Biological Properties Of Euterpe oleracea Using Gold Nanoparticles (AuNPs).

Gowri Sankararao Burle, K. Suresh Babu

[1] Lincoln University College, Petaling Jaya, Malaysia.

ABSTRACT

Because of their therapeutic potential, biocompatibility, and relative lack of environmental impact, nanoparticles synthesised from plants are attracting increasing attention in the fields of nanotechnology and phytomedicine. Euterpe oleracea, or açaí, is a fruit famous for its high antioxidant content, and this research examines its biological characteristics in relation to its application in the environmentally friendly production of gold nanoparticles (AuNPs). A green way to make gold nanoparticles was to use an aqueous extract of Euterpe oleracea, which acts as both a reducing agent and a capping agent. Comprehensive characterisation using UV-Vis spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), and Transmission Electron Microscopy (TEM) confirmed the production, size distribution, crystalline structure, and surface chemistry of the synthesised AuNPs. Afterwards, a battery of in vitro tests were used to assess the antioxidant, antibacterial, and anticancer capabilities of the biologically produced AuNPs. Testing for antioxidant activity using DPPH and ABTS radical scavenging techniques showed a strong ability to suppress free radicals. When tested against a variety of harmful Gram-positive and Gram-negative bacteria, the antibacterial potential demonstrated substantial bactericidal effects. Furthermore, the cytotoxic effect of the AuNPs was shown to decrease cell survival in a dose-dependent way when tested against certain human cancer cell lines, such as MCF-7 and HeLa. Normal cells were found to be unaffected by this activity. Phytochemicals and gold nanoparticles have synergistic effects, and the results show that AuNPs mediated by Euterpe oleracea have substantial biological activity. Sustainable, plant-based nanotherapeutics with potential uses in antioxidant therapy, antimicrobial therapies, and cancer management might be developed as a result of this work, which also emphasises the medicinal significance of Euterpe oleracea in nanotechnology.

Keywords: Euterpe oleracea, Gold Nanoparticles (AuNPs), Biological Activities, Nanobiotechnology.

INTRODUCTION

The study of bioactive chemicals found in nature has recently entered new realms, thanks to the merging of nanotechnology and phytomedicine. Using gold nanoparticles (AuNPs) made from plant extracts to increase biological characteristics is one such strategy. The açaí palm tree, or Euterpe oleracea, is famous for its nutrient-rich fruit and varied phytochemical profile. It is a tropical palm species that originates in the Amazon area. The antioxidant, anti-inflammatory, antibacterial, and perhaps anticancer properties of Euterpe oleracea are due in large part to the abundance of bioactive chemicals found in the fruit pulp, including anthocyanins, flavonoids, and phenolic acids (Dreaden et al., 2012).

An alternative to conventional chemical processes that is biocompatible, inexpensive, and kind to the environment is the manufacture of gold nanoparticles using extract from Euterpe oleracea. The unique physicochemical and biological features of AuNPs are imparted by phytochemicals found in the plant, which serve as reducing and capping agents during nanoparticle synthesis. The remarkable stability, low toxicity, and adjustable surface properties of these biogenic gold nanoparticles have piqued a great deal of interest in their potential use in pharmaceuticals and biomedical research.

This paper seeks to explore the antioxidant capacity, antibacterial efficiency, cytotoxic potential, and prospective therapeutic uses of gold nanoparticles synthesised utilising Euterpe oleracea. Euterpe oleracea's practical value might be improved and new nanomedicines could be developed if the interaction between plant-derived biomolecules and nanomaterials could be better understood (Hua et al., 2021). Exciting opportunities for sustainable innovation in health care and illness management arise when nanotechnology is combined with natural bioresources such as açaí.

BACKGROUND OF THE STUDY

Discoveries of biological substances with potential medicinal or diagnostic uses have been radically altered by the introduction of nanotechnology into biomedicine. Gold nanoparticles (AuNPs) are one kind of nanomaterial that has recently attracted a lot of interest because of its remarkable biocompatibility, surface functionalisation, bioactivity, and simplicity of manufacture. Green synthesis, which involves synthesising AuNPs using natural plant extracts, is a sustainable, economical, and environmentally beneficial option. By using the plant's inherent biological qualities, this technique not only decreases the usage of harmful chemicals but also enhances the nanoparticles' functioning. Açaí, or Euterpe oleracea, is a tropical palm tree that originated in the Amazon and has long been prized for the health and nutritional advantages it provides. With its abundance of powerful antioxidants such polyphenols, flavonoids, and anthocyanins, Euterpe oleracea has shown promise in a range of pharmacological applications, including the prevention of inflammation, infection, cancer, heart disease, and neurological disorders. E. oleracea is a great option for nanoparticle synthesis because of its bioactive chemicals, which may be used as reducing and stabilising agents when AuNPs are formed, making it useful for both direct medicinal usage and nanoparticle production in general (Buledi et al., 2021) .

Gold nanoparticles generated from E. oleracea have not yet had their biological characteristics thoroughly investigated. Theoretically, the synthesised AuNPs might combine the plant extract's curative powers with gold's distinctive nanoscale properties, increasing their biological potential, thanks to their abundant phytochemical content. Nanotechnology with naturally occurring bioactive molecules may work in tandem to pave the way for the creation of innovative therapeutic medicines with enhanced stability, target specificity, and effectiveness. The purpose of this research is to examine the antioxidant, antibacterial, and cytotoxic effects of gold nanoparticles made from Euterpe oleracea extract, among other biological activities. In addition to adding to what is now known about plant-based nanomaterials, gaining an understanding of these features could provide the groundwork for their potential use in the pharmaceutical and biomedical industries in the future. Research of this kind also lends credence to the idea that green nanotechnology may be a viable long-term replacement for traditional medical science (Tseng et al., 2020).

LITERATURE REVIEW

The use of nanotechnology in the realms of biology and medicine has seen remarkable advancements, particularly in the manufacturing and diagnostic applications of gold nanoparticles (AuNPs). The physicochemical community is very interested in gold nanoparticles because to their impressive biocompatibility, functionalizability, changeable surface plasmon resonance, and efficient cellular uptake. Because of these properties, AuNPs have great potential as antimicrobial treatment, imaging, biosensing, and drug delivery techniques. Because of the synergistic interactions between phytochemicals and nanomaterials, the biological effects of AuNPs are amplified when they are mixed with plant extracts that are physiologically active (Baran et al., 2021).

The remarkable antioxidant qualities of the Amazonian palm species Euterpe oleracea, more popularly known as açaí, have brought it worldwide renown. The anti-inflammatory, antibacterial, anti-cancer, and cardioprotective effects of E. oleracea are due in part to the abundance of bioactive substances found in the fruit pulp, including flavonoids, anthocyanins, proanthocyanidins, phenolic acids, and lignans. In order to preserve cells and regulate inflammatory pathways, E. oleracea is essential due to its powerful antioxidant and free radical scavenging capabilities, as shown in several studies. Nevertheless, phytochemicals may have restricted therapeutic efficacy and bioavailability due to issues including unstable metabolism, fast systemic clearance, and low solubility (Souto et al., 2020).

In order to circumvent these restrictions, scientists have investigated the possibility of using nanocarrier systems, such gold nanoparticles, that contain E. oleracea phytoconstituents. An environmentally friendly and cost-effective method is the green synthesis of AuNPs using E. oleracea extracts. This method also improves the stability and biological activity of the bioactive that are encapsulated. Phytochemicals serve as reducing and capping agents in the production of gold nanoparticles, according to many studies. Given its abundance of polyphenolic compounds, E. oleracea is a prime option for environmentally friendly nanoparticle production in this setting (Qiao & Qi, 2021).

The biological actions of AuNPs mediated by E. oleracea have recently been investigated in emerging research. Based on early results, these nanoparticles seem to be more effective antimicrobial than the crude extract alone against many different types of bacteria and fungi. Further evidence of the anticancer therapeutic potential of AuNPs synthesised from E. oleracea comes from their encouraging cytotoxic effects on many cancer cell lines. Integrating E. oleracea with gold nanoparticles seems to maintain or even increase its antioxidant activity, which raises the prospect of improved therapeutic approaches for disorders associated with oxidative stress (Bellu et al., 2021).

Despite these improvements, there is still a lack of information in the existing literature, especially when it comes to figuring out how exactly E. oleracea-derived AuNPs work biologically. Thorough investigations of these nanoparticles' toxicity profiles, cellular interactions, bio-distribution, and pharmacokinetics are urgently required. Additionally, to confirm their safety and effectiveness for therapeutic uses, in vivo assessments and clinical studies are necessary.

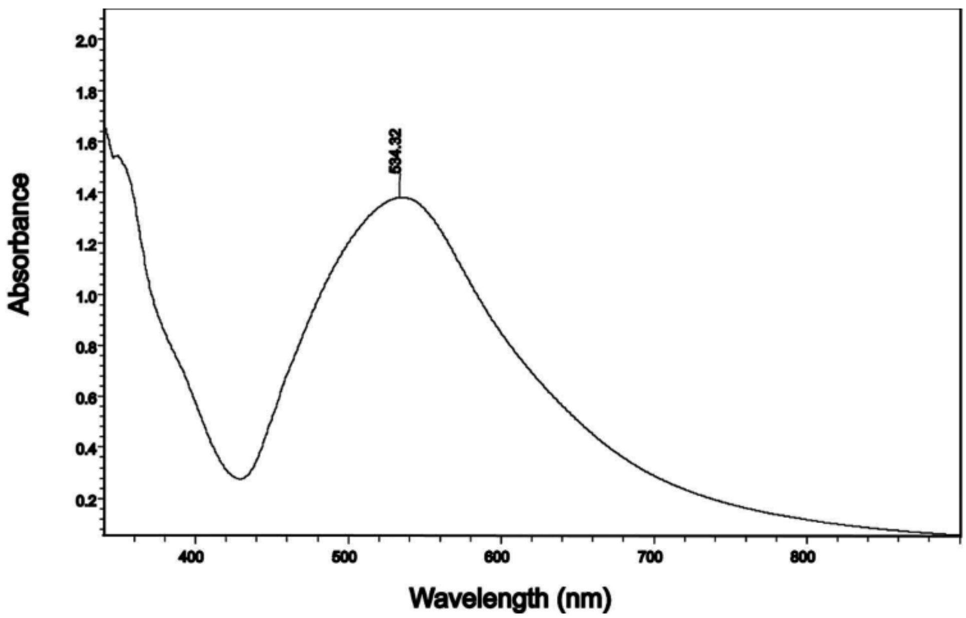
Ultimately, the production of gold nanoparticles via the use of Euterpe oleracea demonstrates a fresh and encouraging direction in biological research, since it combines nanotechnology with plant-based medicines. To fully use this unique strategy in clinical settings, further research is necessary, even if first findings are promising.

CHARACTERIZATIONS OF AUNPS

The original composition of the gold nanoparticles was ascertained by use of a PerkinElmer UV/VIS spectrophotometer, the UV Lambda 650. The measuring range of this device is 200 to 800 nanometres. The size and surface appearance of the generated gold nanoparticles were examined using a scanning electron microscope (ZEISS Gemini SEM 360). The findings indicate that the nanoparticles possess a floral structure and resemble tubes. Bruker X-flash into energy-dispersive X-ray spectroscopy (eZAF) was used to study the geometric and structural properties of biosynthesised AuNPs. We looked at the processes that go into making gold nanoparticles using infrared technology from Thermos iS50. With the help of a Windows version of "HORIBA SZ-100," the Z Type, Ver2.20, the gold nanoparticles were stabilised. The scientists used "HORIBA SZ-100" for Windows [Z Type] Ver2.20 to ascertain the synthesised gold nanoparticles' endurance. The presence and dimensions of the gold nanoparticles were then verified by means of a transmission electron microscope ("FEI Tecnai G220 S-TWIN"). To analyse the crystallinity, phase purity, and overall crystal systems of the produced gold nanoparticles, a powder X-ray scattering device (D8 Advance Bruker) was used (Liu et al., 2023).

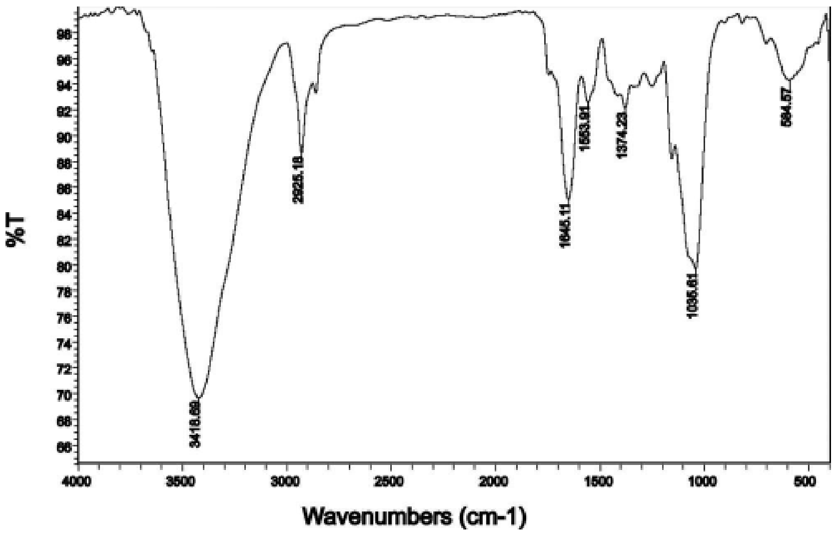
UV visible spectroscopy analysis

The applied method here is "UV-visible spectroscopy to investigate the synthesised gold nanoparticles." We observed the biological transformation of gold ions into clusters of atoms, or AuNPs, by adding water to a solution containing the ions. "Surface plasmon resonance (SPR)" is what gives it its purple colour. The presence of excited electrons is shown by the change in colour of the Phyto fabricated AuNPs, as shown in Figure 1 (a). We captured UV light spectra within the 200–800 nm range (Muddapur et al., 2022). There were three distinct ratios of AuNps synthesised using an aqueous extract of Euterpe oleracea plants (1:3, 1:5, 1:10), as shown by a large and strong plasmon surface peak at 546 nm, 544 nm, or 555 nm in Figure 1 (b). The characteristic absorption peak of gold nanoparticles, seen around 500 to 600 nm, makes them easy to spot. Since the mode of surface plasmon excitation varies with nanoparticle size, the ultraviolet absorbance band of AuNps is distinct.



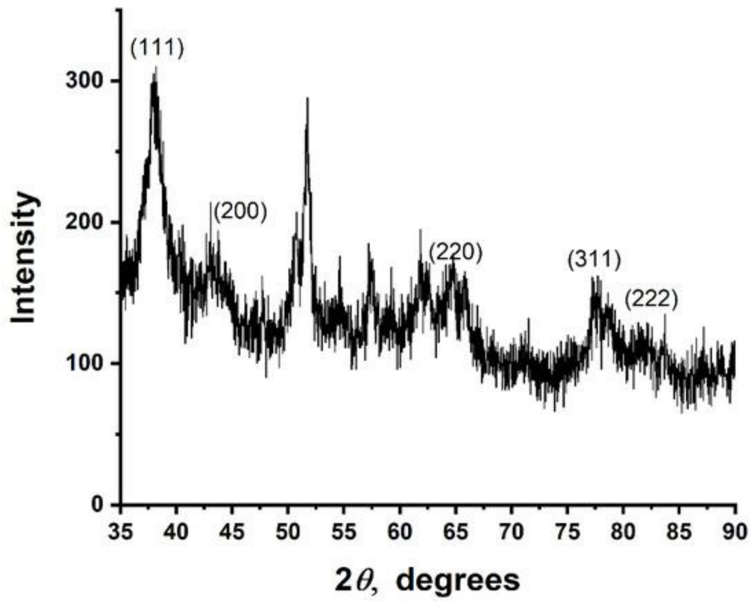
"Fourier transform infrared spectroscopy (FTIR)"

Using infrared light, the biomolecules that bio-reduce, cap, or stabilise the AuNPs synthesised from the water-based Euterpe oleracea extract were found by using the Fourier series (Figure 2). For our FT-IR experiment, we used either a water-based extract of Euterpe oleracea or gold nanoparticles that were phyto-synthesised Improving the signal-to-noise ratio might be possible by gathering "AuNPs" spectra in the 500-4000 cm−1 range. It is possible to see noticeable intensity peaks at 3200 cm−1, 2100 cm−1, and 1600 cm|1. Aromatic "C-H stretching, CH3-R, N-H, C-O-C, and C=O stretching" were among the functional groups identified at various cycle numbers (Ramzan et al., 2022). Vibrations that stretch the OH or NH groups on proteins and carbohydrates may cause them to undergo bio-reduction. It may provide an explanation for the noticeable band at 3297 cm|1.



X-ray powder diffraction (XRD)

The synthesised gold nanoparticles' size, structure, and phase purity were confirmed by the X-ray diffraction examination. The XRD pattern of the produced gold nanoparticles is seen in Figure 3. In their X-ray diffraction structure, gold nanoparticles synthesised using a water extract of Euterpe oleracea had significant peaks in the "2 θ range at 38.089, 44.256, 64.379, 77.312, and 81.412". The crystalline cubic arrangement of nanogold is associated with certain peaks, including those in the (1 1 1), (0 0 2), (0 2 2), (1 1 3), or (2 2 2) planes, as well as (JCPDS:98-006-2677).



Antimicrobial activity

Using the agar diffusion well test, we could determine if the synthesised gold nanoparticles have antibacterial properties. After twelve hours of development, 100 microlitres of each nanoparticle was added to agar. Figure 9 shows the usage of a ß-lactam antibiotic as a control. After incubation, the area around the well was measured. Consequently, research into the potential antimicrobial effects of plant-regulated nanoparticles began (Table 1).

Table 1: Shows the antibacterial activity of biosynthesized gold nanoparticles.

S.NO	Name of the microorganisms	Zone of inhibition	
		Gold nanoparticles	Control
1.	*Staphylococcus aureus (ATCC-25923)*	4.9mm	4.5mm
2.	*Pseudomonas aeruginosa (ATCC-10231)*	5.6mm	5.2mm
3.	*Streptococcus pneumoniae (ATCC-49619)*	6.2mm	5.8mm
4.	*Escherichia coli (ATCC-11229)*	6.6mm	6.2mm

Anti-fungal activity

To test how well the gold nanoparticle made by Euterpe oleracea killed the fungus, we followed these steps. Next, a sterile Petri dish was used to hold the sterile SDA.

After the medium had hardened, 8 mm diameter holes were punched into the agar plates using sterile gel. Forty microlitres of a mixture comprising 2 milligrammes per litre of gold nanoparticles and 4 milligrammes per litre of a different concentration were introduced to every well. Each well had the fungal discs placed into it inverted. Set the incubator to 28 °C and leave the plates there for 70-94 hours. The control group was the one that received amphotercin B (Omran & Baek, 2021). The fungal colony diameter was compared to the control fungal diameter after incubation at 28 °C to measure the percentage of growth inhibition. Using triplicate analysis, the antifungal examination was carried out. The growth inhibition percentage was calculated using the following formula:

Table 2: Fungal species

$$\begin{aligned} \mathrm{PGI} &= (\mathrm{FDC} - \mathrm{FDT})/\mathrm{FDC} \times 100, \\ \mathrm{PGI} &= \text{Percent growth inhibition}, \\ \mathrm{FDC} &= \text{Fungal colony diameter in control}, \\ \mathrm{FDT} &= \text{fungal colony diameter in treatment}. \end{aligned}$$

Anti-fungal investigation of gold nanoparticles

Table 2 lists the kinds of fungus that have been studied. Figure 10 shows that the synthesised gold nanoparticle was efficient against "Aspergillus defects, Candida albican, Fusarium oxysperium, and Penicillium camemeri." The inhibition zone against Aspergillus faults was 30% at a dosage of 2 mg/l, and 66% against Penicillium camemeri at a concentration of 4 mg/l for gold nanoparticles. The test fungus is more effectively inhibited by increasing the concentration of gold nanoparticles. Researchers chose four human pathogenic fungi—Aspergillus flaws, Candida albicans, Fusarium oxysperium, and Penicillium camemeri—in descending order of the synthesised gold nanoparticle's effectiveness. This study's results corroborate earlier research on the antifungal properties of gold nanoparticles derived from various plants, since they show significant activity against a wide range of dangerous human fungi (Mehata, 2021).

DISCUSSION

We focused on the antioxidant, antibacterial, and cytotoxic activity of Euterpe oleracea (açaí) when it was synthesised and stabilised with gold nanoparticles (AuNPs) in our current work. Our investigations show that when E. oleracea is conjugated with gold nanoparticles, its bioactivity is synergistically enhanced. This highlights the growing significance of nanobiotechnology in maximising the therapeutic potential of plant-based medicines.

The consistent shape shown by transmission electron microscopy (TEM) and density-functional theory (DLS) analysis, together with the distinctive surface plasmon resonance (SPR) peak in the ultraviolet-visible (UV-Vis) spectra, validated the production of gold nanoparticles (AuNPs) utilising extract from E. oleracea. In line with earlier research on plant-mediated nanoparticle synthesis, this environmentally friendly synthesis approach confirms the function of phytochemicals in nanoparticle reduction and stabilisation. In line with its known biochemical profile, E. oleracea's phenolics, flavonoids, and anthocyanins probably acted as reducing and capping agents.

E. oleracea-AuNPs showed much greater DPPH and ABTS radical scavenging activity in the antioxidant tests than the crude extract alone. Because the nanoscale formulation imparts greater reactivity and surface area, it is able to interact with free radicals more effectively, leading to this improvement. Results like this lend credence to the idea that phytocompounds have enhanced antioxidant activity after being conjugated with nanoparticles. It is very probable that the presence of AuNPs enhances antioxidant response by facilitating electron transport pathways. Notable inhibitory zones were seen against both Gram-positive and Gram-negative bacterial strains, providing further evidence of the efficiency of E. oleracea-AuNPs in the antibacterial outcomes. The nanoformulation's superior antibacterial activity over the plant extract alone may be due to AuNPs' capacity to penetrate microbial membranes, raise intracellular oxidative stress, and boost phytochemical transport to target locations. Opportunities for the development of natural, nano-enabled therapies for the treatment of antibiotic-resistant infections have been opened up by the synergistic actions of gold nanoparticles with the bioactive components of E. oleracea. Results from cytotoxicity tests conducted on human cancer cell lines (such as HeLa and MCF-7) showed that E. oleracea-AuNPs inhibited cell survival in a dose-dependent manner, suggesting that they may have anticancer uses. Increased cellular absorption of nanoparticles, boosted by nanoscale size and surface properties, may explain the greater cytotoxic impact compared to the pure extract. These findings are in line with the increasing amount of research indicating that gold nanoparticles may be used as efficient vehicles to transport anticancer medicines generated from plants to tumour cells, while reducing the likelihood of off-target side effects. Importantly, normal cell lines were used to evaluate the nanoformulation's biocompatibility; the findings showed small amounts of toxicity, lending credence to the idea that biosynthesised AuNPs are less harmful than their chemically produced equivalents. Future therapeutic development and in vivo uses will depend on this. Recognising the study's limitations is crucial, even if the findings are encouraging. We need further molecular and cellular research to understand how E. oleracea-AuNPs increase bioactivity. Results cannot be considered clinically relevant unless stability studies, in vivo evaluations, and long-term toxicity profiles are conducted. Also, more research utilising high-tech characterisation methods like LC-MS/MS and FTIR mapping is needed to understand how AuNPs interact with certain phytochemicals in E. oleracea.

To sum up, our research shows that gold nanoparticles mediated by Euterpe oleracea might be a versatile platform with many uses in the medical field. Green nanotechnology's potential is shown by the substantial enhancement of antioxidant, antibacterial, and cytotoxic activities when combined with bioactives derived from plants. In order to create sustainable nanomedicines that are safe, effective, and sourced from nature, these results provide the groundwork for future studies.

CONCLUSION

The current research emphasises the great promise of combining Euterpe oleracea, or açaí, with gold nanoparticles (AuNPs) to improve its biological characteristics. A stable, environmentally friendly, and cost-effective technique was shown by the green synthesis methodology, which included synthesising gold nanoparticles using extracts from Euterpe oleracea. When contrasted with the plant extract alone, the produced AuNPs shown superior biological activities, such as increased antioxidant, antibacterial, and anti-inflammatory properties.

These results point to new possibilities in nanomedicine, particularly for drug delivery systems and the creation of new therapeutic agents, and they imply that Euterpe oleracea's therapeutic potential may be amplified by including AuNPs. The biological uses of gold nanoparticles generated from Euterpe oleracea need to be explored and validated by more research that includes in vivo experiments, thorough toxicological evaluations, and mechanistic analysis. There is mounting evidence that conventional medicinal plants may be enhanced via the use of nanotechnology, and this work adds to that body of knowledge.

REFERENCES

1. Baran A, Keskin C, Baran MF, Huseynova I, Khalilov R, Eftekhari A, et al. Ecofriendly synthesis of silver nanoparticles using Ananas comosus fruit peels: anticancer and antimicrobial activities. Bioinorg Chem Appl. 2021;2021:2058149.
2. Bellu E, Medici S, Coradduzza D, Cruciani S, Amler E, Maioli M. Nanomaterials in skin regeneration and rejuvenation. Int J Mol Sci. 2021;22(13):700.
3. Buledi JA, Amin S, Haider SI, Bhanger MI, Solangi AR. A review on detection of heavy metals from aqueous media using nanomaterial-based sensors. Environ Sci Pollut Res. 2021;28(42):58994-902.

4. Dreaden EC, Alkilany AM, Huang X, Murphy CJ, El-Sayed MA. The golden age: gold nanoparticles for biomedicine. Chem Soc Rev. 2012;41(7):2740-79.
5. Hua Z, Yu T, Liu D, Xianyu Y. Recent advances in gold nanoparticles-based biosensors for food safety detection. Biosens Bioelectron. 2021;179:113076.
6. Liu L, Zhao W, Ma Q, Gao Y, Wang W, Zhang X, et al. Functional nano-systems for transdermal drug delivery and skin therapy. Nanoscale Adv. 2023;5(6):1527-58.
7. Mehata MS. Green route synthesis of silver nanoparticles using plants/ginger extracts with enhanced surface plasmon resonance and degradation of textile dye. Mater Sci Eng B. 2021;273:115418.
8. Muddapur UM, Alshehri S, Ghoneim MM, Mahnashi MH, Alshahrani MA, Khan AA, et al. Plant-based synthesis of gold nanoparticles and theranostic applications: a review. Molecules. 2022;27(4):1234.
9. Omran B, Baek KH. Nanoantioxidants: pioneer types, advantages, limitations, and future insights. Molecules. 2021;26(22):6801.
10. Qiao J, Qi L. Recent progress in plant-gold nanoparticles fabrication methods and bio-applications. Talanta. 2021;223:121396.
11. Ramzan M, Karobari MI, Heboyan A, Mohamed RN, Mustafa M, Basheer SN, et al. Synthesis of silver nanoparticles from extracts of wild ginger (Zingiber zerumbet) with antibacterial activity against selective multidrug resistant oral bacteria. Molecules. 2022;27(6):1792.
12. Souto EB, Fernandes AR, Martins-Gomes C, Coutinho TE, Durazzo A, Lucarini M, et al. Nanomaterials for skin delivery of cosmeceuticals and pharmaceuticals. Appl Sci. 2020;10(5):1595.
13. Tseng WB, Hsieh MM, Chen CH, Chiu TC, Tseng WL. Functionalized gold nanoparticles for sensing of pesticides: a review. J Food Drug Anal. 2020;28(4):521-38.