PAPER NAME

Review paper-01.06.2024_FINAL.docx

AUTHOR

Dr. Sudagar Jothi

WORD COUNT

7714 Words

CHARACTER COUNT

45516 Characters

PAGE COUNT

23 Pages

FILE SIZE

10.3MB

SUBMISSION DATE

Jun 6, 2024 4:45 PM GMT+5:30

REPORT DATE

Jun 6, 2024 4:47 PM GMT+5:30

11% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

- 8% Internet database
- 8% Publications database
- Crossref database
- Crossref Posted Content database
- 7% Submitted Works database

Excluded from Similarity Report

- Bibliographic material
- Quoted material
- Cited material
- Small Matches (Less then 8 words)

Bio prospecting of *Aloe Barbadensis Miller* (Aloe Vera) for Silver nanoparticles against breast Cancer: A Review

ABSTRACT

Silver nanoparticles (AgNPs) are gaining substantial importance in the fields of biotechnology and medicine. Its composites are metal oxides, silicates, polymers, graphene, fibers, dendrimers, etc. The greenly synthesized AgNPs possess advantages over conventional AgNPs in the form of fewer chemical reagents and a low temperature and pressure for synthesis. The anticancer efficacy of AgNPs is attributed to a number of variables, including size, shape, surface-to-volume ratio, etc. There are several ways to make SNPs, but the green synthesis of AgNPs, which uses harmless chemicals and natural reagents, has gained significant interest and value. In this review, a comprehensive range of topics related to silver nanoparticles, the environmentally friendly method of producing them from plants such as *Aloe barbadensis miller* (Aloe vera), which have a vast medicinal uses, and their anticancer effectiveness against breast cancer cells are discussed. The synthesized AgNPs are characterized via a range of methods, for instance, Fourier Transform Infrared Spectroscopy (FTIR), UV-visible spectroscopy, Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), and X-ray Diffraction (XRD). This review study includes an investigation into the stability of produced nanoparticles, the wide range of nanoparticle forms, the many techniques used in the conglomeration of nanoparticles, and comparison methods emphasizing the benefits of green synthesis relative to traditional techniques. Furthermore, the discussion explores the chemical and structural makeup of nanoparticles.

Keywords: Silver nanoparticles; Biological synthesis; Anticancer activity; *Aloe barbadensis miller*; Breast cancer cells.

1. INTRODUCTION

Antimicrobial and anticancer therapies are two areas in which **silver nanoparticles (AgNPs)** find extensive use. Additionally, they are being used as biosensors, vaccine adjuvants, and anti-diabetic agents, as well as to promote bone mending and wound healing. The amalgamation methods of AgNPs include biological, chemical and physical routes (Xu et al., 2020). Silver nanoparticles are known for their high anticancer effects. Polymer coating on nanoparticles improves the stability of the suspension against aggregation. However, for biologically synthesized silver nanoparticles, coating is not required, as the plant extract designed for the synthesis of nanoparticles itself functions as a calibration and reduction agent. During the process of chemical binding of silver nanoparticles, coating substances have been designed to alleviate silver nanoparticles, which allow the maintenance of specific sizes and reduce the amount of silver ions that take part in the reaction. These are the crucial factors that determine the toxicity of the silver nanoparticles. Presently, silver nanoparticles have wide applications in the arena of medicine, especially in cancer treatment. Metal nanoparticles will be generated through various ways (Fahmy et al., 2019, Marins et al., 2018, Shah et al., 2015).

The procedure of manufacturing AgNPs by employing plant or leaf extract as a reducing agent is better than other methods since it does not require the laborious task of sustaining cell culture. *Aloe barbadensis miller* gel is utilized in many cosmetic and skincare products. It is also considered a medicinal plant for the medication of burns and lesions. It is now being explored for the amalgamation of silver nanoparticles. Several researchers have indicated that silver nanoparticles can also be obtained from *Jasminum officinale*, *Centella asiatica*, bacteria, fungi, yeast, etc. (Kaviya et al., 2012, Tippayawat et al., 2016, Rahman et al., 2017, Surjushe et al., 2008, Kumar and Yadav 2009, Kulothungan et al., 2022, Sahu et al., 2022). Pioneering attempts were made to give a comprehensive review studies of these plants in detail. Among the various diseases that cause mortality, cancer is a noteworthy issue that needs more attention. One of the main causes of death for individuals in 172 countries worldwide is cancer (Mehrotra and Yadav 2022). Among the cancers, breast cancer accounts for over 2 million cases in women globally, leading to 60,000 deaths per year. Breast cancer has the ability to extend when cancer cells put on the blood or lymphatic system and move to different body parts. The fourth common cancer that prevailed in India in the year 1990 occupies the first position in the last decade (McMillan et al., 2011). Number of cancer cases and cancer-related deaths as per reports is shown in **Fig. 1** (Prakash Sharma et al., 2014, Chávez-Rodríguez et al., 2021).

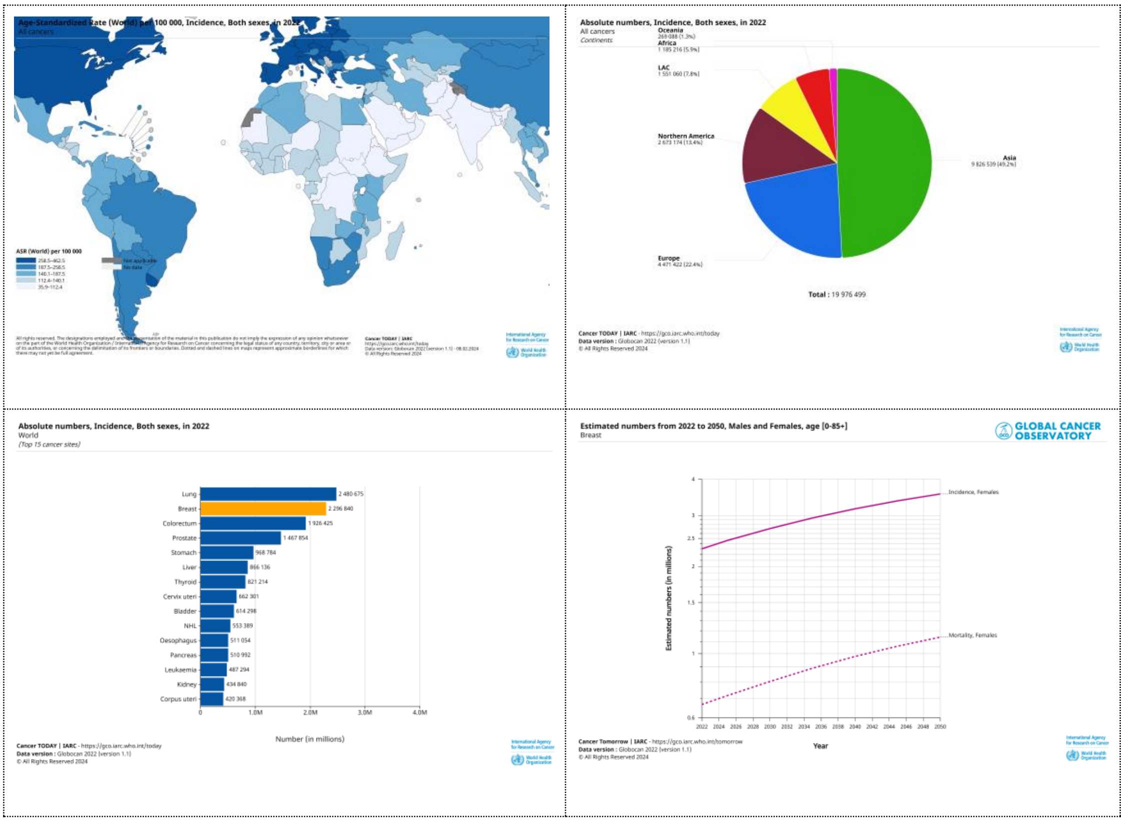

Figure 1: Estimated number of cancer-related deaths in 2022 among both sexes around the world. Graph production: Global Cancer Observatory (http://gco.iarc.fr) Data source: GLOBOCAN2022

Breast cancer stands the prominent cause of mortality among cancer-related diseases. The biological manufacture of AgNPs utilizing *Aloe barbadensis miller*, as well as their anticancer efficacy against breast cancer cells, are the main topics of this review study for the first time. This review article discusses a variety of compounds from these plant extracts and their significant biological activities, the biosynthesis of AgNPs from various plant extracts and their application to cancer cell lines, the various techniques for synthesizing AgNPs, the various capping agents used in the process, the characterization of AgNPs, and the applications of AgNPs.

2. CATEGORIES OF NANOPARTICLES

The nanoparticles are broadly tabulated into three types based on their origin and chief constituents: inorganic, organic nanoparticles, and carbon-based nanoparticles. Organic nanoparticles such as macromolecules, lipid vesicles, microstructure and ferritin are widely used in the medical field as a drug delivery system as they operate well and can be instilled into distinct parts of the body to target cancer cells selectively without destroying normal cells (Khan et al., 2022). Inorganic nanoparticles are generally defined as those that are based on metal or metal oxide. Metal based includes Al, Ag, Cd, Co, Cu, Au, Fe, Pb, Zn and metal-oxide includes Al_2O_3, CeO_2, Fe_2O_3, SiO_2, TiO_2, ZnO. Nanoparticles created entirely based on carbon are called carbon-based nanoparticles, which include fullerenes, graphene, carbon nanotubes (CNT), carbon nanofibers, carbon black, etc. (Fritea et al., 2021, Baig et al., 2021, Pal et al., 2020).

3. SYNTHESIS OF NANOPARTICLES

Top down and bottom-up approaches are the two main categories into which nanoparticle synthesis techniques fall**.** To create nanoparticles, the former method reduces the size of a suitable starting material. The top-down methodology uses a number of chemical and physical processes, including sputtering, laser ablation, and ball milling. Top-down methods are straightforward because they divide or minimize bulk material to produce the desired nanoparticle structure and properties. However, the main pitfall in this approach is the deformity of the surface structure of the produced nanoparticle (Das et al., 2022, Pattekari et al., 2011, Khan et al., 2019). Because of their superior ordering and more uniform chemical composition, bottom-up methodologies are primarily used in the coalescence of nanoparticles rather than top-down methods. Sol-gel synthesis, hydrothermal synthesis, colloidal precipitation, etc. are the most commonly used bottom-up approaches to producing nanoparticles.

The creation of nanoparticles via chemical and physical means is exorbitant and uses hazardous chemicals that can have negative biological and environmental effects. Nanoparticles obtained from chemical processes are not appropriate for medical applications, as many toxic substances might be involved in the production of nanoparticle synthesis (Samuel et al., 2022, Gautam et al., 2021, Ray et al., 2009, Zhang et al., 2020). Thus, a surrogate method is essential for the production of nanoparticles to reduce the cost and toxicity of the material and minimize environmental and biological problems. This led to the investigation and progress of the biological synthesis of nanoparticles, which is cost-effective and associated with less or no toxicity. Researchers found that the molecules produced from living organisms such as plants, fungi, bacteria, algae, etc. can be used as calibration agents to produce nanoparticles (Sharma et al., 2019, Shah et al., 2015, Khandel et al., 2018).

4. BIOLOGICAL SYNTHESIS OF SILVER NANO PARTICLE

In the biological synthesis/green chemistry approach, highly stable and well-characterized AgNPs can be obtained. The appearance and morphology of the silver nanoparticle can be controlled by altering certain parameters such as light, pH, temperature, biomass, etc. (Pandit et al., 2022, Rónavári et al., 2021, Raza et al., 2016). An important factor in a nanoparticle's application is its size and shape. It appears that smaller nanoparticles are more effective than larger ones (Hoshyar et al., 2016, Albanese et al., 2012, Vega-Baudrit et al., 2019). The primary benefit of employing biological methods is the ease of access to microorganisms like bacteria, fungus, and others, as well as the abundance of plants. These are used as calibration agents in the production of AgNPs, which impart more stability and less toxicity to the produced nanoparticles (Garg et al., 2020).

As compared with microbial synthesis from bacteria or fungi or synthesis from algae, the synthesis of AgNPs from plant extract is advantageous due to its vast availability and lower toxicity (Chugh et al., 2021, Mukaratirwa-Muchanyereyi et al., 2022). A wide range of phytochemical extracts can be rapidly used to reduce silver ions. The process of biological synthesis of AgNPs uses blending or combining silver nitrate solution with a suitable plant extract (Ahmed et al., 2016, Song et al., 2009). A typical reaction can be finished in a few minutes or hours. **Table 1** list the *Aloe barbadensis miller* plant extracts that are utilized to create AgNPs.

Table 1: Synthesis of silver nanoparticles from different plant extract

Plant name	Plant part	Method of preparation	Characteristics	Ref.
Aloe barbadensis miller	Leaf	5ml of 10 mM $AgNO_3$ solution was mixed with 5 ml of aloe-vera plant extract diluted with 1% of ammonium solution and kept at room temperature for 48 hrs	It was observed that the maximum absorbance occurs at 430 nm	(Begum et al., 2020)

The green synthesis process is the method used to create nanoparticles from plant extract. Here, an aqueous extract derived from the leaves, stem, seed, or root is combined with the liquid solution of silver salt. Plant extracts are applied as steadying and reducing agents in the synthesis of AgNPs. Many different phytochemicals have the ability to produce AgNPs (Singh et al., 2018, Habeeb Rahuman et al., 2022, Nallamuthu et al., 2012). Silver ions can be minimized by the functional groups of phytochemicals, such as amino groups and aldehydes.

5. CHARACTERIZATION OF SILVER NANOPARTICLE

AgNPs are commonly characterized using heterogeneous techniques including Energy Dispersive Spectroscopy (EDS), FTIR, XRD, SEM, TEM, AFM, and UV-Vis spectroscopy. The analysis of AgNP's UV-Vis spectra is displayed in **Figure 2a (**Fu et al., 2021**)**. Through optical spectrum measurement, the creation of AgNPs can also be ascertained. It measures the light's absorbance or transmittance, which goes through a specific medium that acts as a function of its wavelength. The AgNPs size and shape aspect ratio are key variables influencing the wavelength of light absorbed. The location of the Surface Plasmon Resonance (SPR) band in UV-Vis spectra is reliant on the size and shape of the particles. **Figure 2b** shows the TEM characterization of the structure and morphology of the silver nanoparticle. The TEM method allows observation at the molecular or atomic level. The particle size distribution shown in **Figure 2c** and it gives a mean size of 16 nm (David et al., 2020). The functional group present on the silver nanoparticle can be obtained by using the FTIR technique**.** The FTIR analysis provides an illustration of the agents that function as a stabiliser and minimiser during the biosynthesis of AgNPs. An essential factor in the stability of AgNPs is the capping agent. Each peak in an FTIR analysis corresponds to a particular functional group **(Figure 2d).** Mainly three peaks 1010 cm^{-1}, 1190 cm^{-1} and 1080 cm^{-1} correspond to C-O stretching from alcohol, carboxylic acid, ester and ether; all due to functional groups of proteins and metabolites covering the AgNPs. The crystal structure of the nanoparticle is examined using XRD. **Figure 2e** displays a typical XRD spectrum of AgNPs. XRD provides sample data about the lattice parameters. The dimensions and form of the unit cell of the crystalline phase can be determined from the location of the diffraction peak. Peak can be described using the miller index since it symbolizes a lattice plane. **Figure 2f** displays typical AFM images of the AgNPs, and 2 µm resolution shows the 25-57 nm size, spherical shaped, polydisperse particles.

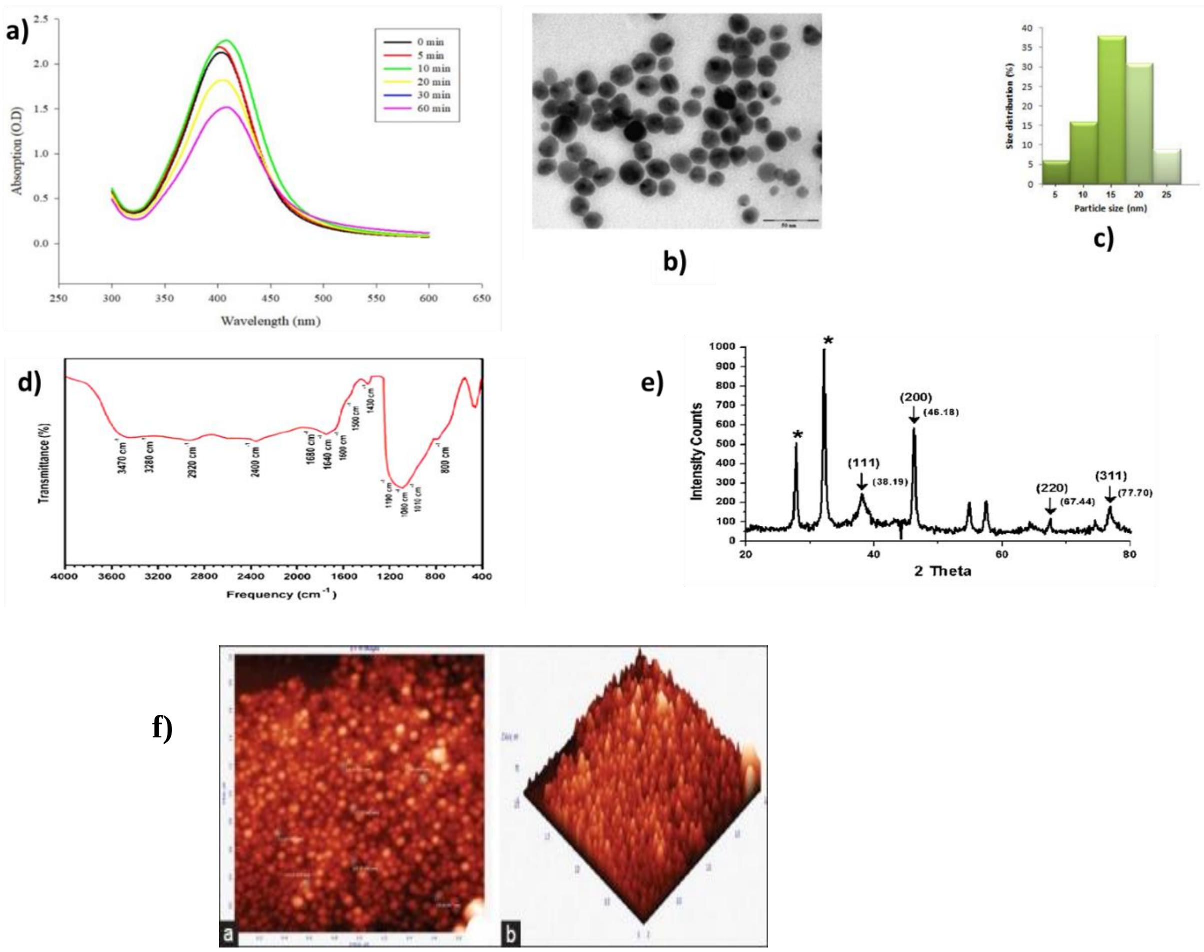

Figure 2: a) UV-Vis absorption spectra of AgNPs (Creative Commons CC-BY license (Fu et al., 2021), © by Lung-Ming Fu et. al., MDPI); b) TEM image of AgNPs; c) histogram of obtained AgNPs (Creative Commons CC-BY license (David et al., 2020), © by David L et. al, Nanomaterials, MDPI); d) FTIR spectra of the silver nanoparticle (reproduced from (Thirunavoukkarasu et al., 2013) after permission, © Elsevier); e) XRD pattern of AgNPs (Creative Commons CC-BY license (Vanaja et al., 2013), © by Vanaja, M et. al, Appl Nanosci, Springer Nature); f) Atomic force microscopy micrograph of synthesized silver nanoparticles (AgNPs) (Creative Commons CC-BY license (Kumar CMK et al., 2016), © by Kumar CMK et. al, J Intercult Ethnopharmacol, SAGEYA)

6. STABILITY OF SILVER NANOPARTICLE

The resilience of nanoparticles is crucial for their utilization in the field of biomedicine. If the synthesized AgNPs are unstable, they would react with other substances, which may result in the worst outcome. Thus, the calibration agent plays a significant role in the union of AgNPs as it prevents the agglomeration and overgrowth of nanoparticles (Burdușel et al., 2018, Gomes et al., 2021, Sidhu et al., 2022, Archana et al., 2023). Generally, natural polysaccharides such as starch, heparin, chitosan, cellulose, glucose, etc. are used as capping agents **(Figure 3a)** (Sidhu et al., 2022). The advantages of using a biogenic capping agent over AgNPs are that these:

1) Prevent agglomeration
2) Provide functional group for the attachment of biomolecules or medicines
3) Control the size of the nanoparticle
4) Impart more storage and stability properties

Capping agents modify the property of nanoparticles thereby making it amenable for the medical field, especially towards cancer treatment **(Figure 3b, Table 2)** (Zafar et al., 2019). In chemical synthesis of nanoparticle PEG, Polyvinyl alcohol etc. are added as capping agents during the time of synthesis to improve the stability (Zafar et al., 2019, Javed et al., 2020). The disadvantage of adding a capping agent is that the addition of chemicals will affect the property of the nanoparticle and is sometimes not suitable for application to the health sector/ medical field. In biological synthesis, addition of chemicals as capping agents is not required as the extract of plants or the microorganism itself contains amino acids and other organic substances which act as calibrator (Pedroso-Santana and Fleitas-Salazar 2022, Nguyen et al., 2022, Chugh et al., 2021).

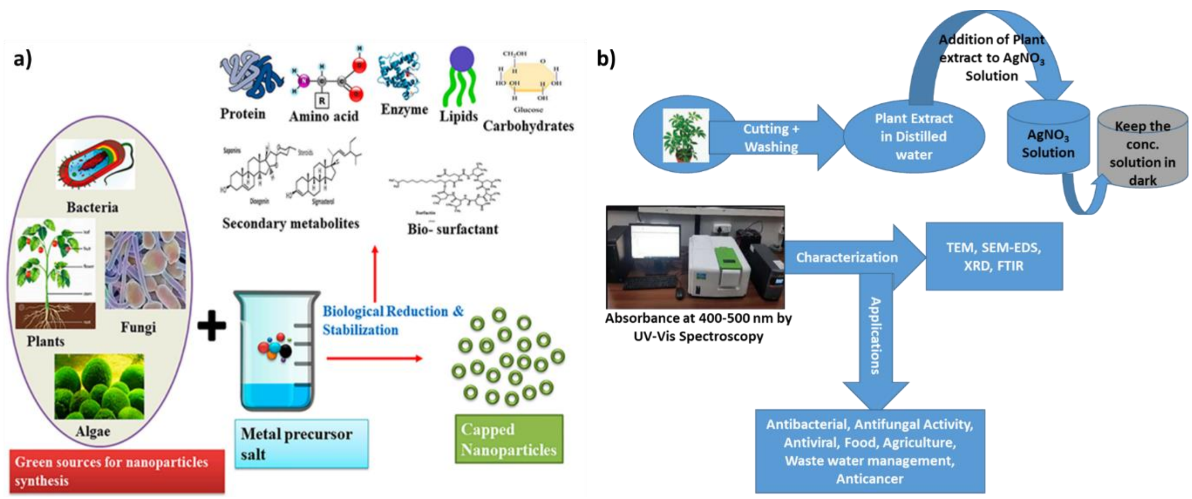

Figure 3: a) Schematic representation of biosynthesis of nanoparticles and capping by various molecules (reproduced from (Sidhu et al., 2022) after permission. © American Chemical Society); b) Illustration of green synthesis of AgNPs from plants (Zafar et al., 2019).

Table 2: List of various balancing agents used for the fusion.

S.no	Capping agent	Nanoparticle synthesized	Size of the particle	Ref.

1	Triethanolamine (TEA)	ZnO	20-30 nm	(Chugh et al., 2021)
2	Oleic acid	ZnO	4-5nm	
3	Thioglycerol	ZnO	3nm	
4	Oleic acid	Ag	13.5nm	(Singh et al., 2009)
5	Polyacrylic acid	Ag	122.4nm	(Li et al., 2013)
6	Hexadecyl amine	Au	4.5-12nm	
7	β-Glucose	Au	5-13nm	
8	Tyrosine	Au	45nm	
9	4-Hexadecylaniline	Au	4.2nm	
10	Ethylene diamine tetra acetic acid	ZnO	20-25nm	(Dumur et al., 2011)
11	Triethanolamine	ZnO	25-30nm	
12	Tetraethylammonium Bromide	ZnO	20-25nm	
13	Ethylene diamine tetra acetic acid	$CdTiO_3$	35-50nm	(Dobbelstein 1975)
14	Polyvinylpyrrolidone	$CdTiO_3$	35-50nm	
15	Diethanolamine	$CdTiO_3$	35-50nm	
16	sodium dodecyl sulphate	$CdTiO_3$	35-50nm	
17	Ethyl cellulose	$NdVO_4$	50-80nm	
18	Starch	$NdVO_4$	<30nm	(Rahimi-Nasrabadi et al., 2016)
19	Tween 80	$NdVO_4$	>30nm	

Capping agents or stabilizers modify the surface property of colloidal nanoparticles and make them perfect for application in the biomedical field such as drug delivery and chemotherapy in cancer.

7. USES OF SILVER NANOPARTICLES

Silver nanoparticles are used in textiles, electronics, coatings, medical devices, food preservation, and other industries as antibacterial agents. AgNPs are frequently used for a number of purposes, such as sterilizing sewage treatment and surgical instruments. Silver nanoparticles show definite improvement in modern commercial applications as coatings for cardiovascular implants, central venous catheters, and neurosurgical catheters. Additionally, they have been applied to latex films used as biomaterials for skin regeneration treatments and to monitor the release rate of nanoparticle films. AgNPs are employed in biosensors, which use the content of AgNPs as biological markers to enable quantitative detection. AgNPs are also utilized in other products, such as clothes and shoes. Additionally, AgNPs are used in plastics, paints, cosmetics, appliances, treatments for cuts and scrapes, and clothing.

Composite systems contain AgNPs, that are utilised to increase conductivity in conductive tinting. AgNPs are used in optical applications for improved metal fluorescence (MEF), better optical spectroscopy, and effective data collection. They also provide superficial raman dispersion (SERS). They are also used in innovative technology in the fields of optoelectronics, nanoengineering, and nanoelectronics. The main applications of silver nanoparticles are shown in **Figure 4** (Mondal, M.S., et al 2023).

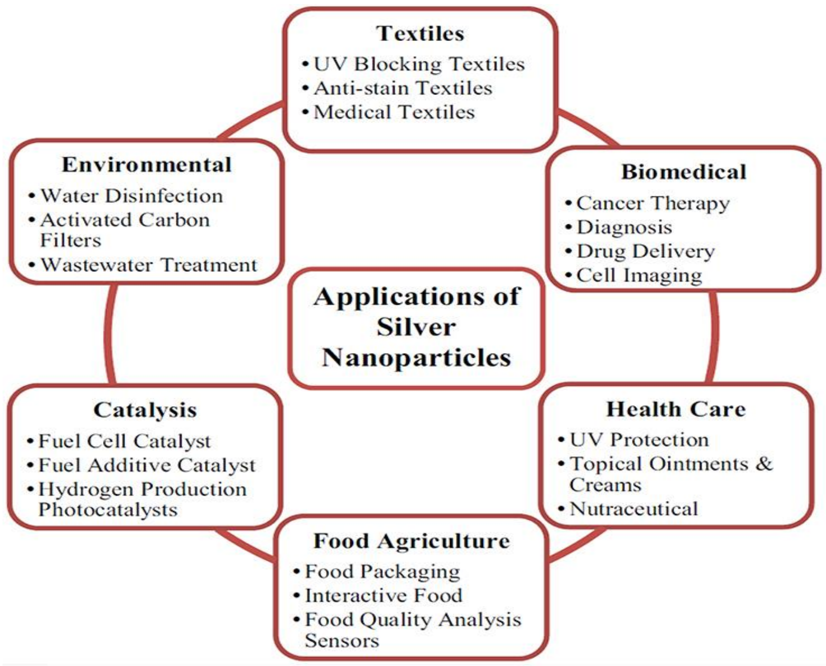

Figure 4: Various applications of Silver nanoparticles.

8. *ALOE BARBADENSIS MILLER*

The *Aloe barbadensis miller* leaf can be partitioned as shown below **(Figure 5).**

- Outer layer that encompasses the vascular bundles
- Interior translucent parenchyma containing the aloe gel

The three components of the *Aloe barbadensis miller* pulp are

- Cell wall
- Deteriorated organelles
- Viscous fluid contained within the cells

Figure 5: *Aloe barbadensis miller* (Aloe-vera) leaves

The inner gel contains 99% water, and the remaining part is made of glucomannans, amino acids, steroids, etc. The intermediate layer consists of anthraquinones and glycosides, and the outer layer is composed of carbohydrates and proteins (Hosseinpour-Mashkani and Sobhani-Nasab 2017). It has components in the form of the chemical composition of crude fiber, crude fat, and ascorbic acid. *Aloe barbadensis miller* has gained significant attention for minimizing the side effects caused by conventional chemotherapy. The most important substances that are responsible for the effects are cinnamic acid, barbalonia, calcium, aloe, etc. (Surjushe et al., 2008, Vega-Gálvez et al., 2014). Aloin, a main ingredient in aloe, has been effective in therapeutic applications in cancer. The US Food and Drug Administration legalized the developmental study of *Aloe barbadensis miller* and HIV/AIDS. *Aloe barbadensis miller*, combined with cisplatin, has been shown to have antineoplastic effects on cervical and breast cancer cells (Guo. et al., 2016). The potential anticancer activity of *Aloe barbadensis miller* leaf extract is owing to the occurrence of anthraquinones. Numerous compounds present in *Aloe barbadensis miller* that contribute to diverse biological activities are listed in **Table 3**.

Table 3 : Compounds and biological activity

S.no	Name of compound	Biological activity	Ref.
1	1-Heptanol, 2-propyl-	Antimicrobial	(Hussain et al., 2015, Hamman 2008, Radha and Laxmipriya 2015)
2	(4,7-Dinitronaphthalen-1-yl) -(4 methoxyphenyl) diazene	Antimicrobial	
3	Tetra decanoic acid	Cancer preventive	
4	Hexadecenoic acid, methyl ester	Antioxidant	
5	1,2-Benzenedicarboxylic acid, butyl octyl ester	Antimicrobial	
6	n-Hexadecenoic acid	Antioxidant	
7	11,14-Eicosadienoic acid, methyl ester	Hypocholesterolaemia	
8	Oleic Acid	Anti-inflammatory and cancer preventive	
9	1,2-Benzenedicarboxylic acid, diisooctyl ester	Antifouling	
10	Squalene	Anti-bacterial and cancer preventive	

These compounds are included in different classes such as Anthraquinones/anthrones, Carbohydrates, Chromones, Enzymes, Inorganic compounds, Vitamins, Saccharides, Proteins etc.

9. GREEN SYNTHESIZED AGNPs USING *ALOE BARBADENSIS MILLER* AND ITS ACTIVITY AGAINST MCF-7 BREAST CANCER CELL LINES

The aqueous leaf extract of Aloe-vera leaves and 1 mM aqueous solution of $AgNO_3$ solution were used to synthesize AgNPs, Which appears to be brownish colour and the UV-Vis spectral analysis confirmed the production of AgNPs by showing a peak at 420 nm

(Alwhibi et al. 2021). FTIR Spectroscopy of synthesised silver nanoparticle using Aloe-vera leaf extract shows peak at 1386.4 cm^{-1} (geminal methyls), 1587.6 cm^{-1} (C=C groups or from aromatic rings), and 1076 cm^{-1} (ether linkages) all point to the potential existence of terpenoids or flavanones on the surface of synthesised AgNPs (Logaranjan et al. 2016). The size, shape and surface morphology of the synthesized AgNPs can be found out by SEM and TEM. Reports suggest that the size of the nanoparticle is about 20-40 nm (Mustafa H. N and S.mohammed 2023). Biogenic silver nanoparticles were synthesized using the extract of Aloe Vera as a potent bio reducer. Spherical shaped nanoparticles were observed and they exhibit anticancer activity against MCF- human breast cancer cell lines. Further in vivo investigations and clinical trials are required to address the formulation of biogenic silver nanoparticles as an environmentally friendly and biocompatible alternative to conventional anticancer medications. It induced detrimental impacts of the numerous cellular components in the malignant cells (Basak et al. 2018).

Aloe-emodin, an anthraquinone present in *Aloe barbadensis miller*, is recognized for triggering apoptosis (programmed cell death) in cancer cells. It curtails the growth of these cells by disrupting the cell cycle and promoting apoptosis through the activation of caspases, which are enzymes crucial for programmed cell death (Shalabi et al. 2015).

Acemannan, a polysaccharide derived from *Aloe barbadensis miller* leaves, boosts the immune system by increasing the activity of macrophages and the production of cytokines, both of which are vital for the body's defense against cancer cells (Liu et al. 2019). *Aloe barbadensis miller* gel is rich in bioactive compounds, including vitamins, minerals, enzymes, and amino acids, which together enhance its therapeutic benefits. It has antioxidant properties that protect cells from oxidative stress and DNA damage, both of which are associated with cancer development (Tong et al. 2021).

Lab studies on cell cultures have shown that *Aloe barbadensis miller* can potentially inhibit the growth of different cancer cell lines, including breast, liver, lung, and colon cancer cells. Few clinical trials have been conducted on humans. Some studies have reported that *Aloe barbadensis miller*, when used as a complementary treatment, can improve the quality of life and reduce tumor-related symptoms in cancer patients. However, more extensive clinical trials are necessary to validate these results. *Aloe barbadensis miller* appears promising as a complementary cancer therapy because it can boost immune function, trigger apoptosis, and guard against oxidative stress. Although preclinical studies are promising, more extensive clinical trials are needed to confirm its effectiveness and safety for cancer patients.

10. BIOSYNTHESIS OF SILVER NANOPARTICLE AND ANTICANCER ACTIVITY

The biological synthesis of AgNPs displays significant anticancer activity against certain cancer cell lines. Nanoparticles are safe at lower doses and cause extremely toxic effects in higher doses. The synthesised silver nanoparticle can selectively kill the cancer cell lines and enable cytotoxicity. In conventional therapy of cancer treatment, the normal cells may also die due to the over dose of medicine, unpredictable side effects, toxicity of the medicine etc. The application of biologically synthesised AgNPs may overcome the disadvantages of conventional therapy in cancer treatment. Thus, different plant species are used as steadying agents and reducing agents to produce AgNPs, and the synthesised nanoparticle can be successfully applied to different cancer cells.

The tiny size and multiple modes of cell death of AgNPs make them special candidates for cancer treatment. AgNPs cause chromosomal instability, oxidative stress, and double-stranded DNA disruption, all of which lead to cell death. AgNPs of smaller sizes (10 nm) generate cellular toxicity at higher levels because they enter the cell more easily and localize inside the nucleus, while larger AgNPs (100 nm) more efficiently produce these outcomes than smaller AgNPs. According to reports, AgNPs cause cytotoxicity in mammalian cells through a number of different mechanisms, including (a) The absorption of free silver ions causes suspension to energy-dependent cellular processes and DNA replication, which results in compromised cellular functions; (b) production of reactive oxygen species (ROS) and free radicals; (c) cell membrane impairment resultant due to direct interaction with AgNPs (Mei et al., 2020). Cell death is caused by ROS which are created when green-synthesis AgNPS are present. ROS production is detrimental to the pathways that cause cell apoptosis. Hydrogen peroxide production alters the membrane potential of mitochondria resulting in the uncoupling of respiration (Avalos et al., 2016).

AgNPs activate nuclear factor kB (NF-kB), produce ROS, lower glutathione (SGH) levels, and produce tumor necrosis factor-alpha (TNF-alpha) when they enter the cell. The increased levels of superoxide radicals change the potential of the mitochondrial transmembrane and disrupt the signaling system, which leads to apoptosis and cell death (Fani et al., 2016, Nishanth et al., 2011). Biological components are harmed by increased ROS generation and decreased GSH, which results in lipid membrane peroxidation, protein carbonylation (a harmful oxidation of proteins), and DNA breakage. Moreover, altered mitochondrial membrane potential triggers the activation of caspases 3 and 9, which kill cells. It triggers the activation of the enzyme c-Jun NH_2 terminal kinase (JNK), which results in the production of apoptotic bodies, and breaks DNA, causing cell cycle arrest (Verano-Braga et al., 2014).

Folkman's theory states that angiogenesis, or the creation of new blood vessels, is what leads to the development of tumors. According to this theory, a tumor's blood supply affects how easily it can grow and spread. These newly formed blood vessels give cancer cells oxygen and nourishment, which allows them to spread to surrounding tissues. Biologically synthesized AgNPs showed effectiveness against a condition similar to retinal neovascularization (RNV). AgNPs inhibited the activation of extracellular signal-related kinase (ERK1/2) and decreased the RNV convinced by vascular endothelial progress factor by regulating the phosphorylation of receptor 2. AgNPs have been used in the treatment of cancer because of their anti-angiogenic characteristics (Ratan et al., 2020).

Proposed mechanisms for the anticancer action of green synthesised AgNPs include the upregulation of caspase 3 and activation of the p53 protein, pH-dependent relief of silver ions, discerning assassination of cancerous cells, and inhibition of Vascular endothelial growth factor (VEGF) induced activities. Apoptosis is induced by caspase-dependent and mitochondrial-dependent pathways, cell cycle arrest in the sub-G1 phase, the generation of ROS, and disruption of cellular equilibrium (Halawani et al., 2020, Lee et al., 2019). AgNPs that are produced sustainably emit silver ions, which can be used as a visual cue that cancer cells are dying. Consequently, the amount of silver ions released within the cells directly leads to the destruction of malignant cells, one by one. Normal cell lines release silver ions differently from cancer cell lines because of pH differences. The release of silver ions is also influenced by the electrostatic contact between healthy and malignant cells (Gurunathan et al., 2015). Due to their anti-angiogenic effectiveness, green-synthesised AgNPs have been proposed as a novel avenue for the treatment of cancer. AgNPs' anticancer potential has been explained by yet another theory. This process includes the breakdown of cells brought on by autophagy, which ends in cell death. Additionally, because autophagolysosomes accumulate in cancer cells and are more prevalent there, greenly produced AgNPs encourage autophagy, which ultimately results in cell death (Shi et al., 2017). A possible mechanism of action of AgNPs in cancer cells is shown schematically in **Figure 6** (Khan et al., 2018).

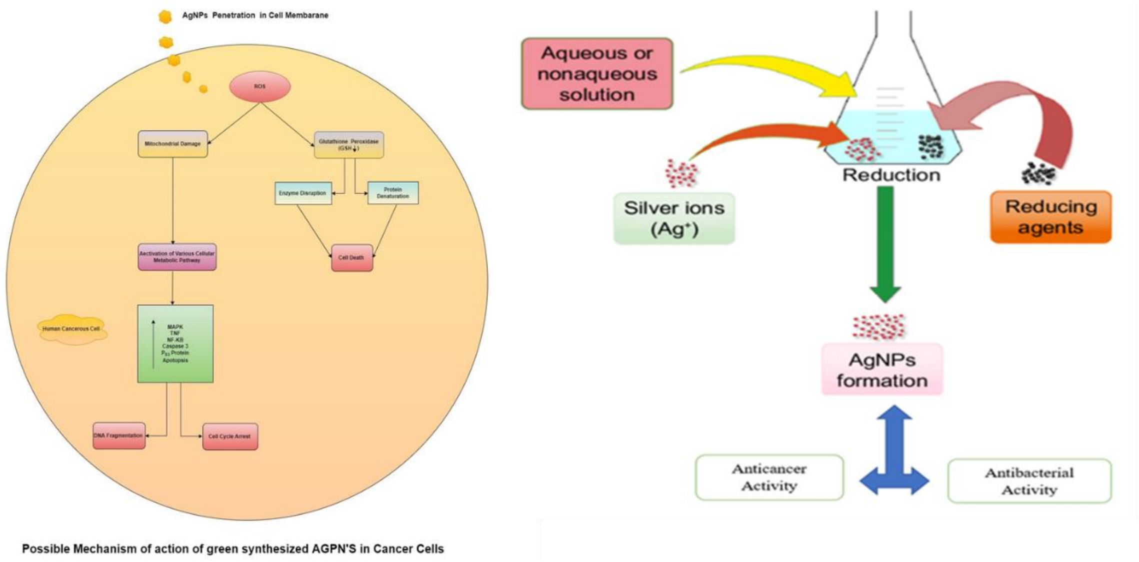

Figure 6: Possible mechanism of action of AgNPs in cancer cells (Creative Commons CC-BY license (Khan et al., 2018), © by Shahid Ullah Khan et. al, Dove press, UK).

CONCLUSION

There are numerous uses for AgNPs in the industrial and biological domains. This review article examined and emphasized the significance of the following:

1) The biological synthesis of AgNPs
2) AgNP synthesis using plant extract
3) AgNPs application in breast cancer cells

A number of successful research studies on AgNPs show their effective anticancer activity. Nonetheless, given that AgNPs are extremely toxic and should be used with caution in the medical field, there are some fundamental worries about their toxicity. The biological synthesis of AgNPs lowers the material's toxicity, allowing for its potential use in the biomedical field. Various studies prove that it can also be used as a drug carrier in therapy for different cancers. With an emphasis on extraction, this review article discussed the green production of AgNPs utilizing *Aloe barbadensis miller* leaves. Lastly, a great deal of research is needed to analyze the toxicity and anticancer effects of nanoparticles in order to prepare clinical trials and cancer drugs.

Future research ideas or directions on AgNPs show exceptional promise but need to be pursued actively if they are to be successful. The creation of AgNPs with single, dual, or multiple functions is the initial direction. Consequently, this type of drug delivery system will be more effective in treating cancer due to its multifunctional actions. Clinical translation will benefit more from the use of multifunctional nanoparticles with one or more targeting, imaging, sensing, and therapeutic applications.

ACKNOWLEDGEMENT

The Chancellor and the VIT group management have our sincere gratitude. We are especially grateful to the Vice-Chancellor of VIT-AP for approving the publication of this review paper. Additionally, acknowledged is the support for Open Access research publications to reputable journals.

REFERENCE

Ahmed S., Ahmad M., Swami B. L., and Ikram S., “A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise,” *J. Adv. Res.*, vol. 7, no. 1, pp. 17–28, Jan. 2016, doi: 10.1016/j.jare.2015.02.007.

Ainil Hawa, Ali Azirah, Suresh Sagadevan, Wahid Zaharah; ”Silver Nanoparticles in Various New Applications”, 2021, doi:http://dx.doi.org/10.5772/intechopen.96105.

Albanese A., Tang P. S., and Chan W. C. W., “The Effect of Nanoparticle Size, Shape, and Surface Chemistry on Biological Systems,” *Annu. Rev. Biomed. Eng.*, vol. 14, no. 1, pp. 1–16, Aug. 2012, doi: 10.1146/annurev-bioeng-071811-150124.

Alwhibi, Mona S., Dina A. Soliman, Manal A. Awad, Asma B. Alangery, Horiah Al Dehaish, and Yasmeen A. Alwasel. 2021. “Green Synthesis of Silver Nanoparticles: Characterization and Its Potential Biomedical Applications.” Green Processing and Synthesis 10 (1): 412–20.

Archana R, Pathak Saurabh, Lim Dong-Kwon, Kim Sang-Koog, Srivastava Ritu, Sharma Shailesh Narain, and Verma, Rajni, ’Recent Advancements in Plant- and Microbe-Mediated Synthesis of Metal and Metal Oxide Nanomaterials and Their Emerging Antimicrobial Applications‘, ACS Appl. Nano Mater. 2023, 6, 10, 8106–8134. https://doi.org/10.1021/acsanm.3c01351

Avalos A., Haza A. I., Mateo D., and Morales P., “Interactions of manufactured silver nanoparticles of different sizes with normal human dermal fibroblasts: Silver nanoparticles and fibroblasts,” *Int. Wound J.*, vol. 13, no. 1, pp. 101–109, Feb. 2016, doi: 10.1111/iwj.12244.

Baig N., Kammakakam I., and Falath W., “Nanomaterials: a review of synthesis methods, properties, recent progress, and challenges,” *Mater. Adv.*, vol. 2, no. 6, pp. 1821–1871, 2021, doi: 10.1039/D0MA00807A.

Basak, Piyali, Ranabir Majumder, Amrita Jasu, Samrat Paul, and Shreya Biswas. 2018. “Potential Therapeutic Activity of Bio-Synthesized Silver Nanoparticles as Anticancer and Antimicrobial Agent.” *IOP Conference Series: Materials Science and Engineering* 410 (September): 012020. https://doi.org/10.1088/1757-899X/410/1/012020.

Begum Q., Kalam M., Kamal M., and Mahboob T., “Biosynthesis, Characterization, and Antibacterial Activity of Silver Nanoparticles Derived from *Aloe barbadensis Miller* Leaf Extract,” *Iran. J. Biotechnol.*, vol. 18, no. 2, Jun. 2020, doi: 10.30498/ijb.2020.145075.2383.

Burdușel A.-C., Gherasim O., Grumezescu A. M., Mogoantă L., Ficai A., and Andronescu E., “Biomedical Applications of Silver Nanoparticles: An Up-to-Date Overview,” *Nanomaterials*, vol. 8, no. 9, p. 681, Aug. 2018, doi: 10.3390/nano8090681.

Chávez-Rodríguez, Lisette & Escobedo Calvario, Oscar & Salas Silva, Soraya & Miranda, Roxana & Ortiz, Leticia & Souza, Verónica & Gutiérrez-Ruiz, María Concepción & Gomez-Quiroz, Luis.

(2021). Fructose Consumption and Hepatocellular Carcinoma Promotion. Livers. 1. 10.3390/livers1040020.

Chugh D., Viswamalya V. S., and Das B., “Green synthesis of silver nanoparticles with algae and the importance of capping agents in the process,” *J. Genet. Eng. Biotechnol.*, vol. 19, no. 1, p. 126, Dec. 2021, doi: 10.1186/s43141-021-00228-w.

Das D., Bhattacharyya S., Bhattacharyya M., and Mandal P., “Green chemistry inspired formation of bioactive stable colloidal nanosilver and its wide-spectrum functionalised properties for sustainable industrial escalation,” *Results Chem.*, vol. 4, p. 100533, Jan. 2022, doi: 10.1016/j.rechem.2022.100533.

David, L.; Moldovan, B. Green Synthesis of Biogenic Silver Nanoparticles for Efficient Catalytic Removal of Harmful Organic Dyes. Nanomaterials 2020, 10, 202. https://doi.org/10.3390/nano10020202

Dobbelstein H., “Immune mechanisms in uremia,” *Klin. Wochenschr.*, vol. 53, no. 10, pp. 461–466, May 1975, doi: 10.1007/BF01468631.

Dumur F., Guerlin A., Dumas E., Bertin D., Gigmes D., and Mayer C. R., “Controlled spontaneous generation of gold nanoparticles assisted by dual reducing and capping agents,” *Gold Bull.*, vol. 44, no. 2, pp. 119–137, Jun. 2011, doi: 10.1007/s13404-011-0018-5.

Fahmy H. M., Mosleh A. M., Elghany A. A., Shams-Eldin E., Abu Serea E. S., Ashour Ali S., and Shalan A. E. “Coated silver nanoparticles: synthesis, cytotoxicity, and optical properties,” *RSC Adv.*, vol. 9, no. 35, pp. 20118–20136, 2019, doi: 10.1039/C9RA02907A.

Fani S., *et al.*, “Anticancer activity of a monobenzyltin complex C1 against MDA-MB-231 cells through induction of Apoptosis and inhibition of breast cancer stem cells,” *Sci. Rep.*, vol. 6, no. 1, p. 38992, Dec. 2016, doi: 10.1038/srep38992.

Fritea L., *et al.*, “Metal Nanoparticles and Carbon-Based Nanomaterials for Improved Performances of Electrochemical (Bio)Sensors with Biomedical Applications,” *Materials*, vol. 14, no. 21, p. 6319, Oct. 2021, doi: 10.3390/ma14216319.

Fu, L.-M.; Hsu, J.-H.; Shih, M.-K.; Hsieh, C.-W.; Ju, W.-J.; Chen, Y.-W.; Lee, B.-H.; Hou, C.-Y. Process Optimization of Silver Nanoparticle Synthesis and Its Application in Mercury Detection. Micromachines 2021, 12, 1123. https://doi.org/10.3390/mi12091123

Garg D., *et al.*, “Synthesis of silver nanoparticles utilizing various biological systems: mechanisms and applications-a review,” *Prog. Biomater.*, vol. 9, no. 3, pp. 81–95, Sep. 2020, doi: 10.1007/s40204-020-00135-2.

Gautam M., Kim J. O., and Yong C. S., “Fabrication of aerosol-based nanoparticles and their applications in biomedical fields,” *J. Pharm. Investig.*, vol. 51, no. 4, pp. 361–375, Jul. 2021, doi: 10.1007/s40005-021-00523-1.

Gomes H. I. O., Martins C. S. M., and Prior J. A. V., “Silver Nanoparticles as Carriers of Anticancer Drugs for Efficient Target Treatment of Cancer Cells,” *Nanomaterials*, vol. 11, no. 4, p. 964, Apr. 2021, doi: 10.3390/nano11040964.

Guo X. and Mei N., “*Aloe vera*: A review of toxicity and adverse clinical effects,” *J. Environ. Sci. Health Part C*, vol. 34, no. 2, pp. 77–96, Apr. 2016, doi: 10.1080/10590501.2016.1166826.

Gurunathan S., Jeong J.-K., Han J. W., Zhang X.-F., Park J. H., and Kim J.-H., "Multidimensional effects of biologically synthesized silver nanoparticles in Helicobacter pylori, Helicobacter felis, and human lung (L132) and lung carcinoma A549 cells," *Nanoscale Res. Lett.*, vol. 10, no. 1, p. 35, Dec. 2015, doi: 10.1186/s11671-015-0747-0.

Habeeb Rahuman H. B., *et al.*, "Medicinal plants mediated the green synthesis of silver nanoparticles and their biomedical applications," *IET Nanobiotechnol.*, vol. 16, no. 4, pp. 115–144, Jun. 2022, doi: 10.1049/nbt2.12078.

Halawani E. M., Hassan A. M., and Gad El-Rab S. M., "Nanoformulation of Biogenic Cefotaxime-Conjugated-Silver Nanoparticles for Enhanced Antibacterial Efficacy Against Multidrug-Resistant Bacteria and Anticancer Studies," *Int. J. Nanomedicine*, vol. Volume 15, pp. 1889–1901, Mar. 2020, doi: 10.2147/IJN.S236182.

Hamman J., "Composition and Applications of Aloe vera Leaf Gel," *Molecules*, vol. 13, no. 8, pp. 1599–1616, Aug. 2008, doi: 10.3390/molecules13081599.

Hoshyar N., Gray S., Han H., and Bao G., "The effect of nanoparticle size on *in vivo* pharmacokinetics and cellular interaction," *Nanomed.*, vol. 11, no. 6, pp. 673–692, Mar. 2016, doi: 10.2217/nnm.16.5.

Hosseinpour-Mashkani S. S. and Sobhani-Nasab A., "Investigation the effect of temperature and polymeric capping agents on the size and photocatalytic properties of $NdVO_4$ nanoparticles," *J. Mater. Sci. Mater. Electron.*, vol. 28, no. 21, pp. 16459–16466, Nov. 2017, doi: 10.1007/s10854-017-7557-3.

Hussain A., Sharma C., Khan S., Shah K., and Haque S., "Aloe vera Inhibits Proliferation of Human Breast and Cervical Cancer Cells and Acts Synergistically with Cisplatin," *Asian Pac. J. Cancer Prev.*, vol. 16, no. 7, pp. 2939–2946, Apr. 2015, doi: 10.7314/APJCP.2015.16.7.2939.

Javed R., Zia M., Naz S., Aisida S. O., Ul Ain N., and Ao Q., "Role of capping agents in the application of nanoparticles in biomedicine and environmental remediation: recent trends and future prospects," *J. Nanobiotechnology*, vol. 18, no. 1, p. 172, Dec. 2020, doi: 10.1186/s12951-020-00704-4.

Kaviya S., Santhanalakshmi J., and Viswanathan B., "Biosynthesis of silver nano-flakes by Crossandra infundibuliformis leaf extract," *Mater. Lett.*, vol. 67, no. 1, pp. 64–66, 2012, doi: https://doi.org/10.1016/j.matlet.2011.09.023.

Khan I., Saeed K., and Khan I., "Nanoparticles: Properties, applications and toxicities," *Arab. J. Chem.*, vol. 12, no. 7, pp. 908–931, Nov. 2019, doi: 10.1016/j.arabjc.2017.05.011.

Khan U.S, Saleh TA, Wahab A, Khan MH, Khan D, Ullah Khan W, Rahim A, Kamal S, Ullah Khan F, Fahad S. "Nanosilver: new ageless and versatile biomedical therapeutic scaffold", International journal of nanomedicine, Volume 13:733-762, 2018, doi:10.2147/IJN.S153167.

Khan Y., *et al.*, "Classification, Synthetic, and Characterization Approaches to Nanoparticles, and Their Applications in Various Fields of Nanotechnology: A Review," *Catalysts*, vol. 12, no. 11, p. 1386, Nov. 2022, doi: 10.3390/catal12111386.

Khandel P., Yadaw R. K., Soni D. K., Kanwar L., and Shahi S. K., "Biogenesis of metal nanoparticles and their pharmacological applications: present status and application prospects," *J. Nanostructure Chem.*, vol. 8, no. 3, pp. 217–254, Sep. 2018, doi: 10.1007/s40097-018-0267-4.

Kulothungan V., et al., “Burden of cancers in India - estimates of cancer crude incidence, YLLs, YLDs and DALYs for 2021 and 2025 based on National Cancer Registry Program,” BMC Cancer, vol. 22, no. 1, p. 527, Dec. 2022, doi: 10.1186/s12885-022-09578-1.

Kumar CMK, Yugandhar P, Savithramma N. Biological synthesis of silver nanoparticles from Adansonia digitata L. fruit pulp extract, characterization, and its antimicrobial properties. J Intercult Ethnopharmacol. 2016 Jan 27;5(1):79-85. doi: 10.5455/jice.20160124113632.

Kumar V. and Yadav S. K., “Plant-mediated synthesis of silver and gold nanoparticles and their applications,” J. Chem. Technol. Biotechnol., vol. 84, no. 2, pp. 151–157, Feb. 2009, doi: 10.1002/jctb.2023.

Lee B., and Lee D. G., “Synergistic antibacterial activity of gold nanoparticles caused by apoptosis-like death,” J. Appl. Microbiol., vol. 127, no. 3, pp. 701–712, Sep. 2019, doi: 10.1111/jam.14357.

Li C.-C., Chang S.-J., Su F.-J., Lin S.-W., and Chou Y.-C., “Effects of capping agents on the dispersion of silver nanoparticles,” Colloids Surf. Physicochem. Eng. Asp., vol. 419, pp. 209–215, Feb. 2013, doi: 10.1016/j.colsurfa.2012.11.077.

Liaqat N., Jahan N., Khalil-ur-Rahman, Anwar T., and Qureshi H., “Green synthesized silver nanoparticles: Optimization, characterization, antimicrobial activity, and cytotoxicity study by hemolysis assay,” Front. Chem., vol. 10, p. 952006, Aug. 2022, doi: 10.3389/fchem.2022.952006.

Liu, Chang, Yan Cui, Fuwei Pi, Yuliang Cheng, Yahui Guo, and He Qian. 2019. “Extraction, Purification, Structural Characteristics, Biological Activities and Pharmacological Applications of Acemannan, a Polysaccharide from Aloe Vera: A Review.” *Molecules* 24 (8): 1554. https://doi.org/10.3390/molecules24081554.

Logaranjan, Kaliyaperumal, Anasdass Jaculin Raiza, Subash C. B. Gopinath, Yeng Chen, and Kannaiyan Pandian. 2016. “Shape- and Size-Controlled Synthesis of Silver Nanoparticles Using Aloe Vera Plant Extract and Their Antimicrobial Activity.” *Nanoscale Research Letters* 11 (1): 520. https://doi.org/10.1186/s11671-016-1725-x.

Marins J. A. *et al.*, “Colloidal Stability of Aqueous Suspensions of Polymer-Coated Iron Oxide Nanorods: Implications for Biomedical Applications,” *ACS Appl. Nano Mater.*, vol. 1, no. 12, pp. 6760–6772, Dec. 2018, doi: 10.1021/acsanm.8b01558.

McMillan J., Batrakova E., and Gendelman H. E., “Cell Delivery of Therapeutic Nanoparticles,” in Progress in Molecular Biology and Translational Science, vol. 104, Elsevier, 2011, pp. 563–601. doi: 10.1016/B978-0-12-416020-0.00014-0.

Mehrotra R., and Yadav K., “Breast cancer in India: Present scenario and the challenges ahead,” *World J. Clin. Oncol.*, vol. 13, no. 3, pp. 209–218, Mar. 2022, doi: 10.5306/wjco.v13.i3.209.

Mei L., *et al.*, “Multivalent and synergistic chitosan oligosaccharide-Ag nanocomposites for therapy of bacterial infection,” *Sci. Rep.*, vol. 10, no. 1, p. 10011, 2020, doi: 10.1038/s41598-020-67139-7.

Mondal, M.S., Paul, A. & Rhaman, M. Recycling of silver nanoparticles from electronic waste via green synthesis and application of AgNPs-chitosan based nanocomposite on textile material. Sci Rep 13, 13798 (2023). https://doi.org/10.1038/s41598-023-40668-7.

Mukaratirwa-Muchanyereyi N., Gusha C., Mujuru M., Guyo U., and Nyoni S., “Synthesis of silver nanoparticles using plant extracts from Erythrina abyssinica aerial parts and assessment of their anti-bacterial and anti-oxidant activities,” *Results Chem.*, vol. 4, p. 100402, Jan. 2022, doi: 10.1016/j.rechem.2022.100402.

Mustafa H. N, and inas S.mohammed. 2023. “Synthesis of Silver Nanoparticles by Using Aloe Vera and Bio Application.” *Journal of Nanostructures* 13 (1): 59–65. https://doi.org/10.22052/JNS.2023.01.007.

Nallamuthu T., Venkatalakshmi R. P., Chinnasamy A., and Kannaiyan P., “Synthesis of silver nanoparticles and the antibacterial and anticancer activities of the crude extract of sargassum polycystum C. Agardh,” *Nano Biomed. Eng.*, vol. 4, no. 2, pp. 89–94, Apr. 2012, doi: 10.5101/nbe.v4i2.p89-94.

Nguyen N. T. T., Nguyen L. M., Nguyen T. T. T., Nguyen T. T., Nguyen D. T. C., and Tran T. V., “Formation, antimicrobial activity, and biomedical performance of plant-based nanoparticles: a review,” *Environ. Chem. Lett.*, vol. 20, no. 4, pp. 2531–2571, Aug. 2022, doi: 10.1007/s10311-022-01425-w.

Nishanth R. P., Jyotsna R. G., Schlager J. J., Hussain S. M., and Reddanna P., “Inflammatory responses of RAW 264.7 macrophages upon exposure to nanoparticles: Role of ROS-NFκB signaling pathway,” *Nanotoxicology*, vol. 5, no. 4, pp. 502–516, Dec. 2011, doi: 10.3109/17435390.2010.541604.

Pal Singh J., Kumar M., Sharma A., Pandey G., Chae K. H., and Lee S., “Bottom-Up and Top-Down Approaches for MgO,” in *Sonochemical Reactions*, S. Karakuş, Ed. IntechOpen, 2020. doi: 10.5772/intechopen.91182.

Pandit C.,*et al.*, “Biological agents for synthesis of nanoparticles and their applications,” *J. King Saud Univ. - Sci.*, vol. 34, no. 3, p. 101869, Apr. 2022, doi: 10.1016/j.jksus.2022.101869.

Pattekari P., Zheng Z., Zhang X., Levchenko T., Torchilin V., and Lvov Y., “Top-down and bottom-up approaches in production of aqueous nanocolloids of low solubility drug paclitaxel,” *Phys. Chem. Chem. Phys.*, vol. 13, no. 19, p. 9014, 2011, doi:10.1039/c0cp02549f.

Pedroso-Santana S., and Fleitas-Salazar N., “The Use of Capping Agents in the Stabilization and Functionalization of Metallic Nanoparticles for Biomedical Applications,” *Part. Part. Syst. Charact.*, p. 2200146, Dec. 2022, doi: 10.1002/ppsc.202200146.

Prakash Sharma, Prem, et al. "Potentials of hydrogels in cancer therapy." Current Cancer Therapy Reviews 10.3 (2014): 246-270.

Radha M. H. and Laxmipriya N. P., “Evaluation of biological properties and clinical effectiveness of Aloe vera: A systematic review,” *J. Tradit. Complement. Med.*, vol. 5, no. 1, pp. 21–26, Jan. 2015, doi: 10.1016/j.jtcme.2014.10.006.

Rahimi-Nasrabadi M., Ahmadi F., and Eghbali-Arani M., “Simple morphology-controlled fabrication of $CdTiO_3$ nanoparticles with the aid of different capping agents,” *J. Mater. Sci. Mater. Electron.*, vol. 27, no. 12, pp. 13294–13299, Dec. 2016, doi: 10.1007/s10854-016-5478-1.

Rahman S., Carter P., and Bhattarai N., “Aloe Vera for Tissue Engineering Applications,” *J. Funct. Biomater.*, vol. 8, no. 1, p. 6, Feb. 2017, doi: 10.3390/jfb8010006.

Ray P. C., Yu H., and Fu P. P., “Toxicity and Environmental Risks of Nanomaterials: Challenges and Future Needs,” *J. Environ. Sci. Health Part C*, vol. 27, no. 1, pp. 1–35, Feb. 2009, doi: 10.1080/10590500802708267.

Raza M., Kanwal Z., Rauf A., Sabri A., Riaz S., and Naseem S., “Size- and Shape-Dependent Antibacterial Studies of Silver Nanoparticles Synthesized by Wet Chemical Routes,” *Nanomaterials*, vol. 6, no. 4, p. 74, Apr. 2016, doi: 10.3390/nano6040074.

Rónavári A.,*et al.*, “Green Silver and Gold Nanoparticles: Biological Synthesis Approaches and Potentials for Biomedical Applications,” *Molecules*, vol. 26, no. 4, p. 844, Feb. 2021, doi: 10.3390/molecules26040844.

Sahu, Rashmi, et al. "Pharmacological and Therapeutic Properties of Jasminum officinale. L: A Review." *Indian Journal of Ecology* 49.3 (2022): 1122-1128. DOI: https://doi.org/10.55362/IJE/2022/3640

Samuel M. S., *et al.*, “A Review on Green Synthesis of Nanoparticles and Their Diverse Biomedical and Environmental Applications,” *Catalysts*, vol. 12, no. 5, p. 459, Apr. 2022, doi:10.3390/catal12050459.

Shah M., Fawcett D., Sharma S., Tripathy S., and Poinern G., “Green Synthesis of Metallic Nanoparticles via Biological Entities,” *Materials*, vol. 8, no. 11, pp. 7278–7308, Oct. 2015, doi: 10.3390/ma8115377.

Shalabi, Maram, Kh. Khilo, Mahmoud M. Zakaria, Mahmoud G. Elsebaei, Walied Abdo, and Walaa Awadin. 2015. “Anticancer Activity of Aloe Vera and Calligonum Comosum Extracts Separetely on Hepatocellular Carcinoma Cells.” Asian Pacific Journal of Tropical Biomedicine 5 (5): 375–81. https://doi.org/10.1016/S2221-1691(15)30372-5.

Sharma D., Kanchi S., and Bisetty K., “Biogenic synthesis of nanoparticles: A review,” *Arab. J. Chem.*, vol. 12, no. 8, pp. 3576–3600, Dec. 2019, doi: 10.1016/j.arabjc.2015.11.002.

Sharma, Prem & Kumar, Ravindra & Singh, Anil & Singh, Brajendra & Kumar, Ajay & Rathi, Brijesh. (2014). Potentials of Hydrogels in Cancer Therapy. Current Cancer Therapy Reviews. 10. 10.2174/1573394710031502121116 17.

Shi J., Kantoff P. W., Wooster R., and Farokhzad O. C., “Cancer nanomedicine: progress, challenges and opportunities,” *Nat. Rev. Cancer*, vol. 17, no. 1, pp. 20–37, Jan. 2017, doi: 10.1038/nrc.2016.108.

Sidhu A. K., Verma N., and Kaushal P., “Role of Biogenic Capping Agents in the Synthesis of Metallic Nanoparticles and Evaluation of Their Therapeutic Potential,” *Front. Nanotechnol.*, vol. 3, p. 801620, Jan. 2022, doi: 10.3389/fnano.2021.801620.

Singh A. K., Viswanath V., and Janu V. C., “Synthesis, effect of capping agents, structural, optical and photoluminescence properties of ZnO nanoparticles,” *J. Lumin.*, vol. 129, no. 8, pp. 874–878, Aug. 2009, doi: 10.1016/j.jlumin.2009.03.027.

Singh J., Dutta T., Kim K.-H., Rawat M., Samddar P., and Kumar P., ‘Green synthesis of metals and their oxide nanoparticles: applications for environmental remediation,’ *J. Nanobiotechnology*, vol. 16, no. 1, p. 84, Dec. 2018, doi: 10.1186/s12951-018-0408-4.

Song J. Y. and Kim B. S., “Rapid biological synthesis of silver nanoparticles using plant leaf extracts,” *Bioprocess Biosyst. Eng.*, vol. 32, no. 1, pp. 79–84, Jan. 2009, doi: 10.1007/s00449-008-0224-6.

Surjushe A., Vasani R., and Saple D., “Aloe vera: A short review,” *Indian J. Dermatol.*, vol. 53, no. 4, p. 163, 2008, doi: 10.4103/0019-5154.44785.

Thirunavoukkarasu M., Balaji U., Behera S., Panda P.K., Mishra B.K., 'Biosynthesis of silver nanoparticle from leaf extract of Desmodium gangeticum (L.) DC. and its biomedical potential', Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 116, 2013, 424-427, https://doi.org/10.1016/j.saa.2013.07.033.

Tippayawat P., Phromviyo N., Boueroy P., and Chompoosor A., "Green synthesis of silver nanoparticles in aloe vera plant extract prepared by a hydrothermal method and their synergistic antibacterial activity," *PeerJ*, vol. 4, p. e2589, Oct. 2016, doi: 10.7717/peerj.2589.

Tong, Xueli, Min Li, Di Li, Chunqin Lao, Jingmian Chen, Weijie Xu, Junxi Du, Meijiao Zhang, Xiangcai Yang, and Jiejing Li. 2021. "Aloe Vera Gel Extract: Safety Evaluation for Acute and Chronic Oral Administration in Sprague-Dawley Rats and Anticancer Activity in Breast and Lung Cancer Cells." Journal of Ethnopharmacology 280 (November):114434. https://doi.org/10.1016/j.jep.2021.114434.

Vanaja, M., Annadurai, G. Coleus aromaticus leaf extract mediated synthesis of silver nanoparticles and its bactericidal activity. Appl Nanosci 3, 217–223 (2013). https://doi.org/10.1007/s13204-012-0121-9

Vega-Baudrit J., Gamboa S. M., Rojas E. R., and Martinez V. V., "Synthesis and characterization of silver nanoparticles and their application as an antibacterial agent," *Int. J. Biosens. Bioelectron.*, vol. 5, no. 5, 2019, doi: 10.15406/ijbsbe.2019.05.00172.

Vega-Gálvez A., *et al.*, "Influence of high hydrostatic pressure on quality parameters and structural properties of aloe vera gel (*Aloe barbadensis Miller*)," *J. Food Sci. Technol.*, vol. 51, no. 10, pp. 2481–2489, Oct. 2014, doi: 10.1007/s13197-012-0769-x.

Verano-Braga T., *et al.*, "Insights into the Cellular Response Triggered by Silver Nanoparticles Using Quantitative Proteomics," *ACS Nano*, vol. 8, no. 3, pp. 2161–2175, Mar. 2014, doi: 10.1021/nn4050744.

Xu. L, Wang Y.-Y., Huang J., Chen C.-Y., Wang Z.-X., and Xie H., "Silver nanoparticles: Synthesis, medical applications and biosafety", *Theranostics*, vol. 10, no. 20, pp. 8996–9031, 2020, doi: 10.7150/thno.45413.

Zafar A, Rose Rizvi & Irshad Mahmood, "Biofabrication of silver nanoparticles from various plant extracts: blessing to nanotechnology", International Journal of Environmental Analytical Chemistry, 1029-0397, 2019 June 4, ISSN: 0306-7319, DOI: 10.1080/03067319.2019.1622698.

Zhang D., Ma X., Gu Y., Huang H., and Zhang G., "Green Synthesis of Metallic Nanoparticles and Their Potential Applications to Treat Cancer," *Front. Chem.*, vol. 8, p. 799, Oct. 2020, doi: 10.3389/fchem.2020.00799.

11% Overall Similarity

Top sources found in the following databases:

- 8% Internet database
- 8% Publications database
- Crossref database
- Crossref Posted Content database
- 7% Submitted Works database

TOP SOURCES

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	iopscience.iop.org Internet	1%
2	Piyali Basak, Ranabir Majumder, Amrita Jasu, Samrat Paul, Shreya Bis... Crossref	<1%
3	mdpi.com Internet	<1%
4	VIT University on 2014-07-30 Submitted works	<1%
5	University of Salford on 2023-04-27 Submitted works	<1%
6	cdn.intechopen.com Internet	<1%
7	degruyter.com Internet	<1%
8	mts.intechopen.com Internet	<1%

9	University of KwaZulu-Natal on 2024-01-10 Submitted works	<1%
10	Vladislav Egorov, Lenar Valiullin, Ivan Raginov, Stanislav Grabovskiy et ... Crossref	<1%
11	ethnobotany09.providence.wikispaces.net Internet	<1%
12	"Functional Foods and Nutraceuticals", Springer Science and Business ... Crossref	<1%
13	Dr Rajendra Central Agricultural University on 2024-06-02 Submitted works	<1%
14	Laguna State Polytechnic University on 2024-05-21 Submitted works	<1%
15	Riya Raj, Monika Bhattu, Meenakshi Verma, Roberto Acevedo, Nguyen ... Crossref	<1%
16	Visva-Bharati University, Santiniketan on 2015-03-02 Submitted works	<1%
17	dspace.daffodilvarsity.edu.bd:8080 Internet	<1%
18	link.springer.com Internet	<1%
19	nanoscalereslett.springeropen.com Internet	<1%
20	pubmed.ncbi.nlm.nih.gov Internet	<1%

21	vdoc.pub Internet	<1%
22	marketdataforecast.com Internet	<1%
23	toxicolres.org Internet	<1%
24	Jawaharlal Nehru Technological University on 2021-04-22 Submitted works	<1%
25	Our Lady of Fatima University on 2018-03-16 Submitted works	<1%
26	Rowan University on 2023-03-07 Submitted works	<1%
27	Vels University on 2016-11-08 Submitted works	<1%
28	era.ed.ac.uk Internet	<1%
29	"Exploring the Realms of Nature for Nanosynthesis", Springer Science ... Crossref	<1%
30	Jae Yong Song. "Rapid biological synthesis of silver nanoparticles usin... Crossref	<1%
31	M S Ramaiah University of Applied Sciences on 2023-04-23 Submitted works	<1%
32	Nayem Hossain, Mohammad Aminul Islam, Mohammad Asaduzzaman... Crossref	<1%

33	Westerville High School on 2011-01-03 Submitted works	<1%
34	cancerci.biomedcentral.com Internet	<1%
35	ebooks.ons.org Internet	<1%
36	gyan.iitg.ac.in Internet	<1%
37	journals.innovareacademics.in Internet	<1%
38	spectrabase.com Internet	<1%
39	researchgate.net Internet	<1%
40	science.gov Internet	<1%
41	uvlf.sk Internet	<1%