium oxide nanoparticles

The synthesized Se NPs nanoparticles were curried using UV-visible spectroscopy (UV-VIS), field emission scanning electron microscopy (Fe-SEM), energy dispersive X-ray spectrometry (EDX), X-ray diffraction device (XRD), Fourier-Transform Infrared Spectroscopy (FTIR), and Zeta Potential (ElObeid et al., 2025).

2.7 Antigenotoxicity effect evaluate of clove Ex./ SeO NPs (in vivo)

The trials in this study used male Swiss white mice of the species Mus musculus that ranged in age from 8 to 12 weeks. seven groups were created from the mice:(Negative Control Group, Positive Control Group (15 min) Positive Control Group (30 min), UV Group (15 min) +Nano-Selenium, UV Group (30 min) +Nano-Selenium, UV Group (15 min) +Clove Extract, UV Group (30 min) + Clove Extract). The comet assay was performed to measure the DNA damage in leukocyte were collected into heparinized tubes. Leukocytes were isolated by erythrocyte lysis solution containing Na_2EDTA (0.380 g), NH_4 Cl (8.050 g) and $NaHCO_3$ (0.835 g) in 100 ml distilled water (pH 7.4) and diluted (1:10) to get a working solution. Cells were washed in PBS and diluted to ~105 cells/ ml. Cell suspensions were treated according to the experimental groups and incubated at 25 °C. For slide preparation, a layer of 1% Normal Melt Point agarose was spread, then a Sample were mixed with low MP agarose then add above the NMP agarose layer. Alkaline electrophoresis (300 mM NaOH, 1 mM EDTA, pH≈13) was carried out at 0.6 V/cm for 25 min (~40 mA). Slides were neutralized with 0.4 M Tris (pH 7.5), stained with acridin orang (20 min) and examined under fluorescence microscope, and data analysis of microscope figure determined by using Image J program (Braafladt et al., 2016).

2.8 Statistical Analysis

The Statistical Packages for Social Sciences (SPSS) (2019) program was used to determine how different groups affected the study parameters. The least significant difference (LSD) was used in this study to compare means (Lemenkova, 2019).

3. Results and Discussion

3.1 Alcoholic clove extract

As in the first study by the same researcher clove Ex. was produced in 60 milliliters. The extract from the rotary evaporator was then dried. After drying, twenty grams of dried clove Ex. were left. Figure 1. Table 1 shows the extraction yield of 13.33% for this study. falls within the range of yields reported in earlier studies on clove extraction by (Alfikri et al., 2020). According to research, during the blossoming season.

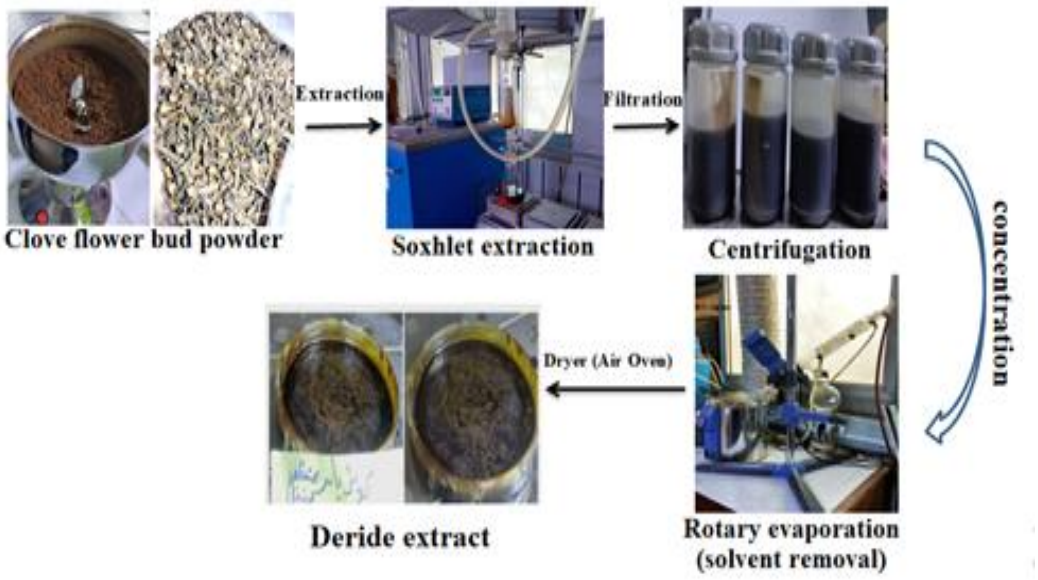

Figure 1. Process of Alcoholic Clove Extract Preparation

Table 1. Percentage of Crude Methanolic Syzygium aromaticum

Plant	Part	W1/g	W2/g	Yield g/100g
Syzygium aromaticum	Flower buds	150	20	13.33

3.2 Qualitative screening of phytochemicals in clove extract

Phytochemical analysis of Alcoholic clone EX showed the presence of phenols and tannins in higher quantities than flavonoids, terpenoids and alkaloids, which in turn were in higher proportions than glycosides, while no steroids were found (Table 2).

The detection results of active compounds in the S. aromaticum extract proved that it contained most of these compounds in good proportions, that are responsible for the biological activity of aromatic and medicinal plants which indicates that the clove extract possesses a good therapeutic property according to the function of each group. These results were in line with other authors (Ezeonu & Ejikeme, 2016; Shirankar et al., 2018). Who found that the Phytochemical analysis of S. aromaticum buds shows the presence of alkaloids, phenols, tannins, flavonoids, terpenoids, and glycosides in ethanolic, methanolic, and aqueous extracts. But not agree with Garba et al. (2019), who found that Phytochemical analysis of Syzygium aromaticum extracts indicated the presence of tannins, saponins, glycosides, flavonoids, phenols, and steroids, but no evidence of alkaloids detection.

Table 2. The result of qualitative screening of Phytochemicals in clove extract

Clove Extract	Phytochemicals					
	Flavonoids	Tannins	Glycosides	Alkaloids	Phenols	Terpenoids
	++	+++	+	++	+++	++

3.3 Biosynthesis of selenium oxide nanoparticle

The selenium nanoparticles extracted from cloves were obtained using the green method described in the first study by the same researcher.

3.4 Characterization of clove extract/selenium oxide nanoparticles

Characterization tests were conducted on the clove-derived nanocellulose, as in the first study by the same researcher, and the results indicated that the preparation process was successful. At wavelengths of 294.5 nm and 664.5 nm, respectively, the clove extract had the maximum absorbance

value of 3.462 and the lowest absorbance value of 0.036. Conversely, for SeO NPs, at wavelengths of 249.0 nm and 216.0 nm, respectively, the greatest absorbance value was 1.87 and the lowest was 0.499. This alteration demonstrates the interaction between selenium nanoparticles and the extract's bioactive ingredients.

The clove extract's FTIR measurements revealed distinctive peaks at (3410, 2933, 1608 cm^{-1}), which are linked to the active ingredient eugenol and are ascribed to hydroxyl, phenolic, and aromatic groups. (OH, C=O, C=C), which are in line , are in charge of stabilizing nanoparticles and reducing selenium. We see a change in the peaks from 1608 to 1639 and 3410 to 3439, which suggests that the clove extract and the nanoparticles are interacting.

The XRD pattern of the green synthesized selenium nanoparticles using clove extract showed the characteristic diffraction peaks at 2θ = 23.49°, 29.76°, 41.27°, 43.67° and 51.63° corresponding to the crystallographic planes (100), (101), (102), (110) and (111), respectively. These peaks are in good agreement with the standard diffraction pattern of crystalline selenium and confirm the successful formation of selenium nanoparticles with a well-defined crystalline structure.

Major elements including carbon (C), oxygen (O), and selenium (Se) are present, along with trace levels of Na, S, Cl, K, Ca, and Zn, according to the EDX examination Clove extract and its bioactive components are organic, as indicated by the prominent C and O peaks. Selenium was successfully introduced to or stabilized in the prepared system, as evidenced by the relatively high selenium concentration that was discovered.

The produced selenium nanoparticles (clove extract/ SeO NPs.) have a zeta potential of −36.53 mV, indicating strong electrostatic stability and a significant negative surface charge. Because there is sufficient electrostatic repulsion between the particles, nanoparticles with zeta potential values greater than ±30 mV are considered stable.

That the form of the produced selenium nanoparticles (SeO NPs) was examined using Fe-SEM. The particles were smooth, spherical and nanoparticles in size ranged from 29.3 to 126.8 nm in size averaged in 44.8 nm Agglomeration was observed which might be related to high surface forces of the particles or to preparation conditions or sample preparation steps in agreement with the results of previous studies. This is consistent with another earlier research.

3.5 Clove Extract/ SeO NPs concentration determination by Atomic Absorption Spectrophotometer.

Estimation of selenium ions' concentration of prepared green synthesis clove extract /SeO NPs. were measured by atomic absorption spectrophotometer (AAS) was reached 108 µg/ml after the color stability.

3.6 Antigenotoxicity effect evaluate of clove Ex./ SeO NPs (in vivo)

According to the results of the Comet assay, the highest Olive Tail Moment values were observed in the positive control groups (Control+) reaching 5.28 ± 0.30 a and 5.06 ± 0.10 after UV exposure for 30 and 15 min, respectively. These high values indicate the extent of DNA damage induced by ultraviolet radiation, which led to increased DNA migration during electrophoresis due to oxidative stress and DNA strand breaks. the therapeutic efficacy of the treatment with clove-mediated selenium nanoparticles was significantly superior over the clove extract alone. Olive Tail Moment values were 2.92 ± 0.14 for the Nano A 30 min group and 2.05 ± 0.40 for the Nano A 15 min group, which was the lowest value among all experimental groups. These much lower values are indicative of a significant decrease of DNA migration and genotoxicity ($P \leq 0.001$). On the other hand, When compared with the negative control group (2.43 ± 0.19), the Nano A 15 min group exhibited a very similar Olive Tail Moment value, indicating that selenium nanoparticles effectively restored DNA integrity to a level close to normal conditions. Likewise, the Nano A 30 min group showed a considerable reduction in DNA damage compared with both the positive control and clove extract-treated groups. While the Olive Tail Moment values were decreased after UV exposure in the clove extract treated groups when compared with the positive control groups. The Extract A 30 min group recorded a value of 4.68 ± 0.21 ab while the Extract A 15 min group recorded a value of 4.47 ± 0.25. Such decrease shows the therapeutic effect of clove extract on UV induced DNA damage. However, the values were comparatively higher than those in the negative control group. The therapeutic activity of clove extract may be attributed to its rich content of phenolic compounds, particularly eugenol and flavonoids, which have potent antioxidant properties and can scavenge reactive oxygen

species (ROS) and decrease oxidative DNA damage. The superior therapeutic performance of clove-mediated selenium nanoparticles may be attributed to several factors. The nanoscale size and large surface area enhance cellular uptake and facilitate interaction with damaged cellular components. In addition, selenium is an essential component of antioxidant enzymes such as glutathione peroxidase (GPx), which plays a critical role in eliminating reactive oxygen species generated by UV radiation. Furthermore, the high bioavailability and stability of selenium nanoparticles enhance their ability to repair DNA damage and protect cellular structures more efficiently than crude plant extracts. Post-treatment with clove extracts reduced DNA damage, but the clove-mediated selenium nanoparticles exhibited a stronger therapeutic effect. The lowest Olive Tail Moment values were observed in the SeNP-treated groups, particularly after 15 minutes of exposure, indicating a significant reduction in genotoxicity and higher therapeutic activity. These findings suggest that clove-mediated selenium nanoparticles possess potent therapeutic potential in repairing UV-induced DNA damage and enhancing genomic stability as presented in Table 3 and Figure 2.

The findings of Hwang et al., who showed that clove extract's strong antioxidant activity and qualities reduce UVB-induced cellular damage and improve tissue regeneration, are consistent with the decrease in Olive Tail Moment seen in the groups treated with extract. Similarly, Gudkov et al. (2023) demonstrated that selenium nanoparticles significantly reduced oxidative damage to DNA and proteins induced by radiation-generated reactive oxygen species. Their study showed that selenium nanoparticles enhanced cellular antioxidant defenses and protected biological tissues from radiation-induced oxidative stress. Similarly, the current study revealed that treatment with clove-mediated selenium nanoparticles markedly decreased Olive Tail Moment values compared with the UV-exposed positive control group, indicating effective repair of UVB-induced DNA damage and reduced genotoxicity. Furthermore, the findings are consistent with those of Akhtar et al. (2020), who reported that nano-formulated myricetin exhibited greater efficacy than its bulk form in reducing DNA damage, as assessed by the comet assay. The authors attributed this enhanced activity to improved cellular uptake and bioavailability of the nano-formulation. Likewise, in the present study, clove-mediated selenium nanoparticles showed superior therapeutic activity compared with clove extract alone, resulting in significantly lower Olive Tail Moment values. This suggests that the nanoscale formulation enhanced the biological activity of selenium and improved its ability to mitigate UVB-induced DNA damage and promote DNA repair mechanisms.

Table 3. Activity of clove Extract and clove Ex/SeO Nanoparticles After UV array treatment in mice (In vivo)

Treatment	Mean ±SE			
	DNA of Head %	DNA of Tail %	Length	Olive Tail moment ™
Nano: A 30 min.	51.00 ±1.69 b	49.00 ±1.59 c	6.00 ±0.45 c	2.92 ±0.14 c
Extract: A 30 min.	37.70 ±1.08 d	62.40 ±1.32 a	7.50 ±0.24 b	4.68 ±0.21 ab
Nano: A 15 min.	48.98 ±0.44 b	51.02 ±0.44 c	4.00 ±0.77 d	2.05 ±0.40 d
Extract: A 15 min.	42.10 ±0.71 c	58.80 ±1.10 b	7.59 ±0.39 b	4.47 ±0.25 b
Control+: 30 min.	49.34 ±1.67 b	50.66 ±1.67 c	10.40 ±0.28 a	5.28 ±0.30 a
Control+: 15 min.	51.60 ±0.34 b	48.60 ±0.50 c	10.42 ±0.19 a	5.06 ±0.10 ab
Control-	55.30 ±0.75 a	44.90 ±0.46 d	5.34 ±0.38 c	2.43 ±0.19 cd
L.S.D.	3.137 **	3.275 **	1.236 **	0.717 **
P-value	0.0001	0.0001	0.0001	0.0001

Means having with the different letters in same column differed significantly. ** (P≤0.01).

* The letters in each column indicate significant differences, Probability at (P≤0.01), Means for five replicates

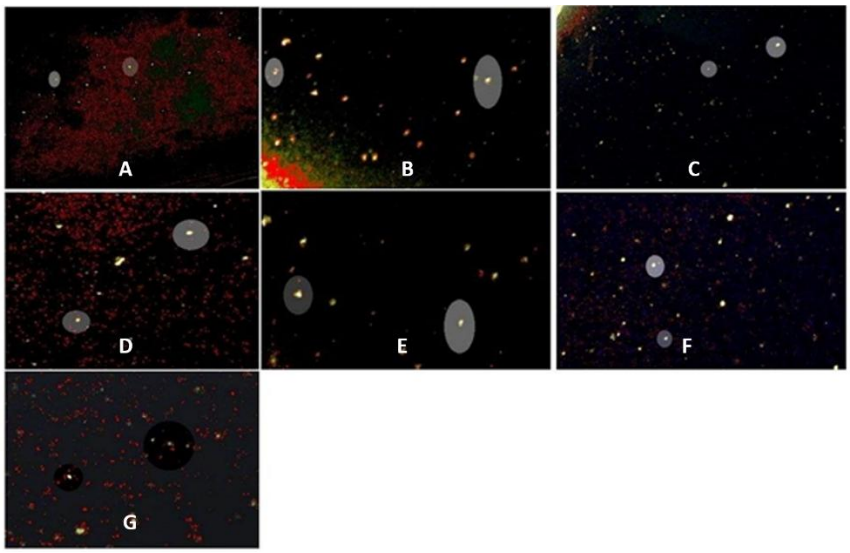

Figure 2. Comet Assay Analysis to Evaluate the of Clove Ex/SeO Nanoparticles Activity After UV Array Treatment in Mice (In vivo): A: SeO Nanoparticles After UV 30 min, B: Clove Extract After 30 min, C: SeO Nanoparticles After 15 min, D: Clove Extract After 15 min, E: Control+: 30 min, F: Control+: 15 min, G: Control.

4. Conclusion

The present study showed that the UV radiation caused significant DNA damage as measured by increased Olive Tail Moment values in the positive control groups. Clove extract after treatment reduced DNA damage and improved DNA integrity whereas better therapeutic efficacy was observed with clove mediated selenium nanoparticles. The lowest value of the Olive Tail Moment (2.05) was in the Nano A 15 min group followed by the Nano A 30 min group (2.92). It indicated a significant decrease in DNA migration and genotoxicity. The higher antioxidant capacity, enhanced bioavailability and efficient cellular uptake of selenium nanoparticles may be responsible for their improved therapeutic activity. Hence, biosynthesised selenium nanoparticles with clove extract are a potential therapeutic agent to reduce the UV-induced DNA damage and enhance the genomic stability.

Acknowledgment

I would like to express my sincere gratitude and deepest appreciation to my supervisors, Professor Dr. Hussein Saleh Hassan and Dr. Labib Ahmed Kadhim, for their outstanding scientific supervision, valuable guidance, and continuous support throughout this study. Their expertise, constructive comments, and dedicated efforts greatly contributed to the successful completion of this research

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Abid, N., Khan, A. M., Shujait, S., Chaudhary, K., Ikram, M., Imran, M., Haider, J., Khan, M., Khan, Q., & Maqbool, M. (2022). Synthesis of nanomaterials using various top-down and bottom-up approaches, influencing factors, advantages, and disadvantages: A review. Advances in Colloid and Interface Science, 300, 102597.

Akhtar, S., Najafzadeh, M., Isreb, M., Newton, L., Gopalan, R. C., & Anderson, D. (2020). Ex vivo/in vitro protective effect of myricetin bulk and nano-forms on PhIP-induced DNA damage in lymphocytes from healthy individuals and pre-cancerous MGUS patients. Archives of Toxicology, 94(7), 2349–2357.

Alfikri, F. N., Pujiarti, R., Wibisono, M. G., & Hardiyanto, E. B. (2020). Yield, quality, and antioxidant activity of clove (Syzygium aromaticum L.) bud oil at the different phenological stages in young and mature trees. Scientifica, 2020(1), 9701701.

Atanasov, A. G., Zotchev, S. B., Dirsch, V. M., & Supuran, C. T. (2021). Natural products in drug discovery: Advances and opportunities. Nature Reviews Drug Discovery, 20(3), 200–216. https://doi.org/10.1038/s41573-020-00114-z

Barboza, J. N., da Silva Maia Bezerra Filho, C., Silva, R. O., Medeiros, J. V., & de Sousa, D. P. (2018). An overview on the anti-inflammatory potential and antioxidant profile of eugenol. Oxidative Medicine and Cellular Longevity, 2018(1), 3957262.

Braafladt, S., Reipa, V., & Atha, D. H. (2016). The comet assay: Automated imaging methods for improved analysis and reproducibility. Scientific Reports, 6(1), 32162.

Cadet, J., & Douki, T. (2018). Formation of UV-induced DNA damage contributing to skin cancer development. Photochemical & Photobiological Sciences, 17(12), 1816–1841.

Cruz, L. Y., Wang, D., & Liu, J. (2019). Biosynthesis of selenium nanoparticles, characterization and X-ray induced radiotherapy for the treatment of lung cancer with interstitial lung disease. Journal of Photochemistry and Photobiology B: Biology, 191, 123–127.

Choudhary, M.K.; Kataria, J.; Cameotra, S.S. and Singh, J. (2015). A facile biomimetic preparation of highly stabilized silver nanoparticles derived from seed extract of Vigna radiate and evaluation of their antibacterial activity. Applied Nanosciences. 6 (1): 105-111

ElObeid, T., Yilmaz, M. T., Ispirli, H., Sagdic, O., Taylan, O., Basahel, A., Karaboga, D., Durak, M. Z., & Dertli, E. (2025). Biosynthesis of alternan-stabilized selenium nanoparticles: A study on characterization and applications for antibacterial and antifungal purposes. Inorganic and Nano-Metal Chemistry, 55(7), 793–806.

Ezeonu, C. S., & Ejikeme, C. M. (2016). Qualitative and quantitative determination of phytochemical contents of indigenous Nigerian softwoods. New Journal of Science, 2016(1), 5601327.

Garba, Z. N., Zhou, W., Lawan, I., Xiao, W., Zhang, M., Wang, L., Chen, L., & Yuan, Z. (2019). An overview of chlorophenols as contaminants and their removal from wastewater by adsorption: A review. Journal of Environmental Management, 241, 59–75.

Gudkov, S. V., Gao, M., Simakin, A. V., Baryshev, A. S., Pobedonostsev, R. V., Baimler, I. V., Rebezov, M. B., Sarimov, R. M., Astashev, M. E., & Dikovskaya, A. O. (2023). Laser ablation-generated crystalline selenium nanoparticles prevent damage of DNA and proteins induced by reactive oxygen species and protect mice against injuries caused by radiation-induced oxidative stress. Materials, 16, 5164.

Hwang, E. S., Lin, P. L., Ngo, H. T., & Yi, T. H. (n.d.). Clove attenuates UVB-induced photodamage and repairs skin barrier function in hairless mice.

Jackson, S. P., & Bartek, J. (2009). The DNA-damage response in human biology and disease. Nature, 461(7267), 1071–1078.

Lemenkova, P. (2019). Numerical data modelling and classification in marine geology by the SPSS statistics. International Journal of Engineering Technologies (IJET), 5(2), 90–99.

Pfeifer, G. P. (2020). Mechanisms of UV-induced mutations and skin cancer. Genome Instability & Disease, 1(3), 99–113.

Roy, S. (2017). Impact of UV radiation on genome stability and human health. In Ultraviolet Light in Human Health, Diseases and Environment (pp. 207–219).

Shirankar, S. S., Dongre, S. G., Limsay, R. P., & Somkuwar, A. P. (2018). The preliminary phytochemical screening of various leaf extracts of plant Limonia acidissima Linn. OPEN ACCESS POLICY, 47(3), 1321–1329.

Talaie, A., & Moussavi, S. M. (2025). The impact of ultraviolet radiation on human health. Journal of Environmental Treatment Techniques, 12(1), 39–66.

Zhang, Y., Liu, X., Wang, Y., & Chen, H. (2020). Extraction optimization of phenolic compounds from Syzygium aromaticum and evaluation of antioxidant activity. Journal of Applied Research on Medicinal and Aromatic Plants, 18, 100247. https://doi.org/10.1016/j.jarmap.2020.100247.