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Plant extract mediated synthesis of gold nanoparticles and its application to treatment of cancer

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Abstract

Plant extract-mediated synthesis of gold nanoparticles is a promising research area with potential applications in various fields including medicine-cancer research, catalysis, and nanoelectronics. Gold nanoparticles have gained serious attention in recent years as a potential cancer treatment due to their unique optical and physical properties. Plant-mediated synthesis of gold nanoparticles is a promising method to produce biocompatible and non-toxic gold nanoparticles (Au-NPs). This study focuses on the current research on the plant-mediated synthesis of gold nanoparticles and their potential treatment for cancer. It also discussed the latest advancement in nanobot technology. The study will also describe the type of plants used for the synthesis of gold nanoparticles, the mechanisms involved in the synthesis, the advantages of using plant-mediated synthesis, and the disadvantages. Additionally, this study will discuss the efficacy of gold nanoparticles as cancer therapeutics and the instrumentation involved in characterizing the gold nanoparticles (Au-NPs), the opportunities for the use of gold nanoparticles (Au-NPs) in cancer treatment and future possible research in the use of nanotechnology in the fight against cancer. Overall, plant-mediated synthesis of gold nanoparticles holds promise as a safe and effective method for cancer treatment.

Keywords: Nanotechnology; Gold green synthesis; Nanobot; Cancer cells

1. Background

This study is about synthesizing of gold nanoparticles (AuNPs) from plant extract or plant materials and applying the synthesized AuNPs for the treatment of cancer in which the cancer cell will engulf it, thereby causing a bubble when light of low emission frequency is reflected on it, therefore the cancel cells will explode. The synthesized Au nanomaterials will be injected into a cancer of a laboratory animals. Since cancer cells clean their surfaces by adsorbing in anything around them. Cure and Nordenstrom (1991) found out that cancer cells have a great concentration of negatively charged glycoproteins on their surface, which is acting as an electrical shield, then the AuNPs will be absorbed

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in by the cancer cells by engulfing it. To understand and characterize the AuNP, the use of specific analytical instrumentals will also be employed.

1.1. Gold Nanoparticle synthesis from plant materials

So many other research has been done on green synthesis of gold from plant extract, but just to name a few such as in Can (2020), Lee (2016), Ahmed and Ikram (2015), Chandran et *al.,* (2006) particularly from Aloe vera leaf extract, Begum et *al.,* (2009) from Black tea extract, Wu and Chen (2007) from Rice vine, Malhotra et *al.,* (2014) from Rice bran extract, Narayanan and Sakthivel (2008) from Coriandrum sativum leaf extract and many others.

1.2. Other related works done on treatment of cancer with Au-NPs

There have been significant works on the use of AuNPs in cancer treatment such as the one conducted by Brown et *al.* (2010) in the use of AuNPs in a platinum based anticancer drugs, by tethering the active component of an anticancer drug which is Oxaliplatin to a AuNPs to improve the drug delivery. Gold on its own has also been used for treatment of cancers in the form of photothermal agents, contrast agents and radiosensitizers (Jain et *al.,* 2012). To gain a deeper understanding of plant extract-mediated synthesis of gold nanoparticles, it is valuable to incorporate insights from the synthesis and applications of ZnO nanomaterials, particularly for antimicrobial and UV protection in healthcare. By comparing the synthesis methods, biocompatibility, and medical uses of Au-NPs and ZnO nanomaterials, we can uncover synergies and unique properties that may advance research in both fields. Additionally, analyzing the characterization techniques and recent technological advancements for both types of nanomaterials will offer comprehensive insights into future research directions and potential integrated healthcare applications (Irede et al., 2024).

1.3. Importance, Applications and Fundamentals

Cancer research is really making progress all over, but a suitable green solution is needed to make the treatment safer, better and affordable for all. Though gold is not really cheap, but more and better improvement will make it available from synthesized plant materials for cancer treatment. Overall, the synthesis of gold nanoparticles using plant extracts offers a cost-effective, environmentally friendly, and sustainable alternative to traditional chemical methods. With further research and optimization, it has the potential to revolutionize the field of nanotechnology and make it available for medicine.

2. Applications

2.1. Localized heating

Wagner *et al.,* (2010), studied 25–30 cells for each sample and the coupling of Nanoparticles containing media (NP-C225) conjugates to cellular membrane and their internalization, verified with SEM. They discovered that the cancer cells engulfed the gold nanoparticles to clean their surface. The engulfed nanoparticles can act as Trojan horses or destructive weapons to the cancer cells. The rupturing of the Au NPs when laser was used to react with it was explained by) when they report on the formation and growth of nanobubbles around laser-heated gold nanoparticles in water. Using a hydrodynamic free-energy model, they show that the temporal evolution of the nanobubble radius is asymmetrical, then the expansion is found to be adiabatic, while the collapse is best described by an isothermal evolution. To understand this asymmetry, compared the simulation results to the solution of the Rayleigh-Plesset equation classically used to describe cavitation phenomena as below:

$$m\rho_{\mathrm{liq}}\left(R_b\ddot{R}_b+\frac{3}{2}\dot{R}_b^2\right)=P_i(t)-P_e(t)-2\frac{\gamma}{R_b}-4\eta\frac{\dot{R}_b}{R_b},$$

$$P_i(t)=P_i^{\max}\left(\frac{R_{b,\max}^3-R^3}{R_b^3(t)-R^3}\right)^{\zeta},$$

When the gold atoms are hit with infrared laser light, which can travel through some centimeters of the tissue, the particles heat up, bubbles are created, the bubble explodes, and the cancer cells are ruptured. Unfortunately, the nanoparticle heater strategy has two problems, the first problem is that some gold nanoparticles invariably end up in and around normal cells and therefore, healthy tissue can get damaged when the lasers go after cancers and the second problem is that the lasers that are normally used for heating the particles fire continuous beams of infrared light. It can spread the heat far beyond cancer cells and into the normal tissue. The effect can be debilitating or dangerous.To mitigate these two problems, the Au-NPs is decorated with immune protein antibodies such as Monoclonal antibody (Tami et al, 1986), which can specifically latch onto receptors that sit on the surface of squamous cells. It can concentrate the

particles, creating clusters of dozens of them in and around cancer cells. And instead of firing continuous laser beams, ultrashort infrared pulses be used (Service, 2016).

2.2. The effect of rupturing of the cancer cell walls with gold nanoparticles

2.2.1. Mechanical Rupturing

First is the cancer cell cannot form resistance against mechanical rupturing by the exploding nanoparticles. The ruptured cancer cells can now allow treatment drugs/medications to penetrate them.

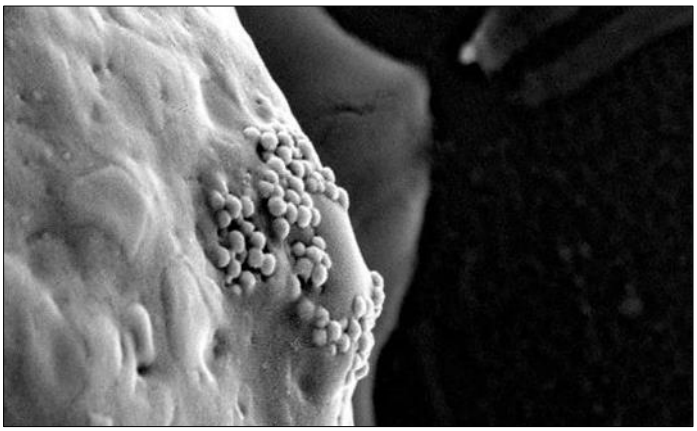

Figure 1 AuNPs on the surface of Cancer cells (reproduced from Wagner et al., 2010)

2.2.2. Reactive oxygen species (ROS) generation

gold nanoparticles can generate ROS, which are highly reactive molecules that can cause oxidative damage to cell membranes and other cellular components. ROS can lead to lipid peroxidation, protein oxidation, and DNA damage, which can ultimately lead to cell death. (Valentina et al., 2020). The generation of ROS by gold nanoparticles is thought to be due to the interaction between the nanoparticles and intracellular components such as mitochondria or lysosomes. Gold nanoparticles can generate free radicals, which can then react with oxygen to form ROS. The generation of ROS can be influenced by the size, shape, surface chemistry, and concentration of the gold nanoparticles, as well as the duration of exposure and the type of cancer cells. The generation of ROS by gold nanoparticles has been shown to be a promising mechanism for cancer therapy. By generating ROS, gold nanoparticles can induce oxidative stress in cancer cells, leading to cell death. This approach has the potential to selectively target cancer cells while sparing healthy cells, which can help to reduce the side effects of traditional chemotherapy. However, further research is needed to optimize the use of gold nanoparticles in generating ROS for cancer therapy, and to better understand the potential toxicity and long-term effects of this approach. (Abdal, 2017)

2.2.3. Disruption of membrane integrity

Gold nanoparticles can interact with the lipid bilayer of cell membranes, disrupting their integrity and causing the release of cellular contents. This can lead to cell death and inflammation. The interaction can cause structural changes in the lipid bilayer, leading to increased permeability and loss of function. This can ultimately cause the release of cellular contents, which can lead to cell death and inflammation. The interaction between gold nanoparticles and the cell membrane can be influenced by several factors such as the size, shape, surface charge, and surface chemistry of the nanoparticles, as well as the type and stage of cancer. Studies have shown that gold nanoparticles can cause the disruption of the cell membrane in various types of cancer cells, including breast cancer, lung cancer, and prostate cancer (Engstrom et al., 2020). The disruption of the membrane integrity by gold nanoparticles has been proposed as a potential mechanism for cancer therapy (Baptista et al., 2018). By disrupting the membrane, gold nanoparticles can induce cell death and inflammation, which can lead to the elimination of cancer cells. However, further research is needed to better understand the underlying mechanisms of this approach and to optimize the use of gold nanoparticles in cancer therapy. Additionally, the potential toxicity and long-term effects of this approach should be carefully evaluated.

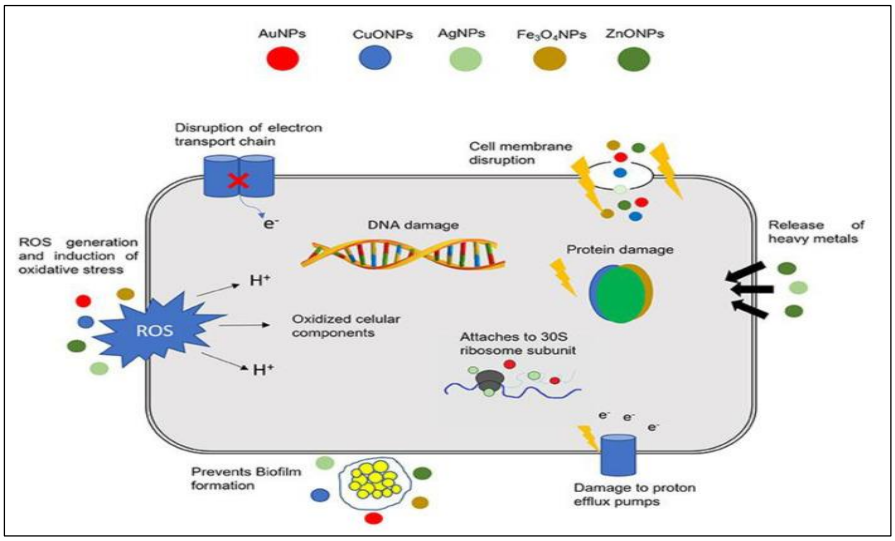

Figure 2 Different mechanisms of action of nanoparticles (NPs) in bacterial cells (reproduced from Baptista et al., 2018)

2.2.4. Mechanical disruption

Gold nanoparticles can also cause mechanical damage to cancer cell walls by inducing mechanical stress or shear forces. This can lead to the deformation or rupture of the cell membrane, which can cause cell death (Kashani and Packirisamy, 2021).

3. NanoBoTs

According to Interesting Engineering (2024), researchers have made significant progress in developing nanorobots that can target and destroy cancer cells while sparing healthy tissue. Here are the key points about this innovative approach:

3.1. Design and Mechanism

- Creation using DNA Origami Techniques: Scientists have utilized DNA origami techniques to design and construct these nanorobots. This method allows for the creation of precise nanoscale structures by folding DNA into specific shapes. These shapes are engineered to achieve specific functions necessary for targeting and treating cancer cells.
- Peptide Arrangement and Function: The nanorobots are embedded with peptides arranged in a hexagonal pattern. These peptides play a crucial role in the activation of cell death receptors, which are proteins on the surface of cancer cells that can trigger programmed cell death (apoptosis). By specifically targeting these receptors, the nanorobots can induce the death of cancer cells.
- Controlled Release Mechanism: The active "weapon" of the nanorobots is concealed within the DNA nanostructure. This design ensures that the lethal agents are only released when the nanorobots reach their target, preventing the indiscriminate killing of healthy cells. The DNA nanostructure acts as a protective casing that responds to specific signals or environmental conditions present in cancerous tissues, ensuring targeted action (Zhan, et al., 2023).

3.2. Targeting Cancer Cells

- Specific Protein Recognition: The nanorobots are meticulously programmed to recognize and bind to specific proteins that are predominantly found on the surfaces of cancer cells. One such protein is nucleolin, which is often overexpressed on the surface of various cancer cells but is present at much lower levels on normal cells. This differential expression allows the nanorobots to distinguish between cancerous and healthy cells, ensuring targeted delivery of their therapeutic payload.
- Activation in Tumor Microenvironment: Tumors often create a distinct microenvironment that differs significantly from that of normal tissues. One key characteristic of this microenvironment is its acidity, with a typical pH of around 6.5, compared to the neutral pH of approximately 7.4 found in healthy tissues. The nanorobots are designed to remain inactive until they encounter this acidic environment. This pH-sensitive activation mechanism ensures that the nanorobots are only triggered in the vicinity of tumors, thereby

preventing premature release of their therapeutic agents and minimizing potential damage to healthy cells (Chen and Xu, 2016).

3.3. Effectiveness

- Reduction in Tumor Growth: In preclinical studies conducted on mice, the nanorobots demonstrated significant effectiveness in combating cancer. The results showed that the nanorobots were able to reduce tumor growth by up to 70%. This substantial decrease highlights the potential of these nanorobots as a powerful therapeutic tool in the treatment of cancer.
- Mechanism of Action - Cutting off Blood Supply: The nanorobots work by targeting the blood vessels that supply nutrients and oxygen to the tumors. By delivering therapeutic agents that specifically attack these blood vessels, the nanorobots effectively cut off the blood supply to the tumors. This process, known as anti-angiogenesis, leads to the starvation of the tumor cells, depriving them of the essential resources they need to grow and survive.
- Rapid Tissue Damage: The impact of the nanorobots on the tumor is both swift and severe. Once the blood supply is disrupted, the tumors begin to experience rapid tissue damage. Within just 24 hours of treatment, significant damage to the tumor tissue can be observed. This rapid onset of action is crucial for quickly reducing the tumor burden and preventing further growth and metastasis (Aggarwal and Kumar, 2022).

3.4. Safety

- No Impact on Healthy Tissues: In the conducted animal studies, the nanorobots were observed to selectively target cancer cells without affecting healthy tissues. This high degree of specificity is crucial for minimizing unintended side effects and ensuring the safety of the treatment. The design of the nanorobots, which includes mechanisms for recognizing specific proteins on cancer cells and activating only in the acidic tumor microenvironment, plays a key role in this selective targeting.
- Rapid Clearance from the Body: One of the significant safety features of the nanorobots is their ability to be quickly cleared from the body. Most of the nanorobots were found to be eliminated within 24 hours after administration. This rapid clearance reduces the risk of potential long-term side effects and toxicity, as the nanorobots do not linger in the body for extended periods. Efficient clearance mechanisms, such as renal filtration and metabolic breakdown, help ensure that the nanorobots do not accumulate in healthy tissues or organs (Kong, et al., 2023).

3.5. Current Status and Future Directions

- Testing in Animal Models: The nanorobot technology has undergone rigorous testing in animal models, including mice and miniature pigs. These studies have shown promising results in terms of both effectiveness and safety. In mice, the nanorobots significantly reduced tumor growth and caused rapid tissue damage to tumors without affecting healthy tissues. In miniature pigs, similar success was observed, further validating the potential of this technology in larger, more complex organisms.
- Need for Advanced Cancer Models: Before proceeding to human trials, researchers must conduct further studies using more advanced and diverse cancer models. These models will help to better simulate the complexity and variability of human cancers, providing a more comprehensive understanding of how nanorobots interact with different types of tumors and the broader physiological environment. This step is crucial to ensure the robustness and reliability of the technology in a clinical setting (Arvidsson and Hansen, 2020).

While this nanorobot technology shows great potential for targeted cancer treatment, it is still in the early stages of development and requires further research before it can be considered for human use. Animal studies, particularly in mice and miniature pigs, have demonstrated promising results. These studies have shown that nanorobots can significantly reduce tumor growth, induce rapid tissue damage to tumors, and clear quickly from the body, all while sparing healthy tissues.

Before advancing to human trials, it is essential to test nanorobots in more advanced and diverse cancer models. These models should better represent the complexity and variability of human cancers to ensure that the nanorobots are effective and safe across different cancer types and stages. Enhancing the specificity and selectivity of nanorobots is critical. Researchers need to continue developing and refining recognition mechanisms that allow nanorobots to accurately identify and bind to a broader range of cancer markers, ensuring they target only cancer cells while leaving healthy tissues unharmed. Additionally, comprehensive evaluations of potential side effects are necessary. This includes

examining both short-term and long-term effects, any possible immune responses, and interactions with non-target tissues. Thorough toxicological studies will help ensure the technology's safety for human use.

Efficient and effective delivery of nanorobots to the tumor site is crucial. Researchers should explore various delivery routes, such as intravenous, intratumoral, or targeted delivery systems, to determine the most effective method. Investigating the potential of combining nanorobot technology with existing cancer treatments, such as chemotherapy, immunotherapy, or radiation therapy, could lead to enhanced therapeutic outcomes. As the technology progresses towards clinical trials, scaling up the production of nanorobots will be necessary. Ensuring consistency, purity, and stability of nanorobots at larger scales is essential for clinical applications. After successful preclinical studies, the next step will be conducting clinical trials in humans to test the safety, efficacy, and optimal dosing of nanorobots in cancer patients. Long-term monitoring of patients who receive nanorobot treatment will be crucial to assess the durability of the therapeutic effects and identify any delayed adverse events, helping refine the technology and treatment protocols based on real-world outcomes (Li, et al. 2017; Arvidsson & Hansen, 2020).

4. Synthesis and Experimentation

Synthesis of gold nanoplates from algal extract: In a typical experiment to synthesize gold nanoplates by using the algal extract, an aqueous solution of $HAuCl_4$ (10 mm, 1 mL) was added to the algal extract (10 mL). The reaction was allowed to proceed under gentle stirring at room temperature for 48 hr (Xie *et al.,* 2007). The algal extract formed was a light-yellow liquid. The color of the algal extract–$HAuCl_4$ aqueous solution mixture changed from yellow to reddish brown after 48hr of ageing. Such a color transition is often indicative of changes in the metal oxidation state. In this case, Au^{III} was reduced to Au^0 by some yet-to-be identified biomolecules in the algal extract (Xie *et al.,* 2007). A possible growth process can be reconstructed from the TEM images and UV/Vis spectra, which includes three distinctive stages: reduction of Au^{III} ions to form gold nuclei, an induction process to form triangular-shaped seeds, and the growth of triangular shaped seeds into triangular nanoplates. The mechanism for forming the triangular-shaped seeds is not clear at present and research are underway to unravel it.

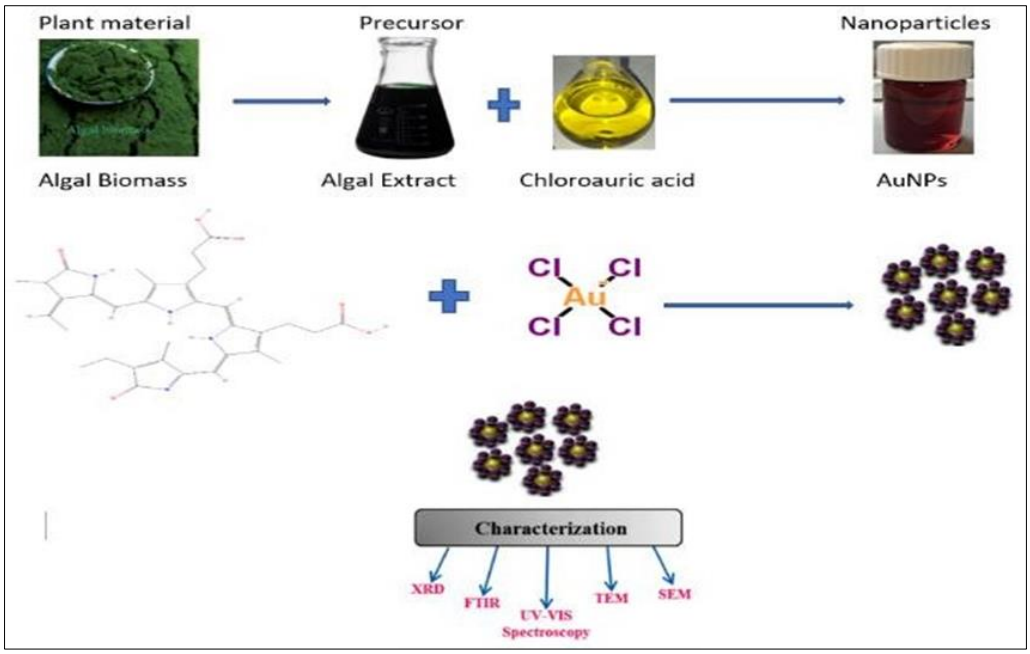

Figure 3 Synthesis of AuNPs from Algal Extract and its Characterization

4.1. To summarize the above procedure

- Plant extract selection: Choose an aqueous peel of plant extract such as G. mangostana or plant alga that have phytochemicals such as phenols, flavonoids and terpenoids. These compounds have been shown to be effective in reducing gold ions to gold nanoparticles.
- Plant extract preparation: The plant materials are thoroughly washed and grinded into fine powder. An extract is prepared by mixing the plant powder with a solvent such as water or ethanol. The extract can be obtained by filtering the mixture and collecting the filtrate.

- Reduction of the gold ions: A solution of gold ion is prepared by dissolving a suitable gold salt such as gold chloride (AuCl) in water. The plant extract with the gold ion solution is mixed and allowed to incubate. The phytochemicals in the extract will act as reducing agents, which will reduce the gold ions to gold nanoparticles (Au-NPs).
- Characterization: The synthesized gold nanoparticles is characterized by using some spectroscopic techniques
- Optimization: The conditions of the synthesis process is optimized by varying the concentration of the plant extract, gold ion concentration, pH, and temperature. This will help to obtain more gold nanoparticles of a desired size and shape.
- Applications: The potential applications of the synthesized gold nanoparticles in various fields' s evaluated such as medicine, catalysis, and nanoelectronics.

5. Instrumentation and Characterization

Transmission electron microscopy (TEM) will help us to describe the particle size and morphology of the gold nanoparticles. Fourier transform infrared spectroscopy (FTIR) and X-ray photoelectron spectroscopy (XPS) measurements will be used for the identification of the biomolecules that bound specifically on the gold surface. Particularly, XPS will be used for understanding the electronic structure, elemental composition, oxidation states, ligand binding (surface- sensitive). FTIR will also be used for understanding the surface composition, ligand binding. Atomic force microscopy (AFM) will be used to understand the planarity of the algal- synthesized gold nanoplates. UV-Vis will be used to understand or characterize the Optical properties, size, concentration, agglomeration state, hints on NP shape. ICP-MS will be used to characterize the elemental composition, size, size distribution and NP concentration. XRD will be used for the characterization of the crystal structure, composition, and crystalline grain size.

Integrating X-ray medical imaging with the study of plant extract-mediated synthesis of gold nanoparticles (Au-NPs) can enhance their application in cancer treatment by providing detailed structural analysis, tracking their distribution in biological systems, and assessing their biocompatibility and toxicity. High-resolution X-ray imaging techniques like CT and X-ray microscopy can analyze the size, shape, and distribution of Au-NPs, and monitor their interaction with cancer cells in vivo. Additionally, X-ray imaging can help investigate the synthesis mechanisms involving plant extracts and evaluate the effectiveness of different imaging techniques for characterizing and optimizing Au-NPs for medical use (Irede et al., 2024).

5.1. Advantages of this approach

In this approach, natural substance such as green plant is used and it will involve the *bio-reduction of a green plant extract by chloroauric acid to produce the gold nanoparticle of interest* and after when it is administered to the patient, a *laser light of low emission radiation will be used to excite the gold nanoparticles in the body to make the AuNPs explode,* thereby bursting or ripping off the cancer cells and killing them. In summary, there are several advantages to using plant extract-mediated synthesis of gold nanoparticles for cancer treatment. Some of the key benefits are explained below:

- Cost-effective: The plant extract-mediated synthesis method is a cost-effective alternative to traditional chemical synthesis methods, which can be expensive and require the use of toxic chemicals.
- Environmentally friendly: This method is environmentally friendly and sustainable, as it uses natural plant extracts as reducing agents instead of toxic chemicals.
- Non-toxic: The gold nanoparticles synthesized using plant extracts are non-toxic and biocompatible, making them safe for use in medical applications such as cancer treatment.
- Selective targeting: The gold nanoparticles synthesized using plant extracts/materials can be functionalized or modified with tumor-targeting ligands or antibodies, which can selectively target cancer cells and spare healthy the cells.
- Enhanced efficacy: The small size of gold nanoparticles and their unique optical and electrical properties make them effective at penetrating tissues and enhancing the efficacy of chemotherapy or radiation therapy.
- Easy synthesis: The synthesis of gold nanoparticles using plant extracts is a simple and straightforward process, which can be easily scaled up for large-scale production.

5.2. Disadvantages of this approach

The use of plant-synthesized gold nanoparticles for cancer treatment shows great promise, There are a few potential disadvantages associated with the use of plant-based synthesis of gold nanoparticles for cancer therapy and limitations

to this approach. It may be challenging to control the size and shape of the nanoparticles produced using this method, which could impact their efficacy in targeting cancer cells. (Ying et al., 2022). The stability and shelf-life of the synthesized nanoparticles may be lower compared to those produced through other methods, which could limit their practical applications (Wang, et al., 2014). The cost and scalability of plant-based synthesis may be a concern, as large quantities of plant material may be required to produce sufficient quantities of nanoparticles for clinical use (Muddapur et al., 2022). There may be regulatory and safety concerns associated with using nanoparticles synthesized from plants, including potential issues related to consistency, purity, and potential side effects on the body. One major limitation is the lack of standardization in the synthesis process, as the properties of the nanoparticles can vary depending on the plant species, growth conditions, and extraction methods used. This can make it difficult to compare results across studies and develop a consistent and reliable method for nanoparticle synthesis. The efficacy of plant-synthesized gold nanoparticles for cancer treatment has not yet been fully established, and more research is needed to determine their safety and effectiveness in vivo. Clinical trials are necessary to evaluate the potential of these nanoparticles as a cancer therapy, but their use in humans is still in the early stages of development.

5.3. Opportunities in the use of gold nano particles synthesized from green plant

So much research has been done and more research is still in progress on the possibilities of using gold synthesized from green plant to cure cancer. If it is successful, we will understand that gold can be synthesized from plant for medicinal uses, administered to a cancer patient, then the cancer cells will adsorb the gold nanoparticles, laser of low emission frequency can be used to excite the administered gold and cause it to explode to rip off and kill the cancel cells. We would also understand that there are several opportunities and research prospects in nano chemistry which are.

- Photothermal therapy: Due to their special optical characteristics, gold nanoparticles can absorb light and turn it into heat. Gold nanoparticles can be utilized in photothermal treatment to target and destroy cancer cells using this feature (Li et al., 2019).
- Radiotherapy: By serving as radiosensitizers, gold nanoparticles can improve the effectiveness of radiation treatment. A lot of low-energy electrons are produced when gold nanoparticles are exposed to radiation; these electrons can harm cancer cells (Chen et al., 2020).
- Targeted medication delivery: Gold nanoparticles can be functionalized with tumor-targeting ligands or antibodies to deliver pharmaceuticals to the tumor's location while targeting cancer cells only. Chemotherapy's adverse effects may be lessened, and its effectiveness may be increased using this strategy (Gholipourmalekabadi et al., 2017).
- Diagnostic: In diagnostic imaging procedures like computed tomography (CT) scans, gold nanoparticles can be utilized as contrast agents. They have a high X-ray absorption rate and can improve picture contrast, which makes it simpler to find malignancies (Mahan and Doiron, 2018).

6. Suggestions to Researchers

6.1. Green Synthesis of Nanomaterials for Cancer Treatment

- Plant Extracts for Nanoparticle Synthesis: Investigate the use of various plant extracts in the green synthesis of metallic nanoparticles (e.g., gold, silver, and zinc oxide) and their effectiveness in targeting and killing cancer cells.
- Microbial Synthesis of Nanoparticles: Explore the potential of using bacteria, fungi, and algae to biosynthesize nanoparticles and assess their cytotoxic effects on different cancer cell lines.
- Green Chemistry Approaches for Magnetic Nanoparticles: Develop eco-friendly methods for synthesizing magnetic nanoparticles and study their use in hyperthermia therapy to treat cancer.
- Biodegradable Nanocarriers for Drug Delivery: Design and synthesize biodegradable nanocarriers using natural polymers (e.g., chitosan, cellulose) for the targeted delivery of anticancer drugs, minimizing side effects and improving efficacy.
- Green Synthesis of Carbon-Based Nanomaterials: Investigate the production of carbon nanotubes, graphene, and graphene oxide using green synthesis methods and their applications in cancer therapy (Singh, et al., 2023).

6.2. Nanotechnology Studies for Cancer Cell Killing

- Functionalization of Nanoparticles for Targeted Therapy: Study the functionalization of nanoparticles with targeting ligands (e.g., antibodies, peptides) to specifically bind to cancer cell receptors and deliver therapeutic agents.

- Photothermal and Photodynamic Therapy: Research the use of nanoparticles that generate heat or reactive oxygen species upon light activation to selectively kill cancer cells while sparing healthy tissue.
- Nanoparticle-Based Immunotherapy: Explore how nanoparticles can be used to deliver immune-modulating agents that activate the body's immune system to recognize and destroy cancer cells.
- Nanoparticles for Gene Therapy: Investigate the potential of using nanoparticles as carriers for gene-editing tools (e.g., CRISPR/Cas9) to target and modify cancer-causing genes (Chehelgerdi, et al., 2023).

6.3. Nanobot Technology in Health and Cancer Research

- Design and Optimization of Nanobots for Drug Delivery: Develop and optimize nanobots capable of navigating through the bloodstream to deliver chemotherapeutic agents directly to tumor sites, improving treatment efficacy and reducing side effects.
- Nanobot-Assisted Surgery: Research the potential of nanobots in assisting with minimally invasive surgeries by precisely targeting and removing cancerous tissues.
- Real-Time Monitoring and Diagnostics: Create nanobots equipped with sensors that can provide real-time monitoring of cancer biomarkers and tumor microenvironments, facilitating early detection and personalized treatment.
- Nanobot-Mediated Gene Editing: Study the use of nanobots to deliver gene-editing tools to specific cells, enabling precise modifications of genetic material to treat or prevent cancer.
- Targeted Cancer Cell Apoptosis: Develop nanobots programmed to induce apoptosis (programmed cell death) selectively in cancer cells, minimizing damage to surrounding healthy tissues.
- Multifunctional Nanobots for Combined Therapies: Investigate the design of multifunctional nanobots that can simultaneously deliver multiple therapeutic agents, such as chemotherapeutics, immunotherapeutics, and gene therapies, to enhance overall treatment efficacy (Kong et al., 2023).

These research topics encompass a range of innovative approaches in the green synthesis of nanomaterials, nanotechnology studies, and nanobot technology, all aimed at improving cancer treatment and outcomes.

7. conclusion

Research into gold nanoparticles synthesis from green plant material in chemistry has provided several opportunities and invitation to more research and exploration. More research has been done, some are going now and more discoveries will be achieved. There is opportunity and solution for the eradication of cancel cells in human and there can be a final opportunity to find a lasting solution to manage, treat or eradicate cancer. In all, there are some advantages and disadvantages of plant synthesis of gold nanoparticles (Au-NPs) from green plant.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflict of interest and the work was funded by the authors.

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