OPEN ACCESS

Saudi Journal of Biomedical Research
Abbreviated Key Title: Saudi J Biomed Res
ISSN 2518-3214 (Print) | ISSN 2518-3222 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Green Synthesis of Silver (Ag) Nanoparticles with Green Tea Leaf, Its Characterization, and Molecular Docking Analysis against Diabetes

Durga M[1]*, Shilpa P[1], Priyadharshini I[1], Dhanalakshmi S[1]

[1]Department of Biochemistry and Bioinformatics & CTM, Dr. MGR Janaki College of Arts and Science for Women, University of Madras, Chennai-600028, Tamil Nadu, India

DOI: https://doi.org/10.36348/sjbr.2024.v09i06.002 | **Received:** 12.07.2024 | **Accepted:** 16.08.2024 | **Published:** 19.08.2024

***Corresponding author:** Dr. Durga M
Department of Biochemistry and Bioinformatics & CTM, Dr. MGR Janaki College of Arts and Science for Women, University of Madras, Chennai-600028, Tamil Nadu, India

Abstract

The Green synthesis method is proved to be one of the simplest and efficient ways for material synthesis. Silver nanoparticles were synthesized using a green synthesis method, with silver nitrate and green tea leaves as precursors. The sample is then characterized using versatile characterization techniques such as Scanning Electron Microscope (SEM), UV Spectroscopy, Raman Spectroscopy and Particle size analyser (PSA). The PSA pattern has shown that the particles are pure. The surface morphology is obtained through SEM image and it has suggested that nano particles were aggregates. The nanoparticles have shown interactions between silver and oxygen atoms supported by Raman. Molecular docking is a pivotal computational technique widely used in drug discovery to predict the preferred orientation of a ligand as it binds to a receptor's active site. This approach is fundamental to understand molecular interactions at the atomic level, thereby facilitating the design of new drugs by high affinity and specificity. The process involves simulating the interaction between molecules to determine the optimal binding configuration, using algorithms that assess the binding energy and stability of the resulting complex.

Keywords: Green Synthesis, Silver Nanoparticles, Material Synthesis, Silver Nitrate, Green Tea Leaf, Characterization Techniques, Molecular Docking.

1. INTRODUCTION

Nanotechnology, a multidisciplinary field that operates at the atomic and molecular levels, is revolutionizing various industries and scientific disciplines. It involves designing, producing, and applying materials and devices with dimensions typically ranging from 1 to 100 nanometres. This technology uses the special physical, chemical, and biological properties that appear at the nanoscale to create new advances in medicine, electronics, energy, and environmental science [1-10]. For example, in medicine, nanotechnology has enabled the development of targeted drug delivery systems, which improve treatment efficacy and reduce side effects. In electronics, it has contributed to the creation of smaller, more efficient devices. The potential applications of nanotechnology are vast, offering opportunities to enhance material performance, energy efficiency, and environmental sustainability. As research progresses, the integration of nanotechnology into everyday products and industrial processes is expected to increase, underscoring its transformative impact on society [11-15].

At the nanoscale, typically defined as between 1 and 100 nanometers, materials often exhibit unique properties that differ significantly from their bulk counterparts. These properties can include altered electrical conductivity, chemical reactivity, strength, and optical characteristics. Nanoparticles, which are particles within this size range, possess a high surface area to volume ratio, giving them distinct physical and chemical properties [16-24].

The green synthesis of metallic nanoparticles has emerged as a promising research area in recent years. This approach has gained prominence due to its simplicity, cost-effectiveness, reduced time consumption, non-toxic by-products, environmental friendliness, and scalability for large-scale production. Unlike chemical synthesis methods, which may leave toxic chemical residues on the nanoparticle surfaces, green synthesis is considered a more reliable and economical route. This review aims to highlight the advantages of using various biomolecules as sustainable,

Citation: Durga M, Shilpa P, Priyadharshini I, Dhanalakshmi S (2024). Green Synthesis of Silver (Ag) Nanoparticles with Green Tea Leaf, Its Characterization, and Molecular Docking Analysis against Diabetes. *Saudi J Biomed Res*, *9*(6): 107-117.

eco-friendly components for synthesizing metal and metal oxide nanoparticles [24-35].

Green tea leaves, derived from the Camellia sinensis plant, are renowned for their health benefits, delicate flavour, and cultural importance. Unlike black tea, green tea leaves are not fermented, preserving their natural antioxidants and nutrients. Processing methods such as steaming or pan-firing produce different styles of green tea, including Sencha, Matcha, and Gyokuro, each with distinct flavour profiles. Green tea is rich in catechins, particularly epigallocatechin gallate (EGCG), which is believed to contribute to its antioxidant and potential health-promoting properties. Some reported benefits of green tea include improved brain function, fat loss, and a reduced risk of certain diseases [36-43].

1.1 AIM

To evaluate the characterization of silver nanoparticles (Ag NPs) synthesized using green tea leaf extract through a green synthesis method. This approach is chosen for its cost-effectiveness, non-toxicity, biocompatibility, and environmental safety. Additionally, the synthesized Ag NPs have potential applications across various industries and fields.

1.2 Objective

The utilize of nanoparticles in pharmaceutical, known as nanomedicine, plays a significant part in diagnosing and treating illnesses. Among different metallic nanoparticles, silver nanoparticles (Ag NPs) are especially prevalent due to their assorted physical, chemical, and organic properties, which incorporate antiviral, antifungal, anti-inflammatory, and anticancer exercises. In this consider, Ag NPs were synthesized employing a nontoxic and eco-friendly strategy. Green tea (GT) leaf extricates served as a decreasing operator, changing over silver particles into free Ag NPs. Based on these discoveries, Ag NPs inferred from GT leaf extricates can be suggested as an antimicrobial operator for treating unremitting diseases. To think about the characterization of silver nanoparticles.

i. Scanning Electron Microscope (SEM)
ii. Raman Spectroscopy
iii. UV Spectroscopy
iv. Particle Size Analyzer (PSA)

2. METHODOLOGY AND MATERIALS USED

2.1.1 Extraction Procedure for Plant Extracts:

Dried, Green Tea (GT) leaves (1 g) obtained in the form of leaves. Purchased from a store.

2.2.2 GT Extraction

Add 30 ml of water to 1 g dried ground GT leaves. Heat the mixture for 30 minutes at 50°C under magnetic stirring. Cool the mixture and filter it.

2.1 Green Synthesis of Ag NPs

2.2.1 Procedure

Preparation of AgNO3 Solution: Dissolve 0.17g AgNO3 in 10ml deionized water to form a 0.1M concentration.

Add GT Extract: Mix 0.2g of 20% aqueous GT extract solution into the silver nitrate solution.

Add NaOH Solution:

Dissolve 0.4g NaOH in 10ml deionized water to form a 0.1M concentration. Add this solution dropwise to the mixture of GT extract and silver nitrate.

Heating: Heat the resulting solution for 30 minutes at 50°C to increase the yield of Ag NPs.

Precipitation Process: A dark brown or black coloured precipitate is obtained.

Separation: Separate the GT Ag NPs by centrifugation (6000 rpm) and wash with 50% acetone/ethanol.

Drying: Dry the washed precipitate at 80°C and at pressure 47.4 kPa for 16 hours in a vacuum oven.

Final Product: Ag Nano Particle is obtained [44-58].

The total prepares of green synthesis of Ag NPs by utilizing the dried leaf extricate of green tea leaf was found to be effective. The method is summarized in a stream chart (Figure 1).

3. MOLECULAR DOCKING

Molecular docking is a computational strategy utilized to anticipate the interaction between a small molecule (ligand) and a macromolecule, typically a protein or nucleic acid. This method plays a crucial role in drug discovery and development, as it helps in understanding how a drug binds to its target, the strength and specificity of this interaction, and potential biological effects [100].

The process of molecular docking involves the prediction of the most favorable binding position and orientation of a ligand within the binding site of the target macromolecule. The main goal is to achieve the best fit, considering both the geometric and energetic compatibility between the ligand and the receptor [101].

Insulin is a key hormone involved in the regulation of glucose homeostasis, and its interaction with various ligands can influence its function and stability [102]. The use of silver, a metal with notable antimicrobial properties, in combination with maltose, a disaccharide, as a ligand offers potential therapeutic applications, including enhanced stability or bioavailability of insulin [103].

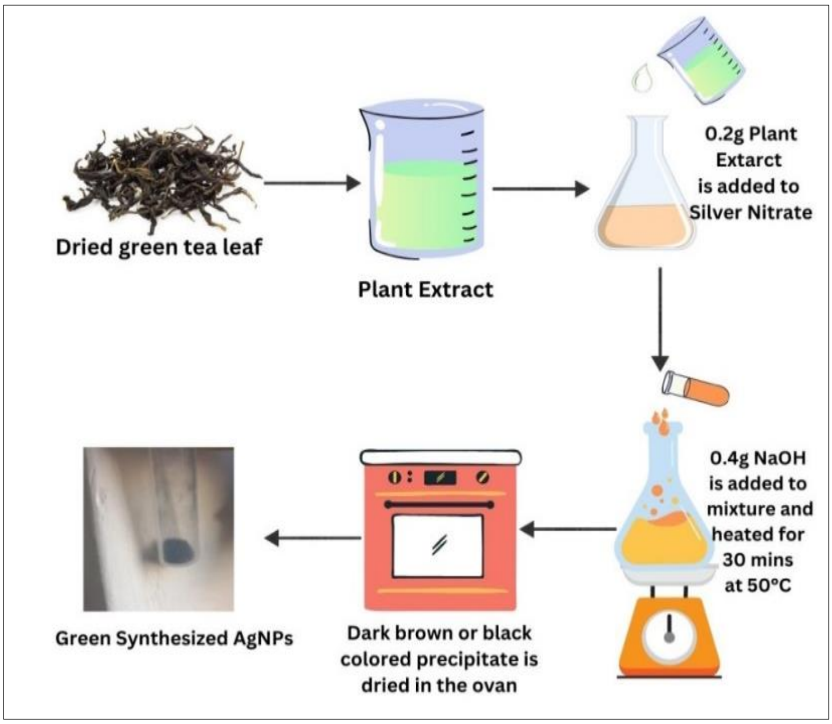


Figure 1: Summary of Green Synthesis of Ag NPs with Green tea leaf

3.1 Molecular Docking Process

3.1.1 Protein and Ligand Preparation

Protein Preparation:

Obtain the three-dimensional structure of insulin from the Protein Data Bank (PDB I'D: - 2OMI). Prepare the protein by removing water molecules, adding hydrogen atoms, and optimizing the conformation.

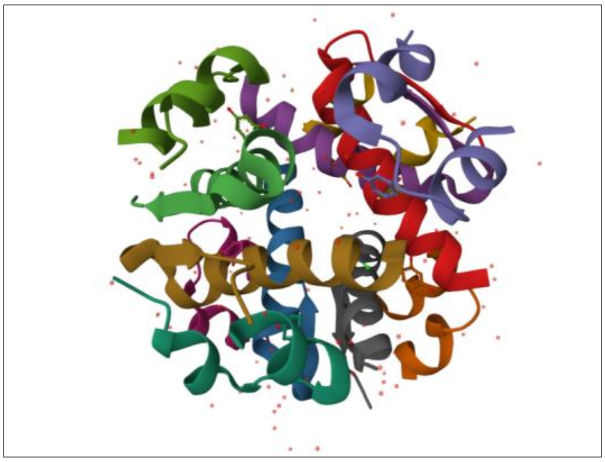


Figure 2: 3D Structure of protein (Insulin)

Ligand Preparation:

Construct the ligand, silver with maltose, ensuring accurate coordination of silver ions. Optimize the ligand's geometry, paying special attention to silver's unique electronic properties.

Silver-Maltose Ligand:

Silver-maltose complexes are of interest in various fields, including nanotechnology, biomedicine, and material science, due to their potential antimicrobial and catalytic properties. In silicon studies involve using computational methods to predict and analyse the interactions, structure, and properties of such complexes.

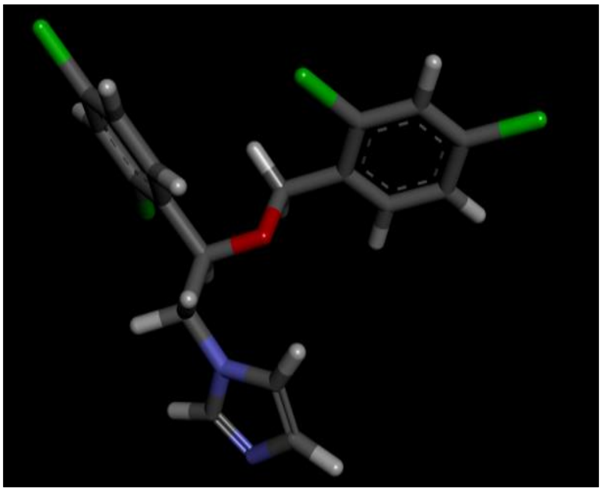


Figure 3: 3D Structure of Ligand

3.1.2 Docking Simulation

Software and Algorithms:

Use docking software like Auto Dock.These programs predict binding affinity and ligand orientation using scoring functions.

Scoring Functions:

Evaluate binding affinity based on interactions like hydrogen bonding, hydrophobic interactions, van der Waals forces, and electrostatic interactions. Special focus on the silver ion's role in these interactions.

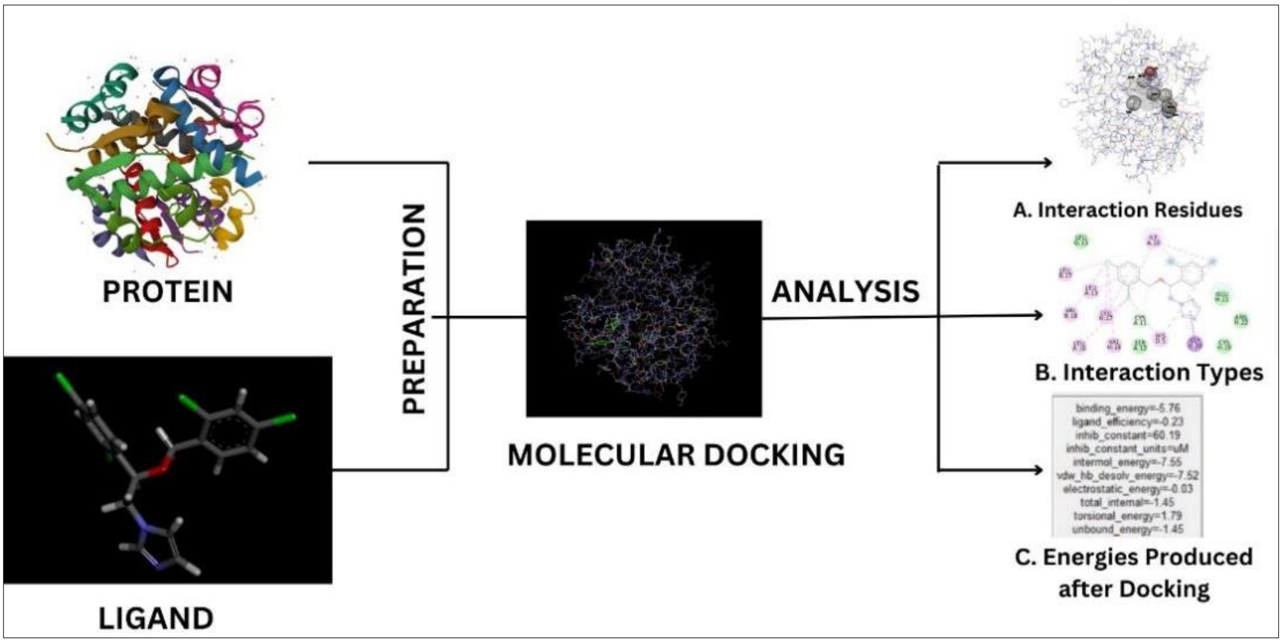
3.1.3 Analysis of Docking Results

Binding Affinity and Pose:

Report binding affinity as a docking score or binding energy. Analyse the ligand's orientation (pose) in the binding pocket to understand potential interactions. The best pose has the lowest binding energy and maximizes favourable interactions.

Interaction Mapping:

Identify key residues in the binding site interacting with the ligand. Include coordination bonds with the silver ion and hydrogen bonds with maltose, among other stabilizing interactions.



```
binding_energy=-5.76
ligand_efficiency=-0.23
inhib_constant=60.19
inhib_constant_units=uM
intermol_energy=-7.55
vdw_hb_desolv_energy=-7.52
electrostatic_energy=-0.03
total_internal=-1.45
torsional_energy=1.79
unbound_energy=-1.45
```

Figure 4: Summary of Molecular Docking

3.1.4 Silver-Maltose against Insulin

In silicon studies of silver-maltose complexes against insulin typically involve understanding the interactions between these complexes and the insulin molecule. The goal could be to explore potential applications such as drug delivery, enhancement of insulin stability, or even therapeutic interventions.

Molecular Docking:

This technique helps predict the binding sites and affinity of the silver-maltose complex on the insulin molecule. It can identify potential interaction sites and the nature of these interactions (e.g., hydrogen bonding, Vander Waals forces).

Molecular Dynamics Simulations:

These simulations provide insights into the stability of the silver-maltose complex when bound to insulin and any conformational changes in the insulin molecule. This can reveal how the complex might affect the structure and function of insulin.

Quantum Chemical Calculations:

These calculations can elucidate the electronic properties of the silver-maltose-insulin interaction, such as charge distribution and binding energies, which are crucial for understanding the strength and nature of the interaction.

Such insilico studies are crucial for predicting the feasibility and safety of using silver-maltose complexes in clinical settings, particularly in managing insulin-related conditions like diabetes. They provide a foundational understanding that can guide experimental studies and potential drug development [59-75].

4. RESULTS AND DISCUSSION

4.1 Characterization

The Characterization of Silver Nano particle is carried out Scanning Electron

Microscope (SEM), Raman Spectroscopy, UV Spectroscopy, Particle Size Analyzer (PSA) and Molecular Docking Analysis.

4.1.1. Sem Images

Green tea (GT) Ag NPs were observed in SEM images to contain particles of different sizes below 80 nm, with the majority of the particles falling between 58 and 74 nm and mostly distributed as aggregates. Because of the extract's capping agents, which stabilized the aggregates, the nanoparticles inside were probably not in direct contact with one another. It is well known that these phytochemicals actively stabilize and decrease metal nanoparticles [76-80].

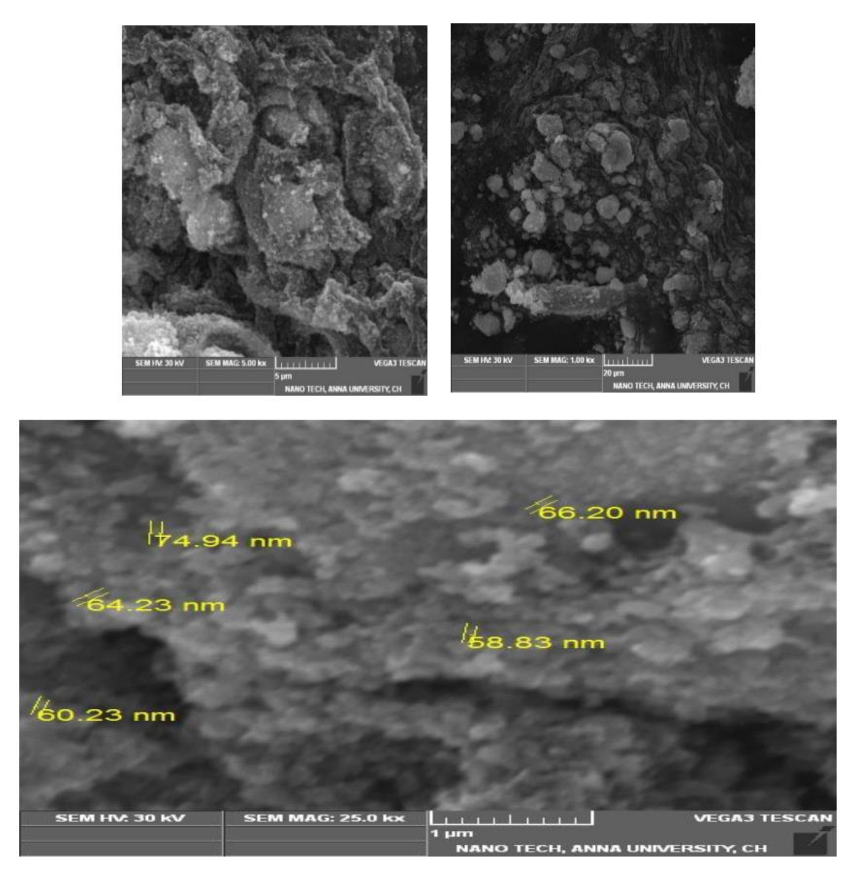
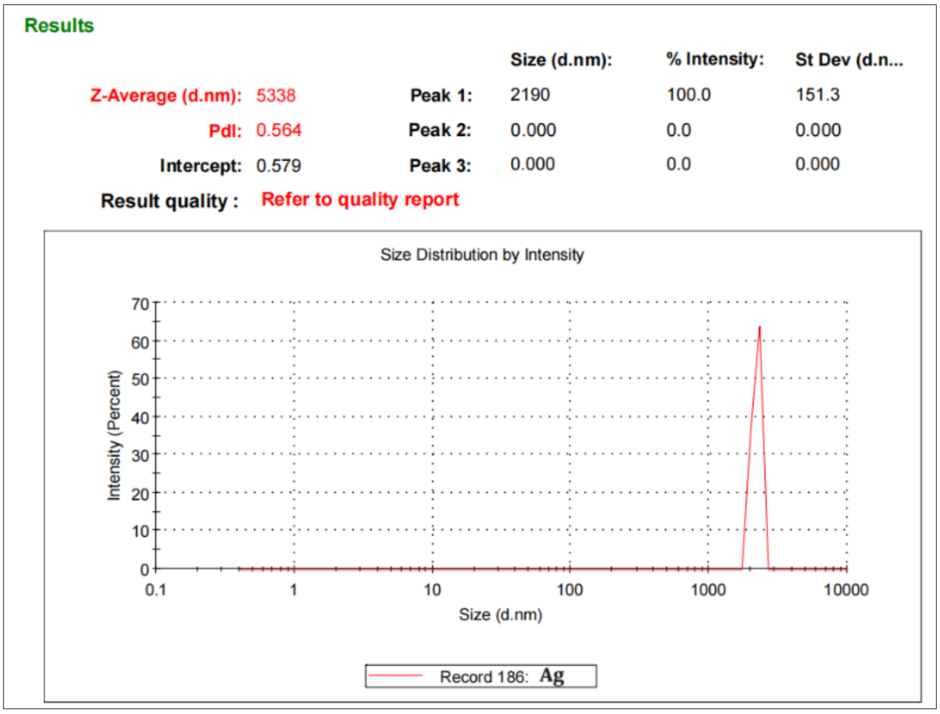


Figure 5: SEM image with nanometer particles

4.1.2 Particle Size Analyzer (PSA)

The average particle size of the silver nanoparticles made with green tea leaf extract is 2190 nm, according to the particle size analyzer image [81-83].



Results

			Size (d.nm):	% Intensity:	St Dev (d.n...
Z-Average (d.nm):	5338	Peak 1:	2190	100.0	151.3
PdI:	0.564	Peak 2:	0.000	0.0	0.000
Intercept:	0.579	Peak 3:	0.000	0.0	0.000

Result quality : Refer to quality report

Figure 6: Graph for particale size analyzer

4.1.3 Raman Spectroscopy

The Ag NPs exhibit strong Raman enhancement, attributed to their rough surface. The results indicate that the density of Ag NPs significantly affects the Raman enhancement, with the optimal concentration of sodium citrate being 0.2% [84-90].

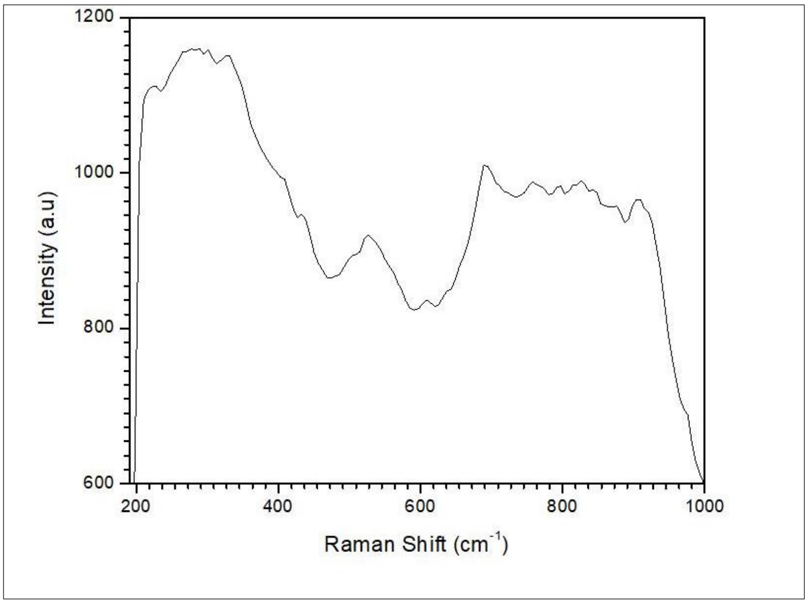


Figure 7: Graph for Raman spectroscopy

4.1.4 UV Spectroscopy

A popular instrument for confirming the formation of silver nanoparticles (Ag NPs) in a colloidal solution via the phenomena of surface plasmon resonance in metallic nanoparticles is the UV-vis spectrometer. The size, shape, concentration, and aggregation state of the nanoparticles all affect this optical quality. The GT Ag NP solution's UV-vis scan showed a clear Gaussian-shaped peak at 410 nm. Grand claims that the activation of surface plasmon vibrations is responsible for the characteristic 400–450 nm absorption band that corresponds to Ag NPs [91-99].

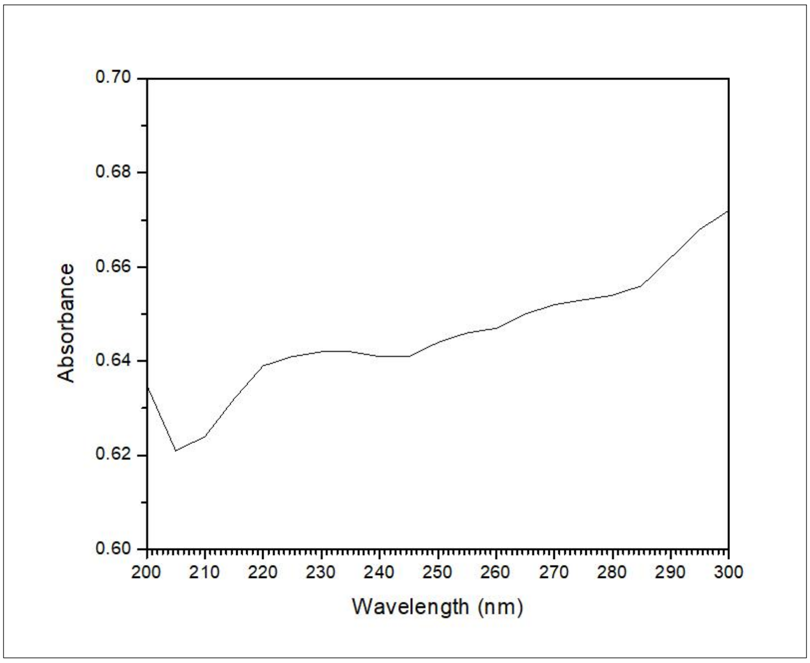


Figure 8: Graph for UV spectroscopy

4.2 Antidiabetic Activity by In Silico Analysis

4.2.1 Molecular Docking Analysis

The results from molecular docking can provide valuable information on how the silver-maltose ligand affects insulin. For instance, if the ligand stabilizes insulin or enhances its bioavailability, it could have significant therapeutic implications. Additionally, understanding the specific interactions can guide the design of more effective insulin formulations or delivery systems [104].

The molecular docking study, conducted using Auto Dock 4.2, explored the biological interaction between the silver-maltose ligand and protein insulin. The results, illustrated in Figure 7, indicate that silver-maltose ligand bind to insulin, with the ligand showing a binding energy of less than -5.76 kcal/mol. This negative binding energy suggests a favourable interaction with the protein's binding residues, as detailed in Table 1. The docking process generated 100 poses, all of which localized to a single binding site on the insulin, indicating a high affinity of the silver atoms for these sites. According to Hevener *et al.*, a Root Mean Square Deviation (RMSD) of less than 2.0 Å is required for a docking pose to be considered valid [105]. The re-docking results confirmed the reliability of the poses, with RMSD values under 1.0 Å. Interaction analysis revealed that the silver-maltose ligand can effectively interact with the GLY20 and CYS19 residues of insulin [106].

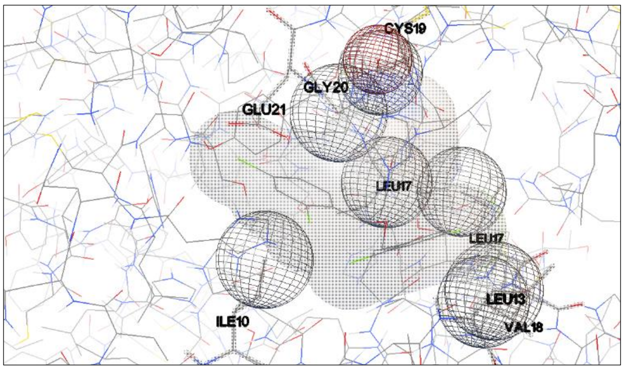


Figure 9: Interactions between silver atoms and the amino acid residues (Insulin)

Table 1: Molecular docking analysis of silver-maltose molecules

Macromolecule	Binding energy (cal/mol)	Inhibition constant ki (mM)	Metal chelating residues	Distance (Å)
Insulin	-5.76	60.19	Ag—GLY20 Ag—CYS19	2.62 2.54

The results of this study showed that the silver-maltose ligand interact with the glycine and Cysteine residue of insulin. The search algorithm evaluates and generates ligand poses at the target's binding sites by analysing several factors: final intermolecular energy, Van der Waals interaction energy, hydrogen bond energy, solvation energy, electrostatic energy, and the ligand's roto-translational and internal degrees of freedom. Given that the silver-maltose ligand has torsional energy can be disregarded. Although the binding energies for a single silver atom may appear low compared to organic ligands, so, silver-maltose ligand is drawn and interaction has been formed with protein (insulin) [107].

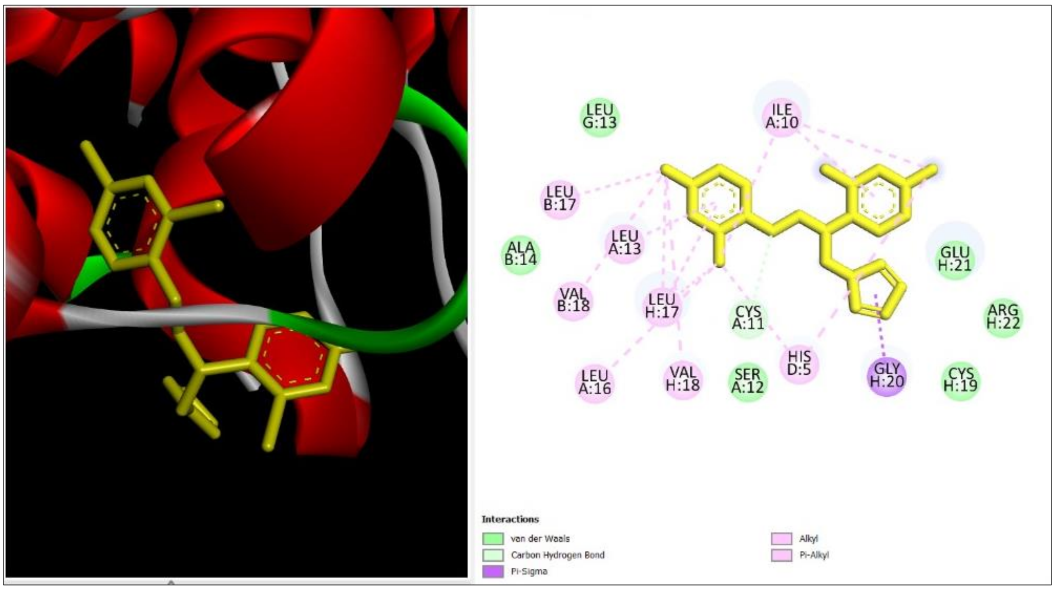


Figure 10: 2D and 3D structure of ligand and protein interaction

4 CONCLUSION

The synthesized silver nanoparticles were characterized using UV-vis spectroscopy, particle size analysis (PSA), Raman spectroscopy, and scanning electron microscopy (SEM). The morphology of the green tea (GT) Ag NPs appeared irregular and aggregated. Differences in the UV spectra between the GT extract and the GT Ag NPs indicated the functional groups involved in reducing Ag+ ions into nanoparticles. The silver nanoparticles were synthesized from silver nitrate and green tea leaves using a green synthesis method.

Green synthesis of Ag NPs is a more environmentally friendly, cost-effective, and efficient approach. The characterization of the nanoparticles and composites was performed using PSA, SEM, Raman spectroscopy, and UV-vis spectroscopy.

SEM images revealed that the silver nanoparticles were in the form of aggregates, with sizes in the nanometre range.

PSA confirmed the presence of silver in the particle size distribution.

UV-vis spectroscopy confirmed that the nanoparticles absorb light, indicating the presence of chemical substances.

Raman spectroscopy provided information on the chemical composition.

Molecular docking studies involving insulin and a ligand composed of silver and maltose revealed insights into the binding characteristics of the ligand, suggesting potential therapeutic applications. Future research could include molecular dynamics simulations to validate and refine these docking results, as well as in vitro experiments to confirm the computational predictions.

Based on the results, we conclude that the synthesized Ag NPs have potential applications across multiple disciplines.

REFERENCES

1. Drexler, K. E. (1986). Engines of Creation: The Coming Era of Nanotechnology. Doubleday. ISBN 978-0-385-19973-5.
2. Drexler, K. E. (1992). Nano systems: Molecular Machinery, Manufacturing, and Computation. New York: John Wiley & Sons. ISBN 978-0-471-57547-4.
3. Hübler, A. W., & Osuagwu, O. (2010). Digital quantum batteries: Energy and information storage in nanovacuum tube arrays. *Complexity*, *15*(5), 48-55.
4. Shinn, E., Hübler, A., Lyon, D., Perdekamp, M. G., Bezryadin, A., & Belkin, A. (2013). Nuclear energy conversion with stacks of graphene nanocapacitors. *Complexity*, *18*(3), 24-27.
5. Elishakoff, I., Pentaras, D., Dujat, K., Versaci, C., Muscolino, G., Storch, J., Bucas, S., Challamel, N., Natsuki, T., Zhang, Y.Y., Wang, C. M., & Ghyselinck, G. (2012). Carbon Nanotubes and Nano Sensors: Vibrations, Buckling, and Ballistic Impact, ISTE-Wiley, London, XIII+pp.421; ISBN 978-1-84821-345-6.
6. Lyon, D., & Hubler, A. (2013). Gap size dependence of the dielectric strength in nano vacuum gaps. *IEEE Transactions on Dielectrics and Electrical Insulation*, *20*(4), 1467-1471.
7. Saini, R., Saini, S., & Sharma, S. (2010). Nanotechnology: the future medicine. *Journal of cutaneous and aesthetic surgery*, *3*(1), 32-33.
8. Buzea, C., Pacheco, I. I., & Robbie, K. (2007). Nanomaterials and nanoparticles: sources and toxicity. *Biointerphases*, *2*(4), MR17-MR71.
9. Vert, M., Doi, Y., Hellwich, K. H., Hess, M., Hodge, P., Kubisa, P., ... & Schué, F. (2012). Terminology for biorelated polymers and applications (IUPAC Recommendations 2012). *Pure and Applied Chemistry*, *84*(2), 377-410.
10. Vert, M., Doi, Y., Hellwich, K. H., Hess, M., Hodge, P., Kubisa, P., ... & Schué, F. (2012). Terminology for biorelated polymers and applications (IUPAC Recommendations 2012). *Pure and Applied Chemistry*, *84*(2), 377-410.
11. Torres-Torres, C., López-Suárez, A., Can-Uc, B., Rangel-Rojo, R., Tamayo-Rivera, L., & Oliver, A. (2015). Collective optical Kerr effect exhibited by an integrated configuration of silicon quantum dots and gold nanoparticles embedded in ion-implanted silica. *Nanotechnology*, *26*(29), 295701.
12. Hornyak, G. L. (2009). *Fundamentals of Nanotechnology*. Boca Raton, Florida: Taylor & Francis Group.
13. Sadri, R., Hosseini, M., Kazi, S. N., Bagheri, S., Abdelrazek, A. H., Ahmadi, G., ... & Abidin, N. I. Z. (2018). A facile, bio-based, novel approach for synthesis of covalently functionalized graphene nanoplatelet nano-coolants toward improved thermo-physical and heat transfer properties. *Journal of colloid and interface science*, *509*, 140-152.
14. Hübler, A. W., & Osuagwu, O. (2010). Digital quantum batteries: Energy and information storage in nanovacuum tube arrays. *Complexity*, *15*(5), 48-55.
15. Portela, C. M., Vidyasagar, A., Krödel, S., Weissenbach, T., Yee, D. W., Greer, J. R., & Kochmann, D. M. (2020). Extreme mechanical resilience of self-assembled nanolabyrinthine materials. *Proceedings of the National Academy of Sciences*, *117*(11), 5686-5693.
16. Eldridge, T. (8 January 2014). "Achieving industry integration with nanomaterials through financial markets". Nanotechnology_Now.
17. McGovern, C. (2010). "Commoditization of nanomaterials". Nanotechnol. *Perceptions*, *6*(3), 155–178.

18. AZO Nano Classification of Nanomaterials, the Four Main Types of Intentionally Produced Nanomaterials
19. Journal of Pharmacy & BioAllied Sciences - Iron Oxide Nanoparticles
20. Phys.org Carbon Nanotubes find real world applications
21. Dai, H. (2002). Carbon nanotubes: synthesis, integration, and properties. *Accounts of chemical research*, *35*(12), 1035-1044.
22. Kimling, J., Maier, M., Okenve, B., Kotaidis, V., Ballot, H., & Plech, A. (2006). Turkevich method for gold nanoparticle synthesis revisited. *The Journal of Physical Chemistry B*, *110*(32), 15700-15707.
23. García-Barrasa, J., López-de-Luzuriaga, J. M., & Monge, M. (2011). Silver nanoparticles: synthesis through chemical methods in solution and biomedical applications. *Central European journal of chemistry*, *9*, 7-19.
24. Yang, M., & Xia, J. J. (2013). Preparation and characterization of platinum nanorods using ascorbic acid as the reducing agent. *Advanced Materials Research*, *774*, 577-580.
25. An, K., & Somorjai, G. A. (2012). Size and shape control of metal nanoparticles for reaction selectivity in catalysis. *ChemCatChem*, *4*(10), 1512-1524.
26. Yin, X., Chen, S., & Wu, A. (2010). Green chemistry synthesis of gold nanoparticles using lactic acid as a reducing agent. *Micro & Nano Letters*, *5*(5), 270-273.
27. Sujitha, M. V., & Kannan, S. (2013). Green synthesis of gold nanoparticles using Citrus fruits (Citrus limon, Citrus reticulata and Citrus sinensis) aqueous extract and its characterization. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, *102*, 15-23.
28. Bogireddy, N. K. R., Pal, U., Gomez, L. M., & Agarwal, V. (2018). Size controlled green synthesis of gold nanoparticles using Coffea arabica seed extract and their catalytic performance in 4-nitrophenol reduction. *RSC advances*, *8*(44), 24819-24826.
29. Effects of ultrasound frequency. (2005). *J. Phys. Chem. B*, *109*, 20673–20675.
30. Sahoo, G. P., Basu, S., Samanta, S., & Misra, A. (2015). Microwave-assisted synthesis of anisotropic gold nanocrystals in polymer matrix and their catalytic activities. *Journal of Experimental Nanoscience*, *10*(9), 690-702.
31. Roldán, M. V., Pellegri, N., & de Sanctis, O. (2013). Electrochemical method for Ag-PEG nanoparticles synthesis. *Journal of Nanoparticles*, *2013*(1), 524150.
32. Hoffmann, M. R., Martin, S. T., Choi, W., & Bahnemann, D. W. (1995). Environmental applications of semiconductor photocatalysis. *Chemical reviews*, *95*(1), 69-96.
33. Huang, X., El-Sayed, I. H., Qian, W., & El-Sayed, M. A. (2006). Cancer cell imaging and photothermal therapy in the near-infrared region by using gold nanorods. *Journal of the American Chemical Society*, *128*(6), 2115-2120.
34. Kim, J. S., Kuk, E., Yu, K. N., Kim, J. H., Park, S. J., Lee, H. J., ... & Cho, M. H. (2007). Antimicrobial effects of silver nanoparticles. *Nanomedicine: Nanotechnology, biology and medicine*, *3*(1), 95-101.
35. Laurent, S., Forge, D., Port, M., Roch, A., Robic, C., Vander Elst, L., & Muller, R. N. (2008). Magnetic iron oxide nanoparticles: synthesis, stabilization, vectorization, physicochemical characterizations, and biological applications. *Chemical reviews*, *108*(6), 2064-2110.
36. Livage, J., Henry, M., & Sanchez, C. (1988). Sol-gel chemistry of transition metal oxides. *Progress in solid state chemistry*, *18*(4), 259-341.
37. O'Neal, D. P., Hirsch, L. R., & Halas, N. J. (2016). Photo-thermal tumor ablation in mice using near infrared-absorbing nanoparticles. *Cancer Lett*, *209*, 171–6.
38. Oskam, G. (2006). Metal oxide nanoparticles: synthesis, characterization and application. *Journal of sol-gel science and technology*, *37*, 161-164.
39. Sastry, M., Ahmad, A., Khan, M. I., & Kumar, R. (2003). Biosynthesis of metal nanoparticles using fungi and actinomycete. *Current science*, 162-170.
40. Su, X. Y., Liu, P. D., Wu, H., & Gu, N. (2014). Enhancement of radiosensitization by metal-based nanoparticles in cancer radiation therapy. *Cancer biology & medicine*, *11*(2), 86.
41. Cao, G. (2004). Nanastructures and nanomaterials—synthesis, properties and applications. Singapore: *World Scientific*.
42. Dizaj, S. M., Lotfipour, F., Barzegar-Jalali, M., Zarrintan, M. H., & Adibkia, K. (2014). Antimicrobial activity of the metals and metal oxide nanoparticles. *Materials Science and Engineering: C*, *44*, 278-284.
43. Fair, R. J., & Tor, Y. (2014). Antibiotics and bacterial resistance in the 21st century. *Perspectives in medicinal chemistry*, *6*, PMC-S14459.
44. Jayaraman, R. (2009). Antibiotic resistance: an overview of mechanisms and a paradigm shift. *Current science*, 1475-1484.
45. Pelgrift, R. Y., & Friedman, A. J. (2013). Nanotechnology as a therapeutic tool to combat microbial resistance. *Advanced drug delivery reviews*, *65*(13-14), 1803-1815.
46. Habibi, M. H., & Rezvani, Z. (2015). Photocatalytic degradation of an azo textile dye (CI Reactive Red 195 (3BF)) in aqueous solution over copper cobaltite nanocomposite coated on glass by Doctor Blade method. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, *147*, 173-177.
47. Carmen, Z., & Daniela, S. (2012). *Textile organic dyes-characteristics, polluting effects and separation/elimination procedures from industrial effluents-a critical overview* (Vol. 3, pp. 55-86). Rijeka: IntechOpen.
48. Padhi, B. S. (2012). Pollution due to synthetic dyes toxicity & carcinogenicity studies and

remediation. *International journal of environmental sciences*, *3*(3), 940-955.

49. Dutta, A. K., Maji, S. K., & Adhikary, B. (2014). γ-Fe2O3 nanoparticles: an easily recoverable effective photo-catalyst for the degradation of rose bengal and methylene blue dyes in the waste-water treatment plant. *Materials Research Bulletin*, *49*, 28-34.
50. Gonawala, K. H., & Mehta, M. J. (2014). Removal of color from different dye wastewater by using ferric oxide as an adsorbent. *Int J Eng Res Appl*, *4*(5), 102-109.
51. Jyoti, K., & Singh, A. (2016). Green synthesis of nanostructured silver particles and their catalytic application in dye degradation. *Journal of Genetic Engineering and Biotechnology*, *14*(2), 311-317.
52. Wesenberg, D., Kyriakides, I., & Agathos, S. N. (2003). White-rot fungi and their enzymes for the treatment of industrial dye effluents. *Biotechnology advances*, *22*(1-2), 161-187.
53. Mehta, V. N., Kumar, M. A., & Kailasa, S. K. (2013). Colorimetric detection of copper in water samples using dopamine dithiocarbamate-functionalized Au nanoparticles. *Industrial & Engineering Chemistry Research*, *52*(12), 4414-4420.
54. Que, E. L., Domaille, D. W., & Chang, C. J. (2008). Metals in neurobiology: probing their chemistry and biology with molecular imaging. *Chemical reviews*, *108*(5), 1517-1549.
55. Aragay, G., Pons, J., & Merkoçi, A. (2011). Recent trends in macro-, micro-, and nanomaterial-based tools and strategies for heavy-metal detection. *Chemical reviews*, *111*(5), 3433-3458.
56. Nolan, E. M., & Lippard, S. J. (2008). Tools and tactics for the optical detection of mercuric ion. *Chemical reviews*, *108*(9), 3443-3480.
57. Ray, P. C. (2010). Size and shape dependent second order nonlinear optical properties of nanomaterials and their application in biological and chemical sensing. *Chemical reviews*, *110*(9), 5332-5365.
58. Zhang, M., Liu, Y. Q., & Ye, B. C. (2012). Colorimetric assay for parallel detection of Cd 2+, Ni 2+ and Co 2+ using peptide-modified gold nanoparticles. *Analyst*, *137*(3), 601-607.
59. Annadhasan, M., Muthukumarasamyvel, T., Sankar Babu, V. R., & Rajendiran, N. (2014). Green synthesized silver and gold nanoparticles for colorimetric detection of Hg2+, Pb2+, and Mn2+ in aqueous medium. *ACS Sustainable Chemistry & Engineering*, *2*(4), 887-896.
60. Maiti, S., Barman, G., & Konar Laha, J. (2016). Detection of heavy metals (Cu+ 2, Hg+ 2) by biosynthesized silver nanoparticles. *Applied Nanoscience*, *6*, 529-538.
61. Karthiga, D., & Anthony, S. P. (2013). Selective colorimetric sensing of toxic metal cations by green synthesized silver nanoparticles over a wide pH range. *Rsc Advances*, *3*(37), 16765-16774.
62. Sneha, K., Sathishkumar, M., Mao, J., Kwak, I. S., & Yun, Y. S. (2010). Corynebacterium glutamicum-mediated crystallization of silver ions through sorption and reduction processes. *Chemical Engineering Journal*, *162*(3), 989-996.
63. Kalishwaralal, K., Deepak, V., Ramkumarpandian, S., Nellaiah, H., & Sangiliyandi, G. (2008). Extracellular biosynthesis of silver nanoparticles by the culture supernatant of Bacillus licheniformis. *Materials letters*, *62*(29), 4411-4413.
64. Mittal, A. K., Chisti, Y., & Banerjee, U. C. (2013). Synthesis of metallic nanoparticles using plant extracts. *Biotechnology advances*, *31*(2), 346-356.
65. Dwivedi, A. D., & Gopal, K. (2010). Biosynthesis of silver and gold nanoparticles using Chenopodium album leaf extract. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *369*(1-3), 27-33.
66. Jha, A. K., Prasad, K., Kumar, V., & Prasad, K. (2009). Biosynthesis of silver nanoparticles using Eclipta leaf. *Biotechnology progress*, *25*(5), 1476-1479.
67. Malik, P., Shankar, R., Malik, V., Sharma, N., & Mukherjee, T. K. (2014). Green chemistry based benign routes for nanoparticle synthesis. *Journal of Nanoparticles*, *2014*(1), 302429.
68. Li, X., Xu, H., Chen, Z. S., & Chen, G. (2011). Biosynthesis of nanoparticles by microorganisms and their applications. *Journal of nanomaterials*, *2011*(1), 270974.
69. Mukunthan, K. S., & Balaji, S. (2012). Cashew apple juice (Anacardium occidentale L.) speeds up the synthesis of silver nanoparticles. *International Journal of Green Nanotechnology*, *4*(2), 71-79.
70. Mathew, L., Chandrasekaran, N., & Mukherjee, A. (2010). Biomimetic synthesis of nanoparticles: science, technology & applicability. *Biomimetics learning from nature*.
71. Ahmad, N., Sharma, S., Alam, M. K., Singh, V. N., Shamsi, S. F., Mehta, B. R., & Fatma, A. (2010). Rapid synthesis of silver nanoparticles using dried medicinal plant of basil. *Colloids and Surfaces B: Biointerfaces*, *81*(1), 81-86.
72. Panigrahi, S., Kundu, S., Ghosh, S., Nath, S., & Pal, T. (2004). General method of synthesis for metal nanoparticles. *Journal of nanoparticle Research*, *6*(4), 411-414.
73. Zayed, M. F., Eisa, W. H., & Shabaka, A. A. (2012). Malva parviflora extract assisted green synthesis of silver nanoparticles. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, *98*, 423-428.
74. Gruen, L. C. (1975). Interaction of amino acids with silver (I) ions. *Biochimica et Biophysica Acta (BBA)-Protein Structure*, *386*(1), 270-274.
75. Tan, Y. N., Lee, J. Y., & Wang, D. I. (2010). Uncovering the design rules for peptide synthesis of metal nanoparticles. *Journal of the American Chemical Society*, *132*(16), 5677-5686.
76. Li, S., Shen, Y., Xie, A., Yu, X., Qiu, L., Zhang, L., & Zhang, Q. (2007). Green synthesis of silver nanoparticles using Capsicum annuum L. extract. *Green Chemistry*, *9*(8), 852-858.

77. Huang, J., Li, Q., Sun, D., Lu, Y., Su, Y., Yang, X., ... & Chen, C. (2007). Biosynthesis of silver and gold nanoparticles by novel sundried Cinnamomum camphora leaf. *Nanotechnology*, *18*(10), 105104.
78. Mude, N., Ingle, A., Gade, A., & Rai, M. (2009). Synthesis of silver nanoparticles using callus extract of Carica papaya—a first report. *Journal of Plant Biochemistry and Biotechnology*, *18*, 83-86.
79. Kesharwani, J., Yoon, K. Y., Hwang, J., & Rai, M. (2009). Phytofabrication of silver nanoparticles by leaf extract of Datura metel: hypothetical mechanism involved in synthesis. *Journal of Bionanoscience*, *3*(1), 39-44.
80. Shankar, S. S., Ahmad, A., Pasricha, R., & Sastry, M. (2003). Bioreduction of chloroaurate ions by geranium leaves and its endophytic fungus yields gold nanoparticles of different shapes. *Journal of Materials Chemistry*, *13*(7), 1822-1826.
81. Singh, A. K., Talat, M., Singh, D. P., & Srivastava, O. N. (2010). Biosynthesis of gold and silver nanoparticles by natural precursor clove and their functionalization with amine group. *Journal of Nanoparticle Research*, *12*, 1667-1675.
82. Glusker, J. P., Katz, A. K., & Bock, C. W. (1999). Metal ions in biological systems. *Rigaku J, 16*, 8–17.
83. Si, S., & Mandal, T. K. (2007). Tryptophan‐based peptides to synthesize gold and silver nanoparticles: a mechanistic and kinetic study. *Chemistry–A European Journal*, *13*(11), 3160-3168.
84. Shah, M., Fawcett, D., Sharma, S., Tripathy, S. K., & Poinern, G. E. J. (2015). Green synthesis of metallic nanoparticles via biological entities. *Materials*, *8*(11), 7278-7308.
85. Khan, N., & Mukhtar, H. (2013). Tea and health: studies in humans. *Current pharmaceutical design*, *19*(34), 6141-6147.
86. Dattner, C., & Boussabba, S. (2003). Emmanuelle Javelle (ed.). The Book of Green Tea. Universe Books. p. 13. ISBN 978-0-7893-0853-5.
87. Briggs, H. (2 May 2017). "Secrets of tea plant revealed by science". BBC News. Retrieved 2 May 2017.
88. "The world's first Scottish tea (at £10 a cup)", The Independent, 17 November 2014.
89. Jump up to:a b The International Camellia Society (ICS), DE: Uniklinik Sårland, archived from the original on 21 August 2006
90. Ming, T. L. (1992). "A revision of Camellia sect. Thea". *Acta Botanica Yunnanica (in Chinese), 14*(2), 115–32.
91. Jump up to: a b "Black tea". MedlinePlus, US National Library of Medicine. 30 November 2017. Retrieved 27 February 2018.
92. "Green tea". National Center for Complementary and Integrative Health, US National Institutes of Health. 30 November 2016. Retrieved 27 February 2018.
93. Li, X., Shen, J., Du, A., Zhang, Z., Gao, G., Yang, H., & Wu, J. (2012). Facile synthesis of silver nanoparticles with high concentration via a CTAB-induced silver mirror reaction. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *400*, 73-79.
94. Laghrib, F., Farahi, A., Bakasse, M., Lahrich, S., & El Mhammedi, M. A. (2019). Chemical synthesis of nanosilver on chitosan and electroanalysis activity against the p-nitroaniline reduction. *Journal of Electroanalytical Chemistry*, *845*, 111-118.
95. Morris, G. M., & Lim-Wilby, M. (2008). Molecular docking. *Molecular modeling of proteins*, 365-382.
96. Trott, O., & Olson, A. J. (2010). AutoDock Vina: improving the speed and accuracy of docking with a new scoring function, efficient optimization, and multithreading. *Journal of computational chemistry*, *31*(2), 455-461.
97. Kumar, A. (2020). Silver-based antimicrobials: a new class of promising agents. *Antimicrobial Agents and Chemotherapy*, *64*(8), e02300-19.
98. Holt, R. I. G., Simpson, H. L., & Sönksen, P. H. (2003). The role of the growth hormone–insulin‐like growth factor axis in glucose homeostasis. *Diabetic medicine*, *20*(1), 3-15.
99. Hevener, K. E., Zhao, W., Ball, D. M., Babaoglu, K., Qi, J., White, S. W., & Lee, R. E. (2009). Validation of molecular docking programs for virtual screening against dihydropteroate synthase. *Journal of chemical information and modeling*, *49*(2), 444-460.
100. Hussain, A. (2019). Biosynthesized silver nanoparticle (AgNP) from pandanusodorifer leaf extract exhibits anti-metastasis and anti-biofilm potentials. Front. *Microbiol*, *10*, 8.
101. Buglak, A. A., Ramazanov, R. R., & Kononov, A. I. (2019). Silver cluster–amino acid interactions: a quantum-chemical study. *Amino Acids*, *51*(5), 855-864.
102. Mojab, F., Kamalinejad, M., Ghaderi, N., & Vahidipour, H. R. (2003). Phytochemical screening of some species of iranian plants. *Iran. J. Pharm. Sci*, *2*, 77–82.
103. Mostaghasi, E., Zarepour, A., & Zarrabi, A. (2018). Folic acid armed Fe3O4-HPG nanoparticles as a safe nano vehicle for biomedical theranostics. *Journal of the Taiwan Institute of Chemical Engineers*, *82*, 33-41.
104. Ali, H., Houghton, P. J., & Soumyanath, A. (2006). α-Amylase inhibitory activity of some Malaysian plants used to treat diabetes; with particular reference to Phyllanthus amarus. *Journal of ethnopharmacology*, *107*(3), 449-455.
105. Shinde, J., Taldone, T., Barletta, M., Kunaparaju, N., Hu, B., Kumar, S., ... & Zito, S. W. (2008). α-Glucosidase inhibitory activity of Syzygium cumini (Linn.) Skeels seed kernel in vitro and in Goto–Kakizaki (GK) rats. *Carbohydrate research*, *343*(7), 1278-1281.