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Recent advances in applications, antimicrobial, cytotoxic activities and their associated mechanism of green silver nanoparticles: A review

Tavga Sulaiman Rashid [a], Yaseen Galali [b,c], Hayman Kakakhan Awla [d], S. Mohammad Sajadi [e,*]

[a] Department of Plant Protection, College of Agricultural Engineering Sciences, Salahaddin University, Erbil, Iraq
[b] Department of Nutrition and Dietetics, Cihan University-Erbil, Erbil, Iraq
[c] Department of Food Technology, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, Erbil, Iraq
[d] Department of Medical Laboratory, Erbil Technical Health and Medical College, Erbil Polytechnic University, Iraq
[e] Department of Chemistry, Payam e Noor University, Saqqez Branch, Iran

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ABSTRACT

Apart from antibiotic resistance, the increasing incidence of cancers is among the serious health challenges facing humans today around the world. These indeed need new and environmentally friendly solutions. In this respect, synthesis and application of nanoparticles simply AgNPs have become of compelling interest within the last few years, especially within the area of biomedicine. The green synthesis of AgNPs using plant extracts is one of the promising eco-friendly methods that has treated microbial infections and acted against cancerous activities. A literature search on databases Web of Science, PubMed, and Scopus was performed between January 2023 and October 2023 in light of PRISMA. Afterward, screening for articles by title and abstract was implemented. Then, retrieved eligible studies were assessed for full-text inclusion criteria analysis. The reviewed findings show that AgNPs have contributed to health-related applications in the development of consumer goods like UV-resistant ointments and cosmetics. Their biomedical application is huge, especially regarding developing diagnosis devices for viruses such as Ebola, yellow fever, and Dengue. AgNPs thereby exhibited formidable antimicrobial action against a wide array of pathogenic microorganisms, each representing Gram-positive and Gram-negative bacteria. It proved to be effective even against antibiotic-resistant strains and pathogenic fungi. Besides this, their anticancer potentialities are quite extraordinary. In short, all these studies have given evidence for outstanding antimicrobial and anticancer efficiencies of biologically synthesized AgNPs to combat some of the serious health issues of the modern era.

1. Introduction

In recent years, the field of nanotechnology has experienced remarkable advancements, revolutionized various industries and opened up new avenues for scientific exploration [87,110];). However, the conventional methods used in nanotechnology often involve the use of toxic chemicals and have adverse environmental impacts. In response to these concerns, researchers have turned their attention to developing sustainable and eco-friendly approaches, giving rise to the concept of green nanotechnology [152,197]. Green nanotechnology focuses on harnessing natural resources and employing environmentally friendly processes to minimize the negative consequences associated with traditional nanotechnology [122];). One promising area within green nanotechnology is the utilization of plant extracts for the synthesis and manipulation of nanoparticles. By capitalizing on the unique properties of plants, researchers are exploring a more sustainable and biocompatible approach to nanomaterial production [64].

Plants have long been recognized for their diverse bioactive compounds, such as polyphenols, flavonoids, alkaloids, and terpenoids [69]. These compounds possess inherent reducing and stabilizing properties, making them ideal candidates for the synthesis of nanoparticles [208]. By using plant extracts as reducing agents, stabilizers, and capping agents, researchers can produce nanoparticles with controlled sizes, shapes, and surface properties [169]. The utilization of plant extracts in green nanotechnology offers several distinct advantages. Firstly, plant extracts are abundant, renewable, and readily available, ensuring a continuous and sustainable supply of raw materials [119,191]. Additionally, the extraction of these bioactive compounds is often achieved

* Corresponding author.
E-mail address: smohammad.sajadi@gmail.com (S. Mohammad Sajadi).

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using environmentally friendly methods, further enhancing the green aspect of the process [130]. Furthermore, plant-based nanoparticles demonstrate biocompatibility, making them suitable for various applications in food and agriculture, energy, environmental remediation and biomedicine [97]: [29].

AgNPs have been of special interest in biomedical field particularly in the scope of antimicrobials and anticancer studies. This is due to the fact that bacterial resistance and cancer increasing cases. Various studies have been conducted to explore the antimicrobial and anticancer activities of silver nanoparticles synthesized from plant extracts [41,42,187,6]; Xu et al., 2023; [28]. These nanoparticles can potentially disrupt cellular pathways, induce apoptosis, and inhibit tumor growth, making them a subject of intense research for their anticancer properties [188,101].

Silver nanoparticles (AgNPs) exhibit their antimicrobial effects through several mechanisms, such as causing damage to the cell membrane, interacting with DNA, generating free radicals, and promoting the development of bacterial resistance [53]. Despite that, the application of nanoparticles particularly AgNPs need to be studies and comprehended.

This review article provides a comprehensive overview of sustainable approaches for synthesizing AgNPs using plant extracts and explores their antimicrobial and anticancer activity.

2. Methods

2.1. Study selection

For the selection of studies, a systematic search of literature was done in different databases including web of science, PubMed and Scopus based on guideline of PRISMA (Moher et al. 2010). The studies were evaluated by assessing the title and abstract from January 2023 to October 2023. The possible eligible researches were retrieved to assessed for further inclusion criteria.

2.2. Study eligibility criteria

For the eligibility criteria, all the in vivo and in vitro trial models' publication studying AgNPs in English language was included during the review process. AgNPs were utilized as keyword to search and all the eligible studies used conducted in antimicrobial and anti-cancer. Reviews, Guidelines, *meta*-analysis and reports were included focusing on antimicrobial and anticancer properties. The included researches were assessed individually. The possible bias risk was checked for the studies. The researches with duplicate or same results were removed.

2.3. The data extraction

The extraction of the data was done for the studies through choosing interested key measures such as antimicrobial, cytotoxicity, cancer cell line, IC50, incubation time, publication years, the plant parts AgNPs synthesized with, AgNPs particle size and shape.

3. Results and discussion

3.1. Application of Ag NPs

AgNPs has been shown to possess unique application in various aspects of research. Several works underlined the fact that, besides these biomedical applications, AgNPs are used in agriculture and in the food industry, namely in functional foods, food packaging, food preservation, and biosensor analysis. The most relevant papers underlined the importance of AgNPs for biomedical sciences apart from agricultural use, as represented in Fig. 1(Xi-Feng et al, 2016; Bryan et al, 2017). AgNPs have also widely been used in the textile industry for imparting UV resistance, antibacterial, and hydrophobic activity. Furthermore, the application of AgNPs is also conducted in textile industry, UV resistant, antibacterial and hydrophobic activity. AgNPs have excellent potential in environmental applications, especially in waste water treatment. They have successfully been used to fight contamination resulting from accidental spillage of harmful substances and bad disposal practices. In

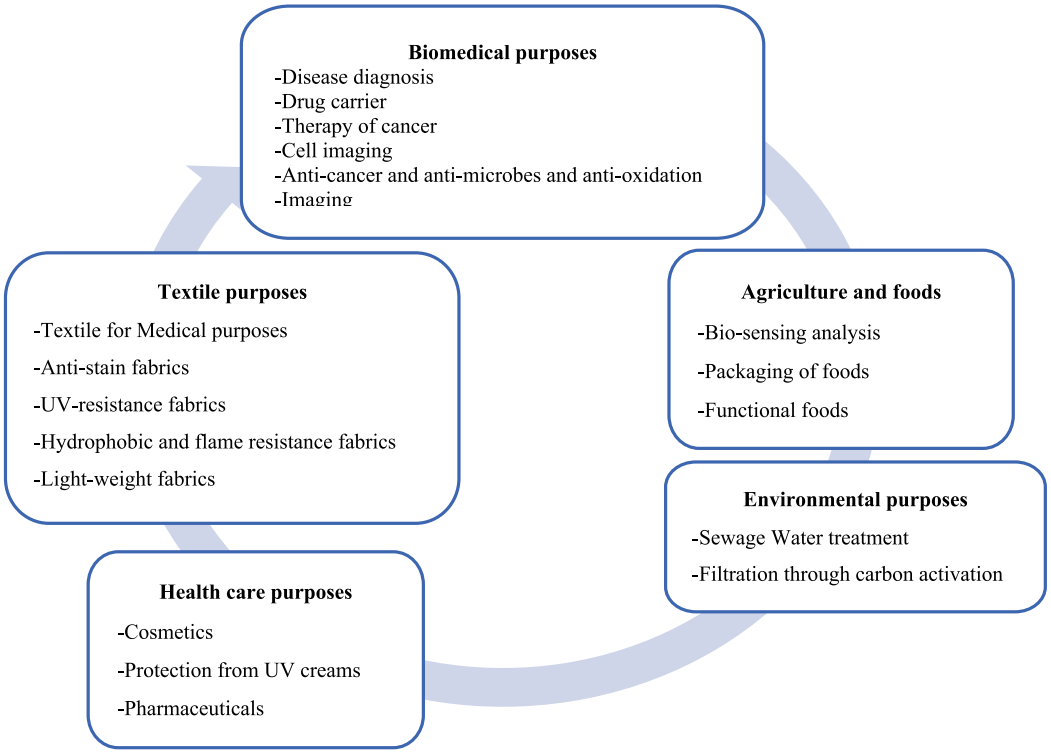

Fig. 1. Application of ag nps in different fields, [reproduced with permission from (Mustapha et al. 2022)].

health, AgNPs have also gained considerable acceptance according to Anjum et al., 2013, and have been incorporated into consumer products such as UV-resistant ointments and cosmetics. AgNPs have represented an important role in a wide range of applications in biomedicine. Current studies have shown the use of AgNPs of different shapes and sizes in the development of diagnostic devices which target viruses such as Ebola, yellow fever, and Dengue among others (Chun-Wan et al, 2015). Further, various studies have demonstrated the potential of biosynthesized AgNPs from plants' extracts as anticancer and antimicrobial agents. This paper discusses further such biomedical applications of AgNPs below.

3.2. Antimicrobial activity against human pathogens

Several recent reports have investigated the antimicrobial activity of Ag NPs synthesized from plant extracts against a spectrum of pathogens, encompassing both human and plant pathogens. Previous studies have employed various plant extracts for the synthesis of these nanoparticles. Table 1 provides an overview of multiple research studies focusing on the synthesis of Ag NPs using plant extracts to combat human pathogens, Table 1.

3.3. Antimicrobial activity against plant pathogens

Various reports and studies show the potential of green AgNPs in combating plant pathogens. For instance, green synthesized AgNPs from the stem bark extracts of plants Boswellia and Shorea and the leaf extract Svensonia, which had a particle size in the range10–50 nm and spherical in shape, exhibited toxicity against *Fusarium oxysporum, Curvularia lunata, Rhizopus arrhizus, Aspergillus niger*, and *Aspergillus flavus* [176]. In 2015, Yugandhar et al. reported antifungal effects of AgNPs derived from the aqueous stem bark extract of Syzygium alternifolium. These nanoparticles exhibited a spherical shape with particle sizes ranging from 4 to 48 nm. They were effective against a range of fungi, including *Alternaria solani, Aspergillus niger, Aspergillus flavus, Penicillium chrysogenum*, and *Trichoderma harzianum*. In the same year, Marslin et al. reported that AgNPs derived from Withania somnifera leaf extracts, characterized by a spherical shape and particle sizes ranging from 70 to 110 nm, effectively inhibited the growth of *Agrobacterium tumefaciens*. AgNPs methanolic extract of *Bergenia ciliata* rhizomes (35 nm) exhibited antifungal activity against *Aspergillus fumigatus, Fusarium solani, Aspergillus niger,* and *A. flavus* [148]. Silver nanoparticles (AgNPs) derived from the aqueous solution of Saudi *Origanum vulgare* L. extract (2–25 nm) was effective in inhibiting the growth of *Alternaria alternate, Paecilomyces variotii*, and *Phialophora alba*, based on the study by Shaik et al. in 2018.

Aqueous extracts of *Psidium guajava* L. leaves with particle sizes of 25 nm exhibited significant inhibition against *Rhizopus oryzae* [207]and *Galega officinalis* showed antimicrobial control against *Pseudomonas syringae* [123]. Aqueous *Melia azedarach* leaf extract with a size of 23 nm functioned as an antifungal agent against *Verticillium dahliae* in eggplants under both in vitro and in vivo conditions [91]. AgNPs produced using stems and flowers of Felty germander (*Teucrium polium* L.) spherical shape and size (10–100 nm) exhibited antifungal activity against *Fusarium oxysporum*, as observed in the study by [72]. Mentha longifolia (20–100 nm) inhibited the growth of *Pectobacterium carotovorum, Xanthomonas oryzae, Xanthomonas vesicatoria*, and *Ralstonia solanacearum*, according to the findings by [90].

The antimicrobial efficacy of *Aaronsohnia factorovskyi* included antifungal activity against *Fusarium oxysporum, Fusarium solani, Helminthosporium rostratum,* and *Alternaria alternata* [8]. Cheeseweed mallow (*Malva parviflora* L.) exhibited antifungal activity against *Helminthosporium rostratum, Fusarium solani, Fusarium oxysporum,* and *Alternaria alternata* [11]. The aqueous extract of *Portulaca oleracea* displayed antifungal effects against *Curvularia spicifera, Macrophomina phaseolina,* and *Bipolaris sp.*[9].

Prunus laurocerasus (cherry laurel) leaf extract also delayed the growth of *Phytopythium vexans, Globisoprangium sylvaticum, G. intermedium, Phytophthora citrophthora* and *Rhizoctonia solani* which cause root and stem rot diseases in kiwifruit [210]. The antibacterial activity of the aqueous extract of Ficus sycomorus leaves was examined by Elkobrosy et al., [58] against *Pectobacterium carotovorum, P. atrosepticum* and *R. solanacearum*. According to Tarighi and Nejad [194], the Cydonia oblonga petal extract was effective under both in vitro and in vivo conditions against *Erwinia amylovora*.

3.4. Mechanisms of Ag NP action on microorganisms

When AgNPs come into contact with microbes, they tend to adhere to the cell wall or membrane of the microorganisms. This binding is a result of the electrostatic attraction between the positive charge of silver ions, generated through AgNP oxidation, and the negatively charged cell membrane of microorganisms [170]. This interaction disrupts the integrity of the cell membrane [93]. Additionally, Ag NPs stimulate the production of reactive oxygen species within microorganisms. Elevated levels of ROS induce oxidative stress, causing damage to cellular components and ultimately leading to cell death [214]. The presence of Ag NPs induces alterations in mitochondrial membrane potential, leading to the uncoupling of respiration. This disruption in mitochondrial function contributes to cellular stress and apoptosis [44]. Ag NPs can also induce DNA damage within microorganisms, resulting in the fragmentation of genetic material. This interference with DNA integrity impedes microbial replication and contributes to the overall antimicrobial effect [35]. Moreover, Ag NPs may interfere with microbial proteins and enzymes, disrupting essential cellular processes. This interference can impact microbial metabolism and compromise vital functions [39]. The release of silver ions from Ag NPs plays a significant role in their antimicrobial activity. These ions can interact with microbial structures, further enhancing the overall antimicrobial effect [47]. All the mechanisms of Ag NPs on microorganisms are illustrated in Fig. 2. It effectively depicts how silver nanoparticles act at multiple sites to exert an antibacterial effect, and that is what makes them potent antimicrobial agents capable of attacking bacterial cells either through physical disruption, genetic damage, or enzymatic interference.

3.5. Anticancer activity of plant silver Nanoparticles

AgNPs derived from various plant parts, including flowers, peels, seeds, roots, stems, and leaves, have been studied for their potential against different types of cancers, such as breast, intestinal, kidney, lung, and stomach cancers (Tables 2). The studies have assessed different cancer lines including MCF-7, DBTRG, U87, MDA-MB-231, U251, COLO 205, HCT 15, HCT-116, HT29, HeLa, AGS, HEP-G2, Callus −7721, HepG2, Hek-293, A549, B16F10, KB, PA1, VCaP and PC3. The Studies have shown that the cytotoxicity of the Ag NPs is mostly dose-dependent. The cytotoxicity of the Ag NPs has been reported by many the studies shown in the table. The DNA inhibition and proliferation, cell apoptosis and cell viability reduction are the most common pathways to show cytotoxic effects.

3.6. Mechanisms of AgNP action on Cancer cells

The proposed and potential mechanism by which AgNPs affect cells and demonstrate anti-cancer properties is shown in Fig. 3 [88]. AgNPs stimulate the generation of reactive oxygen species (ROS), causing cell death. Furthermore, ROS adversely affects signal transduction mechanisms, leading to cell apoptosis. The production of H2O2 influences mitochondrial membrane capacity, resulting in respiration uncoupling [20]. After penetration of AgNPs into the cells, several pathways are altered, leading to the production of ROS, activation of tumor necrosis factor-alpha (TNF-α), and reduction in glutathione levels. Elevated superoxide radical triggers cell death and apoptosis, altering the *trans-*

Table 1
Antimicrobial Activity of Plant-Synthesized Silver Nanoparticles against Human Pathogens (plant parts, Particle Size and Shape).

Plant	Part	Particle size nm	Shape	Microorganism	Reference
Allium cepa	onion broth	33.67	Spherical	*E. coli, S. typhimurium*	[177]
Acalypha indica	Leaves	20–30	Spherical	*E. coli, Vibrio cholerae*	[106]
Solanum torvum	Leaves	125	Spherical	*P. aeruginosa, S. aureus, Aspergillus flavus, A. niger*	[74]
Euphorbia hirta L.	leaves	40–50	Spherical	*Bacillus cereus, B. aureus*	[59]
Cacumen platycladi	Leaves	50–100	Spherical	*E. coli, S. aureus*	[81]
Garcinia mangostana	Leaves	35	Spherical	*E. coli, S. aureus*	[201]
Citrus sinensis	peel	10–35	Spherical	*P. aeruginosa, E. coli,* and *S. aureus*	[99]
Boswellia, Shorea, Svensonia	stem bark and leaves	10–50	Spherical	*B. substilis, Proteus vulgaris, Klebsiella pneumoneae, Aspergillus species, P. aeruginosa*	[176]
Tribulus terrestris L.	fruit bodies	16–28	Spherical	S. pyogens, *P. aeruginosa, E. coli, B. subtilis, S. aureus.*	Gopinath et al., 2012
Leonuri herba		9.9–13.0	Spherical	*P. aeruginosa, E. coli, Enterobacter cloacae*	[85]
Trianthema decandra	Root	36–74	Spherical	*S. aureus, S. faecalis, E. faecalis, E. coli, P. aeruginosa, Proteus vulgaris, B. subtilis, Yersinia enterocolitica, C. albicans*	[71]
Eichornia crassipes	Leaves	10–50	Spherical	*B. subtilis, P. fluorescens, K. pneumonia*	CG [43]
Hibiscus cannabinus	Leaves	9	Spherical	*E. coli, Proteus mirabilis, Shigella flexneri*	[37]
Ceratonia siliqua	leaves	5–40	crystalline in nature and have face-centered cubic geometry.	*E. coli*	[21]
Syzygium cumini	bark	20–60	Spherical	*E. coli, Staphylococcus aureus, P. aeruginosa, Azotobacter chroococcum, B. licheniformis*	[151]
Solanum torvum	fruit	100	Spherical	*E. coli,* Pseudomonas, Bacillus spp.	[158]
Ocimum sanctum (Tulsi)	leaves	18	Spherical	*Staphylococcus aureus, Escherichia coli*	Ramteke et al., 2013
Coleus aromaticus	leaf	44		*B. subtilis, Klebsiella planticola*	[198]
Actaea racemose, Magnolia grandiflora, Aloe sp., *Eucalyptus angophoroides, Sansevieria trifasciata, Impatiens balsamina, Pelargonium graveolens*	leaves	3–15	Spherical	*S. aureus, Kocuria rhizophila, B. thuringiensis, E. coli, P. aeruginosa, S. typhimurium*	[142]
Syzygium cumini, Citrus sinensis, Solanum tricobatum, Centella asiatica	Leaves	53, 41, 52, and 42	Spherical	*P. aeruginosa*	[113]
Alternanthera dentata	Leaves		Spherical	*E. coli, P. aeruginosa, K. pneumonia, Enterococcus faecalis*	Kumar et al., 2014
Pulicaria glutinosa	aerial parts	40–60	Spherical	*E. coli, P. aeruginosa, S. aureus, Micrococcus luteus*	[102]
Tea	leaves	20–90	Spherical	*E. coli*	[190]
Plectranthus amboinicus	leaves	20	Spherical	*E. coli, Penicillium species*	[5]
Malus domestica	Apple fruit		Spherical	*Staphylococcus aureus, Citrobacter koseri, Bacillus cereus, Pseudomonas aeruginosa, Escherichia coli, Candida albicans*	[115]
Acacia leucophloea	bark	17–29	Spherical	*S. aureus, B. cereus, Listeria monocytogenes, Shigella flexneri*	[135]
Parmotrema praesorediosum	lichen	19	Spherical	*Proteus vulgaris, P. aeruginosa,Serratia marcescens, S. typhi, S. epidermidis, S. aureus, B. subtilis,* and *S. faecalis*	[126]
Aloe vera	leaf		Spherical	*B. subtilis, K. pneumoniae, S. typhi*	[51]
Justicia adhatoda L.	leaf	20	Spherical	*P. aeruginosa*	Chatterjee, 2015
Ocimum tenuiflorum, Solanum tricobatum, Syzygium cumini, Centella asiatica, and *Citrus sinensis*	Leaves	28, 26.5, 65, 22.3, and 28.4	Spherical	*S. aureus, P. aeruginosa, E. coli, K. pneumoniae*	[114]
Syzygium alternifolium	stem bark	4 to 48	Spherical	*B. subtilis, S. aureus, E. coli, K. pneumoniae, P. vulgaris, P. aeruginosa, S. typhimurium*	Yugandhar et al., 2015
beetroot	Leaves	15	Spherical	*P. aeruginosa, S. aureus, Streptococcus aureus, E. coli*	[38]
Banana	peel	23.7	Spherical	*B. subtilis, S. aureus, P. aeruginosa, E. coli, C. albicans*	[84]
Clitoria ternatea	whole plant		Spherical	*B. subtilis, S. aureus, E. coli, K. pneumoniae*	[121]
Withania somnifera	Leaves	70–110	Spherical	*S. aureus, P. aeruginosa, Proteus vulgaris, E. coli, C. albicans*	[125].
Capparis spinosa	leaves	10–40	Spherical	*E. coli, S. typhimurium, S. aureus, B. cereus*	[32]
Azadirachta indica	leaves		Spherical	*E. coli*	[206]
Phlomis	Arial parts	25	Spherical	*Staphylococcus aureus, B. cereus, S. typhimurium, E. coli*	[7]
Digitaria radicosa,	leaf	90	Spherical	*S. aureus, E. coli*	[95]

(*continued on next page*)

Table 1 (*continued*)

Plant	Part	Particle size nm	Shape	Microorganism	Reference
Hydrocotyle rotundifolia	leaf	7.39	Spherical	*E. coli*	[108]
Azadirachta indica	Leaves	34	Spherical	*S. aureus, E. coli*	[4]
Aloe vera	gel	5–50	Octahedron	*S. aureus, B. cereus, Micrococcus luteus, E. coli, K. pneumoniae*	[112]
Cacao	Powder	35–42.5	Spherical	*E. coli, P. aeruginosa, S. aureus, S. epidermidis*	[46]
Tamarix gallica	Leaves	5 to 40	Spherical	*E. coli*	[117]
Helicteres isora	root	16–95	Spherical	*S. typhi, P. aeruginosa, B. subtilis, Micrococcus luteus*	[33]
Bergenia ciliata,	rhizomes	35	Spherical	*Micrococcus luteus, S. aureus, Bordetella bronchiseptica, E. aerogenes, Aspergillus fumigatus, A. niger*	[148]
Alstonia scholaris	Leaves		Spherical	*A. flavus, A. fumigatus*	[62]
Luffa acutangula	Fruits	15–41	Spherical	*E. coli, S. cerevisiae*	[98]
Pedalium murex	leaves	20–50	Spherical	*Bacillus subtilis, S. aureus, E. coli, Micrococcus flavus, P. aeruginosa, K. pneumoniae, B. pumilus*	[15]
Callistemon lanceolatus, Decaspermum parviflorum, Eucalyptus citriodora, Melaleuca cajuputi, Rhodomyrtus tomentosa, Syzygiupam campanulatum, Xanthostemon chrysanthus	Leaves			*E. faecalis, S. aureus, Acinetobacter baumannii, E. coli, K.pneumoniae, P. aeruginosa*	[146]
Aloe vera, Portulaca oleracea, and *Cynodon dactylon*	Leaves		Spherical	*B. subtilis, B. cereus, S. aureus, E. faecalis, S. typhi, Shigella species, E. coli, P. aeruginosa, Acinetobacter baumannii*	[1]
Calliandra haematocephala	leaf	70	Spherical	*E. coli*	[154]
Crocus sativus L.	waste materials	10–20	Spherical	*E. coli, P. aeruginosa, K. pneumonia, Shigella flexneri, B. subtilis*	[22]
Azadirachta indica	Leaves		Spherical	*E. coli*	[166]
Coptis Chinensis	rhizome	15	Spherical	*E. coli, B. subtilis*	[3]
Chamaemelum nobile	Flower	24.2	Spherical	*E. coli, S. typhimurium, S. aureus, B. subtilis*	[61]
turmeric	powder	18	Spherical	*E. coli, Listeria monocytogenes*	[13]
pu-erh tea	leaves	4.06	Spherical	*E. coli, K. pneumoniae, S. Typhimurium, S. Enteritidis*	[116]
Origanum vulgare L.	Arial parts	2–25	Spherical	*Shigella sonnei, Micrococcus luteus, E. coli, A. flavus, A. alternate, Paecilomyces variotii, Phialophora alba*	[179]
Datura stramonium	Seeds	20.43	Spherical	*E. coli, S. aureus*	[133]
Phoenix dactylifera, Ferula asafoetida, Acacia nilotica	Fruits	20–60	Spherical	*S. aureus, P. aeruginosa, E. coli*	[131].
Psidium guajava L.	leaves	25	Spherical	*Saccharomyces cerevisiae, A. niger, R. oryzae, B. aryabhattai, B. megaterium, B. subtilis, Arthrobacter creatinolyticus, Alcaligenes faecalis, E. coli*	[207]
Amaranthus tricolor	leaf	40.45	Spherical	*E. coli*	[66]
Ipomoea digitata Linn	flower	–	Spherical	*E. coli and S. epidermidis*	[199]
Camellia sinensis	Green tea powder	–	Spherical	*S. aureus, P. aeruginosa, K. pneumoniae, E. coli, S. enterica,*	[165]
Berberis vulgaris	leaves and roots	30–70	Spherical	*E. coli and S. aureus*	[31]
ginger, garlic, capsicum	Dried powders	20–70	Spherical	*S. aureus, E. coli, C. albicans*	[163]
Galega officinalis	leaves	23	Spherical	*E. coli, S. aureus, P. syringae*	[123]
Ferula gumosa, Ferula latisecta, Teucrium polium, Trachomitum venetum	leaves and stems	5–30	Spherical	*S. aureus, E. coli*	[128]
Impatiens balsamina and Lantana camara	fresh leaves	24	Spherical	*S. aureus, E. coli*	[17]
Fagonia cretica	Whole plant	16	Spherical	*Proteus vulgaris, E. coli, K. pneumoniae*	[215]
Parkia speciosa	leaf	31–35	Spherical	*E. coli, S. aureus, P. aeruginosa, B. subtilis*	[162]
Salvia spinosa	Seeds	19–125	Spherical	*B. subtilis, B. vallismortis, E. coli*	[149]
Semecarpus anacardium, Glochidion lanceolarium, Bridelia retusa	leaf	62.72, 93.23, 74.56	Spherical	*P. aeruginosa, E. coli, S. aureus*	[132]
Carya illinoinensis	leaf	12–30	Spherical	E. coli, P. aeruginosa	[24]
Gymnema sylvestre	leaf	20–30	Spherical	*S. aureus, E. coli*	[156]
Ocimum canum Sims	leaves	15.72	Spherical	*E. coli*	[192]
Ligustrum lucidum	leaf	13	Spherical	*Setosphaeria turcica*	[82]

(*continued on next page*)

Table 1 (*continued*)

Plant	Part	Particle size nm	Shape	Microorganism	Reference
Origanum vulgare, Thymus vulgaris, Syzygium aromaticum L., Rosmarinus officinalis L., and Poiretia latifolia	essential oils	18.6–22.4	Spherical	*S. aureus*	[118]
Withania coagulans	Fruit	10–40	Spherical	*E. faecalis, S. aureus, E. coli, P. vulgaris, S. typhi, Vibrio cholerae*	Keshari et al., 2020
Aaronsohnia factorovskyi	leaves	12–17	Spherical	*S. aureus, B. subtilis, P. aeruginosa, E. coli*	[8]
Citrus limetta	peel	18	Spherical	*Micrococcus luteus, Streptococcus mutans, Staphylococcus epidermidis, Staphylococcus aureus, E. coli, Candida* spp.	[54]
Lysiloma acapulcensis	–	5	Spherical	*E. coli, S. aureus, P. aeruginosa, C. albicans*	[70]
Justicia adhatoda	leaf		Spherical	*S. aureus, E. coli*	[196]
Cestrum nocturnum	leaf	20	Spherical	*E. faecalis, E. coli, S. typhi*	[100]
Hibiscus	leaves	12–17	Spherical	*S. aureus, E. coli,*	[184]
Nymphaea odorata	leaves	20–30	Spherical	*S. aureus, E. coli,*	[156]
Phyla dulcis Trev.	Leaves	63–76	Spherical	*E. coli, S. Typhimurium, L. monocytogenes, S. aureus*	[40]
Origanum vulgare L.	Leaves	1–50	Round	*S. aureus, B. subtilis, E. coli, S. Typhimurium*	[77]
Verthemia Iphionides	essential oil	–	Spherical	*P. aerogenes, E. coli, P. aeruginosa, S. aureus, S. epidermidis*	[14]
Ocimum gratissimum	Leaves	12–60	Spherical, hexagonal and triangular	*E. coli, K. pneumoniae*	[180]
Aloe vera	inner gel	–	Spherical	*S. aureus, E. coli, P. aeruginosa,* Enterobacter species	[16]
Berberis vulgaris, Brassica nigra, Capsella bursa-pastoris, Lavandula angustifolia,Origanum vulgare,	–	41 63–85 2–25 30–70 151–481	spherical, spherical, triangular, Polygonal, octahedral	*S. aureus, Listeria monocytogenes, E. coli, S. enterica ser. Typhimurium, P. aeruginosa*	[168]
Scrophularia striata	leaf	25–40	Spherical	*S. aureus, A. baumannii, E. coli*	[55]
Acacia cyanophylla	Fresh aerial parts	88.11	Spherical	*E. coli*	[89]
Zataria multiflora	Leaves	25.5	Spherical	*S. aureus*	[27]
Areca catechu	Fruits	25	Spherical	*E. faecalis*	[45]
Carissa carandas L.	leaf	35	Spherical	*S. typhimurium, E. faecalis, Shigella flexneri, Citrobacter species, Gonococci species,*	[186]
Clove	buds		Spherical	*S. aureus, P. aeruginosa, K. pneumoniae*	[178]
Convolvulus fruticosus	aerial parts	45	Spherical	*S. aureus, E. faecalis, A. baumannii, E. coli, P. mirabilis, K. pneumonia, and P. aeruginosa*	[182]
Jujube core		25–35	Spherical	*S. aureus, K. pneumoniae and E. coli*	[138]
Beech	Bark	32	Spherical, rarely triangular, and polygonal	*Candida parapsilosis, C. guilliermondii, C. albicans, C. guilliermondii*	[124]
Spondias mombin	leaf	17	Spherical	*Staphylococcus epidermidis, S. typhi, Proteus mirabilis, Enterobacter cloacae, E. coli, P. aeruginosa*	[171]
Citrus limon	zest	7–28	Cubic	*E. coli, S. aureus, C. albicans*	[104]
Alhagi graecorum	Leaves	10–80	Spherical	*Candida albicans, C. glabrata, C. parapsilosis, C. tropicalis, C. krusei*	[78]
Daucus carota L.	leaf	18.26	Spherical	*E. coli, S. aureus, α-Hemolytic streptococcus, Aspergillus candidus, A. niger, P. cephalosporin*	[56]
Glochidion candolleanum	Leaves	10	spherical and ellipsoidal	*Salmonella enterica and P. aeruginosa*	[25]
Cymbopogon citratus	leaf	47	spherical	*E. coli, S. paratyphi, B. cereus, Vibrio cholera, Shigella flexneri*	[157]
Annona muricata L.	leaf	570	spherical	*E. coli, S. aureus, B. subtilis, A. niger, C. albicans*	[63]
Lawsonia inermis Linn.	Leaves	3.48–19.34	spherical	*Acinetobacter baumannii, K. pneumoniae, Enterococcus faecalis, E. coli, P. aeruginosa, Proteus mirabilis, Staphylococcus arlettae*	[167]
Schinus terebinthifolius Raddi	leaves		spherical	*P. aeruginosa, C. albicans, C. glabrata*	[67]
Petroselinum crispum	seed	30–50	spherical	*E. coli, K. pneumoniae, S. aureus, S. mutans, S. mitis* and *E. faecalis*	[213]
Pistacia vera Sambucus ebulus	hull rhizome	19.32 15.63	spherical	*S. aureus, E. faecalis*	Hashemi et al., 2023
Mentha pulegium Crocus caspius	Leaves	34.5 47.2	spherical	*P. aeruginosa, A. baumannii, K. pneumonia*	Hashemi et al., 2023
Couroupita guianensis	Flower	20	spherical	*B. subtilis, E. coli*	[111]
Aloe vera	gel	80	spherical	*Candida albicans*	[18]

(*continued on next page*)

Table 1 (*continued*)

Plant	Part	Particle size nm	Shape	Microorganism	Reference
Moringa oleifera	seed	90–180	spherical	*E. coli*	Coelho et al. in 2023
Premna integrifolia	root		spherical	*P. aeruginosa, S. aureus, E. coli*	[185]
Moringa oleifera	Fresh leaves	25.235	spherical	*K. pneumoniae, E. coli, Acinetobacter baumannii, P. aeruginosa*	[211]
Tradescantia pallidum var. *purpurea*	leaves	23	spherical	*B. subtilis, P. aeruginosa, S. aureus, E. coli*	[136]
Vernonia amygdalina	leaves	100	spherical	*Streptococcus pyogenes, S. aureus, E. coli, P. aeruginosa*	[195]
Piper betle L.	leaf	20	spherical	*E. coli, S. aureus, C. albicans, A. niger*	Nguyen et al., 2023
Polygonum minus	leaves	6 – 21	spherical	*K. pneumoniae, S. aureus, E. coli, B. subtilis*	[137]
Artemisia sieberi	Shoot	27.5	spherical	*S. aureus, B. subtilis, E. coli, and P. aeruginosa, Candida parapsilosis, C. krusei, C. famata, C. rhodotorula, C. albicans*	[10]
Olive	leaf	28	spherical	*Listeria monocytogenes, B. cereus, S. aureus, Yersinia enterocolitica, Campylobacter jejuni, E. coli*	[12]
Salvia officinalis	Leaves	20	Crystallinity	*S. typhimurium, P. aeruginosa, S. aureus, E. coli*	[193]
Pyrostegia venusta	leaf	12.56	spherical	*Enterococcus faecalis, E. coli, C. albicans, C. glabrata*	[34]
Argyreia nervosa	leaf	10–40	spherical	*E. coli*	[147]
Pyrus pashia	stem barks	23.92	spherical and polydispersed	*E. coli, S. aureus, E. faecalis, S. typhi, Shigella sonnei*	[103]
Juglans regia	Leaves	16–20	spherical	*Aspergillus ochraceus*	[141]
Lippia abyssinica	leaf	26.64–34.29	spherical	*E. coli, S. aureus*	[183]
Cullen tomentosum (Thunb.) J.W. Grimes	whole plant	37	spherical	*B. cereus, S. aureus*	[19]
Teucrium apollinis	Leaves	16	spherical	*P. aeruginosa*	[2]
Croton macrostachyus	leaves and bark	8.9–13.68	spherical	*S. pyogenes, P. aeruginosa*	[49]
Lavandula stoechas	aerial parts	45–65	spherical	*K. pneumoniae, P. mirabilis, E. coli, and S. aureus*	[105]

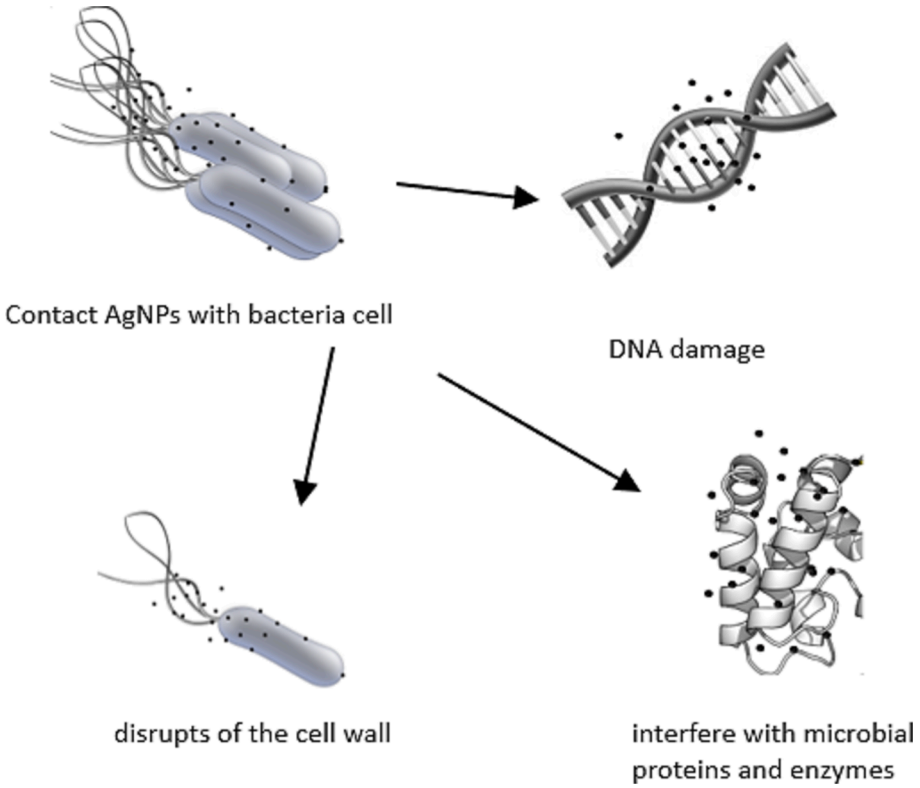

Fig. 2. The effects of green nanoparticles on microorganisms: mechanisms and impacts, [reproduced with permission from (Sameena and Thoppil 2022)].

membrane potential of mitochondria and changing signal pathways [65]. The increased ROS levels and reduced glutathione provoke damage to cell components, including DNA fragmentation, lipid membrane peroxidation, and protein carbonylation. Moreover, the alteration of mitochondrial membrane activates caspases 3 and 9, leading to cell apoptosis. As a result, c-Jun NH2 terminal kinase is activated,

Table 2
Anticancer Activity of Plant-Synthesized Ag NPs: A comparative analysis by cancer type, plant part, and main outcomes.

References	Cancer types	Plants type and Parts	Cell line	The main outcome
[23]	Breast Cancer	Achillea biebersteinii- flower	MCF-7	Viability of cell in DNA inhibited the induction and proliferation of Cell apoptosis on MCF-7 through simulation of programmed genes of dead cells and subspecific gene cycle suppression.
[68]	Breast Cancer	Alternanthera sessilis (Aerial Parts)	MCF-7	AgNPs Presented profound cytotoxic manifestation reaching IC50 value 3.04 μg/mL in comparison to the standard rug (Cisplatin)
[52]	Breast Cancer	Mangifera indica (Seed)	MCF-7	The AgNPs presented moderate (dose dependent) cytotoxic activity
(P. [174]	Breast Cancer	Alternanthera tenella (Leaf part)	MCF-7	AgNPs showed dose dependent cell inhibition activity and MCF-7 cell migration. The IC50 value of the AgNPs was calculated to be 42.5 μg mL (−1)
[57]	Breast Cancer	Andrographis echioides (Leaf)	MCF-7	MCF-7 proliferation was inhibited by AgNPs at 31.5 μg/mL after incubation for 24 h
[181]	Breast Cancer	Citrullus colocynthis (fruits, see, root and leaf)	MCF-7	AgNPs showed affective cytotoxity activity against human breast cancer cell line.
(G. [173]	Breast Cancer	Dendrophthoe falcata (L.f) Ettingsh (Leaf and Mistletoe)	MCF-7	AgNPs can be developed as an imminent alternative for cancer therapy
[161]	Breast Cancer	Erythrina indica (Root)	MCF-7	AgNPs showed significant cytotoxic potent
[134]	Breast Cancer	Olax scandens (Leaf)	MCF-7	AgNPs showed anti-cancer activity
(Castro-Aceituno et al. 2016)	Breast Cancer	Panax ginseng (Leaf)	MCF-7	AgNPs found to be effective cell viability inhibition and oxidative stress induced in MCF7 cell line
[164]	Breast Cancer	Piper longum (Leaf)	MCF-7	AgNPs Showed anti-cancer properties against breast cancer cell lines and IC 50 seemed to be 67 μg/ml/ after 24hr incubation
[80]	Breast Cancer	Quercus (genus) (Fruit Hull)	MCF-7	AgNPs IC50 was seen to be 50 at 0.04 μg/mL after 24 hr incubation
(Deepika Sharma, Lalita Ledwani 2015)	Breast Cancer	Rheum emodi (roots)	MCF-7	AgNPs manifested significant cytotoxic activity against human breast cancer cell line
(Jannathul Firdhouse M 2015)	Breast Cancer	Sesbania grandiflora (Leaf)	MCF-7	AgNPs showed cytotoxic effect. IC_{50} value seen to be 3.04 μg/mL in comparison standard cisplatin drug
[159]	Breast Cancer	Solanum trilobatum (Fruits)	MCF-7	AgNPs showed anti-cancer activity
[127]	Breast Cancer	Syzygium cumini (Flower)	MCF-7	AgNPs at 10 μg/mL was affective against HeLa cells line
[204]	Breast Cancer	Syzygium aromaticum (Fruits)	MCF-7	AgNPs was highly active against breast cancer at 10 to 100 μg
(P. Devaraj, Chirom Aarti 2014)	Breast Cancer	Tabernae montana divaricate (Leaf)	MCF-7	AgNPs showed cytotoxic properties agaist breast cancer cell line (MCF-7)
[94]	Breast Cancer	Taxus baccata (Needles)	MCF-7	AgNPs manifested anticancer properties against MCF-7 cells line with value of IC_{50} at 0.25 μg mL − 1 after 2 days incubation
[36]	Breast Cancer	Ulva lactuca (whole plant)	MCF-7	AgNPs showed mild cytotoxic against human breast cancer cell line
[83]	Breast Cancer	Lantana camara (leaf)	MCF-7	AgNPs demonstrated anti-cancer activity against breast cancer cell line with IC_{50} reaching 46.67 g/mL
[50]	Breast Cancer	Cymodocea Serrulata (Whole parts)	MCF-7	AgNPs demonstrated potential cytotoxicity against breast cancer cells
[73]	Breast cancer	*Tamarindus indica (*fruit shell)	MCF-7	AgNPs demonstrated potential cytotoxicity against breast cancer cells and IC50 seen to be 20 μg/ml
(Lan et al,2023)	Breast cancer	*Callisia fragrans* (leaf)	MCF-7	AGNPs showed anticancer properties and IC50 value showed to be 2.41 μg/ml
[140]	Breast and brain cancer	Luffa acutangula (Leaf)	(DBTRG and U87) and (MCF-7 and MDA-MB-231)	AgNPs showed promising anti-cancer properties.
[212]	Brain	*Taxus wallichiana* (leaf)	U251	AgNPs showed promising result against brain cell line of cancer
(Mata, Reddy Nakkala, and Rani Sadras 2015)	Colon Cancer	Plumeria alba (Flower)	COLO 205	AgNPs showed cytotoxic effect at IC_{50} Seen to be 5.5 and 4 μg/ml respectively after one two days incubation
[175]	Colon Cancer	Citrullus colocynthis (Callus)	COLO 205	AgNPs showed affective cytotoxic activity against human colon cancer cell line.
[150]	Colon Cancer	Vitex Nigundo (Leaf)	HCT 15	AgNPs stimulated −inhibitory impact on HCT15 growth by suppressing proliferative growth cancer cells
(Manikandan et al. 2015)	Colon Cancer	Rosa indica (Petal)	HCT 15	AgNPs showed anticancer properties through protein expression through caspase 3 as well as 9
[109]	Colon Cancer	Commelina L. (Whole)	HCT-116	AgNPs showed cell viability reduction and improved cytotoxicity colon cancer cell line (IC50 concentration found to be of 100–200 μg/ml, respectively
(Kantha Deivi Arunachalam, Lilly Baptista Arun, Sathesh Kumar Annamalai 2015)	Colon Cancer	*Gymnema sylvestre* (Leaf)	HT29	AgNPs proved anti-cancer properties against cancer cell line cells and may Be used as potential anticancer drugs
[48]	Colon Cancer	Anthemis atropatana (Flower)	HT29	Maximum cytotoxity seen at 100 μg/ml

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Table 2 (*continued*)

References	Cancer types	Plants type and Parts	Cell line	The main outcome
[202]	Colon Cancer	*Zingiber officinale* and *Curcuma longa (rhizome)*	HT29	AgNPs showed cytotoxis properties IC_{50} value was at 150.8 μg/mL concentration ranged from 25 to 500 μg/mL.
[127]	Cervical Cancer	Syzygium cumini (Flower)	HeLa	AgNPs at 10 μg/mL was affective against HeLa cells line
[75]	Cervical Cancer	Sargassum vulgare (algae) (Whole)	HeLa	AgNPs can serve as anticancer agent by preventing the irradiation through carcinogenesis
[92]	Cervical Cancer	Podophyllum hexandrum (Leaf)	HeLa	AgNPs showed selectively prevent the HeLa cellular mechanism through DNA damage as well as caspase-mediated death of cell
[200]	Cervical Cancer	Moringa olifera (Stem Bark)	HeLa	AgNPs demonstrated apoptosis induction via generation of ROS in HeLa cancer cell line
[189]	Cervical Cancer	Melia Azedarach (Leaf)	HeLa	AgNPs showed dose-dependent cytotoxic properties. Lethal dose seen to be 300 μg/mL against HeLa cancer cell line.
(Meenatchi and Vijistella Bai 2014)	Cervical Cancer	Heliotropium indicum (Leaf)	HeLa	The anti-cancer properties AgNPs Was dose and duration dependant. The AgNPs significantly inhibited cell growth of cancerous cells.
[155]	Cervical Cancer	Calotropis Gigantean (Latex)	HeLa	AgNPs showed cytotoxic activity and a promising as therapeutic agent
[139]	Cervical Cancer	Acorous calamus (Rhizome)	HeLa	AgNPs showed potential cytotoxicity and IC_{50} after 24 and 48 h was noticed HeLa cells to be 92.48 and 69.44 μg/ml
(Mousavi, Tafvizi, and Zaker Bostanabad 2018)	Gastric ulcer	Artemisia turcomanica (leaf)	AGS	Dose dependant AGNPs showed anti-cancer, cytotoxic and induced apoptosis
[107]	Hepatic Cancer	Rubus glaucus benth (Leaf)	HEP-G2	AgNPs proved no cytotoxicity at the concentration ranging from 0.01 μM to 1.0 μM on Hepatic cancer cell line.
[161]	Hepatic Cancer	Erythrina indica (Root)	HEP-G2	AgNPs showed significant cytotoxic potent
(Castro-Aceituno et al. 2016)	Hepatic Cancer	Panax ginseng (Leaf)	HEP-G2	AgNPs found to be effective cell viability inhibition and oxidative stress induction in HEP-G2 cell line
[145]	Hepatic Cancer	Allium sativum (Whole)	HEP-G2	AgNPs exerted induction and cytotoxic properties in many apoptotic cells even using low coincentration of the NPs from A. sativum
[209]	Hepatic Cancer	Taxus yunnanensis	Callus −7721	AgNPs showed strong anti-cancer properties
(Lan et al, 2023)	Hepatic Cancer	Callisia fragrans (leaf)	HepG2	AGNPs showed anticancer properties and IC50 alue showed to be 2.23 μg/ml
[127]	Kidney Cancer	Syzygium cumini (Flower)	Hek-293	AgNPs at 10 μg/mL was affective against HeLa cells line
[75]	Leukemia Cancer	Sargassum vulgare (algae) (Whole)	HL-60	AgNPs showed anti-cancer properties through anti-oxidant and prophylactic agents
(Mollick et al. 2019)	Lymphoma Cancer	Abelmoschus esculentus (Pulp)	Jurkat	AgNPs effectively decreased membrane potential of mitochondria and improved in cell apoptosis
[36]	Laryngeal Cancer	Ulva lactuca (algae) (Whole)	Hep-2	AgNPs showed mild cytotoxic against human Laryngeal cancer cell line
(Satyavani Kaliamur, Selvaraj Gurudeeban, Ramanathan T. 2012)	Laryngeal Cancer	Suaeda monoica (Leaf)	Hep-2	Synthesised AgNPs at 500 nM showed IC50
[175]	Laryngeal Cancer	Citrullus colocynthis (Callus)	Hep-2	AgNPs significantly decreased cancer cell line viability to half. The authors promise and reasonable alternative to chemical drugs
[204]	Laryngeal Cancer	Syzygium aromaticum (Fruit)	A549	AgNPs was highly active against Laryngeal cancer cell line at 10 to 100 μg
(Kalyani Khanra, Sudipta Panja, Indranil Choudhuri, Anindita Chakraborty 2015)	Lung Cancer	Scoparia dulcis (Leaf)	A549	AgNPs showed more cytotoxic effect on lung cancer comparing to other cancers and might offer therapeutic benefits
[83]	Lung Cancer	Lantana camara (leaf)	A549	AgNPs demonstrated anti-cancer activity against breast cancer cell line with IC_{50} reaching 49.52 g/mL
[203]	Lung Cancer	Rosa damascena (Petal)	A549	AgNPs showed anti-cancer activity and IC50 as 80 μg/mL.
[120]	Lung Cancer	Penicillium decumbens (MTCC 2494) (all the parts)	A549	AgNPs demonstrated sufficient anti-cancer properties after 24 hr incubation at at 80 μg·mL
(Castro-Aceituno et al. 2016)	Lung Cancer	Panax ginseng (Leaf)	A549	AgNPs found to be effective cell viability inhibition and oxidative stress induction in A549 cell line
[172]	Lung Cancer	Origanum vulgare (Leaf)	A549	AgNPs, Showed dose dependant against lung cancer cell line. Lethal dose reached 100 μg/ml.
[134]	Lung Cancer	Olax scandens (Leaf)	A549	The plant showed promising anticancer activity.
[96]	Lung Cancer	Gossypium hirsutum (Leaf)	A549	Cytoxicity of AgNPs seemed to be dose-dependent against A549 cancer cell line. IC50 value was 40 g/mL concentration
[144]	Lung Cancer	Cymodocea serrulata (Leaf)	A549	synthesized AgNPs demonstrated possible cytotoxicity A549 cell line (LD50 = 100 μg/ml)
[76]	Lung Cancer	Artemisia princeps (Leaf)	A549	AgNPs, Helped A549 mitochondrial-mediated cell line apoptosis
[26]	Melanoma Cancer	Excoecaria agallocha L. (Leaf)	B16F10	AgNPs exerted cytotoxicity in vitro and in vivo experiments
[86]	Oral Cancer	Haliclona exigua (Whole)	KB	AgNPs showed anti-cancer properties. The IC_{50} showed to be 0.6 μg/ml
(Bhattacharyya 2016)	Ovarian Cancer	Croton bonplandianum (Leaf)	PA1	AgNPs showed significant anti-cancer
(Kalyani Khanra, Sudipta Panja, Indranil Choudhuri, Anindita Chakraborty 2015)	Ovarian Cancer	Scoparia dulcis (Leaf)	PA1	AgNPs showed less cytotoxity on ovarian cell line comparing to lung cancer

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Table 2 (*continued*)

References	Cancer types	Plants type and Parts	Cell line	The main outcome
[79]	Prostate Cancer	Dimocarpus longan Lour (Peel)	VCaP	AgNPs demonstrated dose-dependent anticancer properties against prostate cancer cell line via reducing sutvivin, bcl-2 and stat3 and improve caspase-3
[153]	Prostate Cancer	Gracilaria edulis (All the parts)	PC3	AgNPs showed less anticancer activity which was 62 % than the ZnoNPs (70 %)
[68]	Prostate Cancer	Alternanthera sessilis (Leaf)	PC3	AgNPs showed significant effect on cancer cell line.
[30]	Breast cancer	*Crataegus monogyna*	PC3	AgNPs showed significant effect on breast cancer cell line.
[129]	acute lymphoblastic leukemia	*Hedera colchica*	PC3	The anticancer activity of AgNPs was conducted on acute lymphoblastic leukemia

ROS = reactive oxygen species.

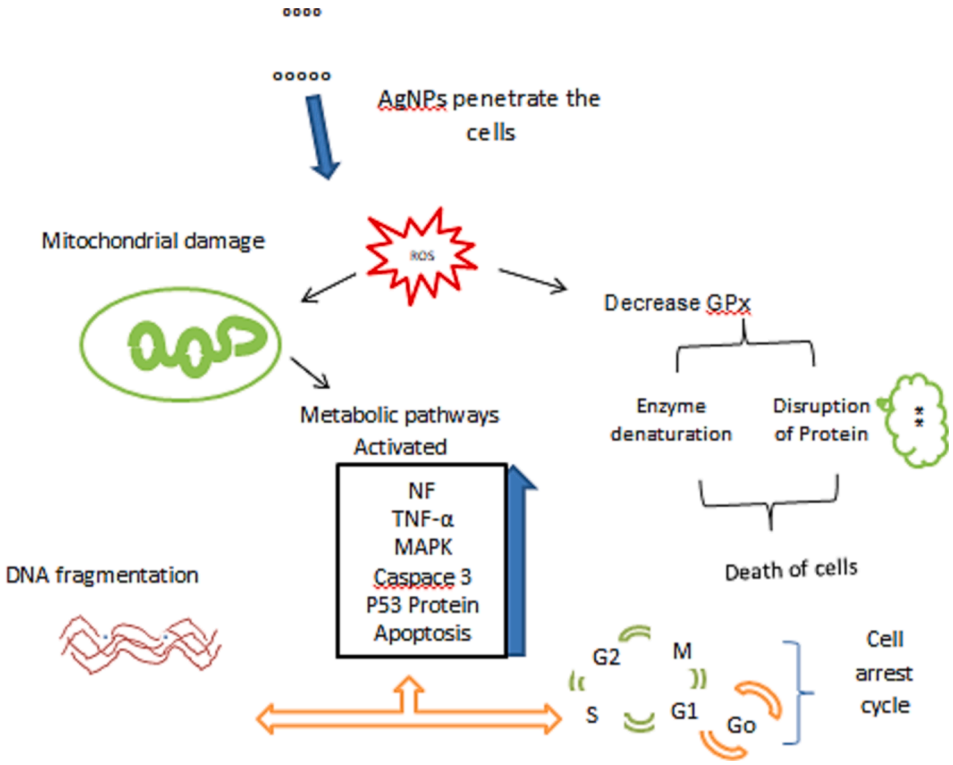

Fig. 3. Proposed anticancer and cytotoxic AgNPs mechanism Glutathione Peroxidase (GPx), [Reproduced with permission from (Jabeen et al. 2021)].

stimulating the formation of apoptotic bodies and disrupting DNA, leading to cycles of cell arrest [205].

Whereby, under thehypothesis of Folkman, blood is responsible in the growth and metastatic spread of malignant cells through neovascularization by facilitating nutrients and oxygen necessary for attacking other cells. In relation to that, AgNPs had demonstrated preventing neovascularization of the retina through inhibiting the growth factors of neovascularization stimulated by endothelial vasculara and ERK1/2 signals via phosphorylation of receptor-2 of endothelial growth factor. AgNPs hence have anti-carcinogenic characteristics due to which it finds its application in cancer therapy [160]. Other proposed mechanisms, pointed out by previous studies, include production of ROS and disturbance of cellular equilibrium, up-regulation of caspase 3 and p53 activation, silver ion generation depending on pH, selective attacking of cancer cells, sub G1 level arresting cell cycle and caspase-induced apoptosis and mitochondrial pathways [60]. Another suggests that AgNPs-induced p53 up-regulation leads to the toxicity of cells [143].

4. Conclusions

This review pinpoints enormous potential for plant-based green-synthesized AgNPs as a potent intervention against human and plant pathogens and new anticancer therapies. In various literatures, the potential antimicrobial efficacy of AgNPs was reportedly very effective, especially against *E. coli* and *S. aureus*, with well-understood mechanisms of action at the nanoscale. Nevertheless, to this date, research has remained largely confined to controlled laboratory settings with minimal application in the real world, especially in plant pathology. These findings point to two important features, the imminent need for an environmentally friendly substitute in the fight against antibiotic-resistant pathogens and the forthcoming potential of AgNPs in cancer treatment. On the other hand, there is a big weakness, most of the researches about AgNPs are theoretical, with only a few studies on agricultural application or in-vivo testing. Further studies should aim to extend their applications in plant-related pathogen controls and conduct practical in vivo experiments to realize their full potential. In summary, the promise of green AgNPs in biomedical applications is reassured; however, it should be translated into application and subsequent steps for practical therapeutic and agricultural uses.

CRediT authorship contribution statement

Tavga Sulaiman Rashid: Writing – original draft. **Yaseen Galali:** Validation, Project administration. **Hayman Kakakhan Awla:** Writing – review & editing, Writing – original draft, Validation. **S. Mohammad Sajadi:** Supervision.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

No data was used for the research described in the article.

References

[1] T.A. Abalkhil, S.A. Alharbi, S.H. Salmen, M. Wainwright, Bactericidal activity of biosynthesized silver nanoparticles against human pathogenic bacteria, Biotechnology & Biotechnological Equipment 31 (2) (2017) 411–417.
[2] W. Abdussalam-Mohammed, L. Mohamed, M.S. Abraheem, M.M. Mansour, A. M. Sherif, Biofabrication of Silver Nanoparticles Using Teucrium Apollinis Extract: Characterization, Stability, and Their Antibacterial Activities, Chemistry 5 (1) (2023) 54–64.
[3] A. Ahmad, Y. Wei, F. Syed, K. Tahir, A.U. Rehman, A. Khan, Q. Yuan, The effects of bacteria-nanoparticles interface on the antibacterial activity of green synthesized silver nanoparticles, Microbial Pathogenesis 102 (2017) 133–142.
[4] S. Ahmed, M. Ahmad, B.L. Swami, S. Ikram, Green synthesis of silver nanoparticles using Azadirachta indica aqueous leaf extract, Journal of Radiation Research and Applied Sciences 9 (1) (2016) 1–7.
[5] B. Ajitha, Y.A.K. Reddy, P.S. Reddy, Biosynthesis of silver nanoparticles using Plectranthus amboinicus leaf extract and its antimicrobial activity, Spectrochimica Acta Part a: Molecular and Biomolecular Spectroscopy 128 (2014) 257–262.
[6] N.S. Alduraihem, R.S. Bhat, S.A. Al-Zahrani, D.M. Elnagar, H.M. Alobaid, M. H. Daghestani, Anticancer and antimicrobial activity of silver nanoparticles synthesized from pods of Acacia nilotica, Processes 11 (2) (2023) 301.
[7] A.R. Allafchian, S.Z. Mirahmadi-Zare, S.A.H. Jalali, S.S. Hashemi, M.R. Vahabi, Green synthesis of silver nanoparticles using phlomis leaf extract and investigation of their antibacterial activity, Journal of Nanostructure in Chemistry 6 (2016) 129–135.
[8] F. Al-Otibi, R.A. Al-Ahaidib, R.I. Alharbi, R.M. Al-Otaibi, G. Albasher, Antimicrobial potential of biosynthesized silver nanoparticles by Aaronsohnia factorovskyi extract, Molecules 26 (1) (2020) 130.
[9] F. Al-Otibi, S.A. Alfuzan, R.I. Alharbi, A.A. Al-Askar, R.M. Al-Otaibi, H.F. Al Subaie, N.M. Moubayed, Comparative study of antifungal activity of two preparations of green silver nanoparticles from Portulaca oleracea extract, Saudi Journal of Biological Sciences 29 (4) (2022) 2772–2781.
[10] F. Al-Otibi, N.A. Alshammry, R.I. Alharbi, M.N. Bin-Jumah, M.M. AlSubaie, Silver Nanoparticles of Artemisia sieberi Extracts: Chemical Composition and Antimicrobial Activities, Plants 12 (11) (2023) 2093.
[11] F. Al-Otibi, K. Perveen, N.A. Al-Saif, R.I. Alharbi, N.A. Bokhari, G. Albasher, M. A. Al-Mosa, Biosynthesis of silver nanoparticles using Malva parviflora and their antifungal activity, Saudi Journal of Biological Sciences 28 (4) (2021) 2229–2235.
[12] B.F. Alowaiesh, H.A.S. Alhaithloul, A.M. Saad, A.A. Hassanin, Green Biogenic of Silver Nanoparticles Using Polyphenolic Extract of Olive Leaf Wastes with Focus on Their Anticancer and Antimicrobial Activities, Plants 12 (6) (2023) 1410.
[13] F.K. Alsammarraie, W. Wang, P. Zhou, A. Mustapha, M. Lin, Green synthesis of silver nanoparticles using turmeric extracts and investigation of their antibacterial activities, Colloids and Surfaces b: Biointerfaces 171 (2018) 398–405.
[14] N.M. Al-Tawarah, H. Qaralleh, A.M. Khlaifat, M.N. Nofal, M. Alqaraleh, K. M. Khleifat, M.A. Al Shhab, Anticancer and antibacterial properties of verthemia iphionides essential oil/silver nanoparticles, Biomed. Pharmacol. J 13 (3) (2020) 1175–1185.
[15] K. Anandalakshmi, J. Venugobal, V.J.A.N. Ramasamy, Characterization of silver nanoparticles by green synthesis method using Pedalium murex leaf extract and their antibacterial activity, Applied Nanoscience 6 (2016) 399–408.
[16] T.R. Anju, S. Parvathy, M.V. Veettil, J. Rosemary, T.H. Ansalna, M. M. Shahzabanu, S. Devika, Green synthesis of silver nanoparticles from Aloe vera leaf extract and its antimicrobial activity, Materials Today: Proceedings 43 (2021) 3956–3960.
[17] Aritonang, H. F., Koleangan, H., & Wuntu, A. D. (2019). Synthesis of silver nanoparticles using aqueous extract of medicinal plants'(Impatiens balsamina and Lantana camara) fresh leaves and analysis of antimicrobial activity. *International journal of microbiology*, *2019*.
[18] M.M.J. Arsène, P.I. Viktorovna, M. Alla, M. Mariya, S.A. Nikolaevitch, A.K. L. Davares, D. Milana, Antifungal activity of silver nanoparticles prepared using Aloe vera extract against Candida albicans, Veterinary World 16 (1) (2023) 18.
[19] J.A. Asong, E.K. Frimpong, H.A. Seepe, L. Katata-Seru, S.O. Amoo, A.O. Aremu, Green Synthesis of Characterized Silver Nanoparticle Using Cullen tomentosum and Assessment of Its Antibacterial Activity, Antibiotics 12 (2) (2023) 203.
[20] A. Avalos, A.I. Haza, D. Mateo, P. Morales, Interactions of Manufactured Silver Nanoparticles of Different Sizes with Normal Human Dermal Fibroblasts, International Wound Journal 13 (1) (2016) 101–109.
[21] A.M. Awwad, N.M. Salem, A.O. Abdeen, Green synthesis of silver nanoparticles using carob leaf extract and its antibacterial activity, International Journal of Industrial Chemistry 4 (2013) 1–6.
[22] G. Bagherzade, M.M. Tavakoli, M.H. Namaei, Green synthesis of silver nanoparticles using aqueous extract of saffron (Crocus sativus L.) wastages and its antibacterial activity against six bacteria, Asian Pacific Journal of Tropical Biomedicine 7 (3) (2017) 227–233.
[23] J. Baharara, F. Namvar, T. Ramezani, M. Mousavi, R. Mohamad, Silver Nanoparticles Biosynthesized Using Achillea Biebersteinii Flower Extract: Apoptosis Induction in MCF-7 Cells via Caspase Activation and Regulation of Bax and Bcl-2 Gene Expression, Molecules (basel, Switzerland) 20 (2) (2015) 2693–2706.
[24] bakht Dalir, S. J., Djahaniani, H., Nabati, F., & Hekmati, M. (2020). Characterization and the evaluation of antimicrobial activities of silver nanoparticles biosynthesized from Carya illinoinensis leaf extract. *Heliyon*, *6*(3).
[25] R. Balachandar, R. Navaneethan, M. Biruntha, K.K.A. Kumar, M. Govarthanan, N. Karmegam, Antibacterial activity of silver nanoparticles phytosynthesized from Glochidion candolleanum leaves, Materials Letters 311 (2022) 131572.
[26] K. Banerjee, S. Das, P. Choudhury, S. Ghosh, R. Baral, S.K. Choudhuri, A Novel Approach of Synthesizing and Evaluating the Anticancer Potential of Silver Oxide Nanoparticles in Vitro, Chemotherapy 62 (5) (2017) 279–289.
[27] H. Barabadi, F. Mojab, H. Vahidi, B. Marashi, N. Talank, O. Hosseini, M. Saravanan, Green synthesis, characterization, antibacterial and biofilm inhibitory activity of silver nanoparticles compared to commercial silver nanoparticles, Inorganic Chemistry Communications 129 (2021) 108647.
[28] A. Baran, et al., Green-Synthesized Characterization, Antioxidant and Antibacterial Applications of CtAC/MNPs-Ag Nanocomposites, Pharmaceuticals 17 (6) (2024) 772.
[29] M.F. Baran, et al., Green synthesis of silver nanoparticles from Allium cepa L. Peel extract, their antioxidant, antipathogenic, and anticholinesterase activity, Molecules 28 (5) (2023) 2310.
[30] F. Barzegarparay, H. Najafzadehvarzi, R. Pourbagher, H. Parsian, S.M. Ghoreishi, S. Mortazavi-Derazkola, Green synthesis of novel selenium nanoparticles using Crataegus monogyna extract (SeNPs@ CM) and investigation of its toxicity, antioxidant capacity, and anticancer activity against MCF-7 as a breast cancer cell line, Biomass Conversion and Biorefinery (2023) 1–10.
[31] M. Behravan, A.H. Panahi, A. Naghizadeh, M. Ziaee, R. Mahdavi, A. Mirzapour, Facile green synthesis of silver nanoparticles using Berberis vulgaris leaf and root aqueous extract and its antibacterial activity, International Journal of Biological Macromolecules 124 (2019) 148–154.
[32] F. Benakashani, A.R. Allafchian, S.A.H. Jalali, Biosynthesis of silver nanoparticles using Capparis spinosa L. leaf extract and their antibacterial activity. *Karbala International Journal of Modern*, Science 2 (4) (2016) 251–258.
[33] S. Bhakya, S. Muthukrishnan, M. Sukumaran, M. Muthukumar, Biogenic synthesis of silver nanoparticles and their antioxidant and antibacterial activity, Applied Nanoscience 6 (2016) 755–766.
[34] M.P. Bhat, R.S. Kumar, A.I. Almansour, N. Arumugam, K. Dupadahalli, M. Rudrappa, S. Nayaka, Characterization, antimicrobial activity and anticancer activity of Pyrostegia venusta leaf extract-synthesized silver nanoparticles against COS-7 cell line, Applied Nanoscience 13 (3) (2023) 2303–2314.
[35] S. Bhatt, V.D. Punetha, R. Pathak, M. Punetha, Graphene in nanomedicine: A review on nano-bio factors and antibacterial activity, Biointerfaces, Colloids and Surfaces B, 2023, p. 113323.
[36] Bhimba, J. Saraniya Devi and B. Valentin. 2012. "Anticancer Activity of Silver Nanoparticles Synthesized by the Seaweed Ulva Lactuca Invitro" 1. https://doi.org/10.4172/scientificreports.242.
[37] M.R. Bindhu, M. Umadevi, Synthesis of monodispersed silver nanoparticles using Hibiscus cannabinus leaf extract and its antimicrobial activity, Spectrochimica Acta Part a: Molecular and Biomolecular Spectroscopy 101 (2013) 184–190.
[38] M.R. Bindhu, M. Umadevi, Antibacterial and catalytic activities of green synthesized silver nanoparticles, Spectrochimica Acta Part a: Molecular and Biomolecular Spectroscopy 135 (2015) 373–378.

[39] A.C. Burduşel, O. Gherasim, A.M. Grumezescu, L. Mogoantă, A. Ficai, E. Andronescu, Biomedical applications of silver nanoparticles: an up-to-date overview, Nanomaterials 8 (9) (2018) 681.

[40] L. Carson, S. Bandara, M. Joseph, T. Green, T. Grady, G. Osuji, S. Woldesenbet, Green synthesis of silver nanoparticles with antimicrobial properties using Phyla dulcis plant extract, Foodborne Pathogens and Disease 17 (8) (2020) 504–511.

[41] V. Castro-Aceituno, S. Ahn, S.Y. Simu, P. Singh, R. Mathiyalagan, H.A. Lee, D. C. Yang, Anticancer activity of silver nanoparticles from Panax ginseng fresh leaves in human cancer cells, Biomedicine & Pharmacotherapy 84 (2016) 158–165.

[42] V. Castro-Aceituno, S. Ahn, S.Y. Simu, P. Singh, R. Mathiyalagan, H.A. Lee, D. C. Yang, Anticancer Activity of Silver Nanoparticles from Panax Ginseng Fresh Leaves in Human Cancer Cells, Biomedicine & Pharmacotherapy = Biomedecine & Pharmacotherapie 84 (December) (2016) 158–165.

[43] CG Kiruba Daniel, S., Nehru, K., & Sivakumar, M. (2012). Rapid biosynthesis of silver nanoparticles using Eichornia crassipes and its antibacterial activity. *Current Nanoscience*, *8*(1), 125-129.

[44] M. Chichova, M. Shkodrova, P. Vasileva, K. Kirilova, D. Doncheva-Stoimenova, Influence of silver nanoparticles on the activity of rat liver mitochondrial ATPase, Journal of Nanoparticle Research 16 (2014) 1–14.

[45] J.S. Choi, H.C. Jung, Y.J. Baek, B.Y. Kim, M.W. Lee, H.D. Kim, S.W. Kim, Antibacterial activity of green-synthesized silver nanoparticles using Areca catechu extract against antibiotic-resistant bacteria, Nanomaterials 11 (1) (2021) 205.

[46] N.R. Chowdhury, M. MacGregor-Ramiasa, P. Zilm, P. Majewski, K. Vasilev, 'Chocolate'silver nanoparticles: Synthesis, antibacterial activity and cytotoxicity, Journal of Colloid and Interface Science 482 (2016) 151–158.

[47] T.C. Dakal, A. Kumar, R.S. Majumdar, V. Yadav, Mechanistic basis of antimicrobial actions of silver nanoparticles, Frontiers in Microbiology 7 (2016) 1831.

[48] S. Dehghanizade, J. Arasteh, A. Mirzaie, Green Synthesis of Silver Nanoparticles Using Anthemis Atropatana Extract: Characterization and in Vitro Biological Activities, Artificial Cells, Nanomedicine, and Biotechnology 46 (1) (2018) 160–1118.

[49] K.D. Dejen, D.Y. Kibret, T.H. Mengesha, E.T. Bekele, A. Tedla, T.A. Bafa, F. T. Derib, Green synthesis and characterisation of silver nanoparticles from leaf and bark extract of Croton macrostachyus for antibacterial activity, Materials Technology 38 (1) (2023) 2164647.

[50] E. Dilipan, P. Sivaperumal, K. Kamala, M. Ramachandran, P. Vivekanandhan, Green Synthesis of Silver Nanoparticles Using Seagrass Cymodocea Serrulata (R. Br.) Asch. & Magnus, Characterization, and Evaluation of Anticancer, Antioxidant, and Antiglycemic Index, Biotechnology and Applied Biochemistry 70 (3) (2023) 1346–1356.

[51] D. Dinesh, K. Murugan, P. Madhiyazhagan, C. Panneerselvam, P. Mahesh Kumar, M. Nicoletti, U. Suresh, Mosquitocidal and antibacterial activity of green-synthesized silver nanoparticles from Aloe vera extracts: towards an effective tool against the malaria vector Anopheles stephensi? Parasitology Research 114 (2015) 1519–1529.

[52] S. Donga, G.R. Bhadu, S. Chanda, Antimicrobial, Antioxidant and Anticancer Activities of Gold Nanoparticles Green Synthesized Using Mangifera Indica Seed Aqueous Extract, Artificial Cells, Nanomedicine, and Biotechnology 48 (1) (2020) 1315–1325.

[53] N. Durán, M. Durán, M.B. De Jesus, A.B. Seabra, W.J. Fávaro, G. Nakazato, Silver nanoparticles: A new view on mechanistic aspects on antimicrobial activity, Nanomedicine: Nanotechnology, Biology and Medicine 12 (3) (2016) 789–799.

[54] T. Dutta, N.N. Ghosh, M. Das, R. Adhikary, V. Mandal, A.P. Chattopadhyay, Green synthesis of antibacterial and antifungal silver nanoparticles using Citrus limetta peel extract: Experimental and theoretical studies, Journal of Environmental Chemical Engineering 8 (4) (2020) 104019.

[55] M.A. Ebrahimzadeh, Z. Hashemi, M. Mohammadyan, M. Fakhar, S. Mortazavi-Derazkola, In vitro cytotoxicity against human cancer cell lines (MCF-7 and AGS), antileishmanial and antibacterial activities of green synthesized silver nanoparticles using Scrophularia striata extract, Surfaces and Interfaces 23 (2021) 100963.

[56] I.P. Ejidike, H.S. Clayton, Green synthesis of silver nanoparticles mediated by Daucus carota L.: antiradical, antimicrobial potentials, in vitro cytotoxicity against brain glioblastoma cells, Green Chemistry Letters and Reviews 15 (2) (2022) 298–311.

[57] K. Elangovan, D. Elumalai, S. Anupriya, R. Shenbhagaraman, P.K. Kaleena, K. Murugesan, Phyto Mediated Biogenic Synthesis of Silver Nanoparticles Using Leaf Extract of Andrographis Echioides and Its Bio-Efficacy on Anticancer and Antibacterial Activities, Journal of Photochemistry and Photobiology. b, Biology 151 (August) (2015) 118–124.

[58] D. Elkobrosy, A.A. Al-Askar, H. El-Gendi, Y. Su, R. Nabil, A. Abdelkhalek, S. Behiry, Nematocidal and Bactericidal Activities of Green Synthesized Silver Nanoparticles Mediated by Ficus sycomorus Leaf Extract, Life 13 (5) (2023) 1083.

[59] E.K. Elumalai, T.N.V.K.V. Prasad, J. Hemachandran, S.V. Therasa, T. Thirumalai, E. David, Extracellular synthesis of silver nanoparticles using leaves of Euphorbia hirta and their antibacterial activities, J Pharm Sci Res 2 (9) (2010) 549–554.

[60] H.J. Eom, J. Choi, P38 MAPK Activation, DNA Damage, Cell Cycle Arrest and Apoptosis as Mechanisms of Toxicity of Silver Nanoparticles in Jurkat T Cells, Environmental Science & Technology 44 (21) (2010) 8337–8342.

[61] H. Erjaee, H. Rajaian, S. Nazifi, Synthesis and characterization of novel silver nanoparticles using Chamaemelum nobile extract for antibacterial application, Advances in Natural Sciences: Nanoscience and Nanotechnology 8 (2) (2017) 025004.

[62] A.S. Ethiraj, S. Jayanthi, C. Ramalingam, C. Banerjee, Control of size and antimicrobial activity of green synthesized silver nanoparticles, Materials Letters 185 (2016) 526–529.

[63] S.A. Ezeamalu, P.C. Aleke, P.F. Uzor, Antimicrobial Evaluation and Characterization of Green Synthesized Silver Nanoparticles Using Annona muricata L. Leaf Extract. *S. Asian Res*, J. Nat. Prod 6 (2) (2023) 64–73.

[64] A.E. Fadiji, D.M.N. Mthiyane, D.C. Onwudiwe, O.O. Babalola, Harnessing the known and unknown impact of nanotechnology on enhancing food security and reducing postharvest losses: Constraints and future prospects, Agronomy 12 (7) (2022) 1657.

[65] Fani, Somayeh, Behnam Kamalidehghan, Kong Mun Lo, Siamak Ebrahimi Nigjeh, Yeap Swee Keong, Firouzeh Dehghan, Rahman Soori, et al. 2016. "Anticancer Activity of a Monobenzyltin Complex C1 against MDA-MB-231 Cells through Induction of Apoptosis and Inhibition of Breast Cancer Stem Cells." Scientific Reports 2016 6:1 6 (1): 1–15.

[66] I. Fatimah, Z.H.V.I. Aftrid, Characteristics and antibacterial activity of green synthesized silver nanoparticles using red spinach (Amaranthus Tricolor L.) leaf extract, Green Chemistry Letters and Reviews 12 (1) (2019) 25–30.

[67] M.D. Ferreira, L.C.D.S. Neta, G.C. Brandao, W.N.L. Dos Santos, Evaluation of the antimicrobial activity of silver nanoparticles biosynthesized from the aqueous extract of Schinus terebinthifolius Raddi leaves, Biotechnology and Applied Biochemistry 70 (3) (2023) 1001–1014.

[68] M.J. Firdhouse, P. Lalitha, Biosynthesis of Silver Nanoparticles Using the Extract of Alternanthera Sessilis-Antiproliferative Effect against Prostate Cancer Cells, Cancer Nanotechnology 4 (6) (2013) 137–143.

[69] Y. Galali, Z.A. Omar, S.M. Sajadi, Biologically Active Components in By-Products of Food Processing, Food Science and. Nutrition. 8 (2020) 3004–3022.

[70] D. Garibo, H.A. Borbón-Nuñez, J.N.D. de León, E. García Mendoza, I. Estrada, Y. Toledano-Magaña, A. Susarrey-Arce, Green synthesis of silver nanoparticles using Lysiloma acapulcensis exhibit high-antimicrobial activity, Scientific Reports 10 (1) (2020) 12805.

[71] R. Geethalakshmi, D.V.L. Sarada, Gold and silver nanoparticles from Trianthema decandra: synthesis, characterization, and antimicrobial properties, International Journal of Nanomedicine (2012) 5375–5384.

[72] S. Ghojavand, M. Madani, J. Karimi, Green synthesis, characterization and antifungal activity of silver nanoparticles using stems and flowers of felty germander, Journal of Inorganic and Organometallic Polymers and Materials 30 (2020) 2987–2997.

[73] A.C. Gomathi, S.R. Xavier Rajarathinam, A. Mohammed Sadiq, S. Rajeshkumar, Anticancer Activity of Silver Nanoparticles Synthesized Using Aqueous Fruit Shell Extract of Tamarindus Indica on MCF-7 Human Breast Cancer Cell Line, Journal of Drug Delivery Science and Technology 55 (February) (2020).

[74] K. Govindaraju, S. Tamilselvan, V. Kiruthiga, G. Singaravelu, Biogenic silver nanoparticles by Solanum torvum and their promising antimicrobial activity, Journal of Biopesticides 3(Special Issue), 394 (2010).

[75] K. Govindaraju, K. Krishnamoorthy, S.A. Alsagaby, G. Singaravelu, M. Premanathan, Green Synthesis of Silver Nanoparticles for Selective Toxicity towards Cancer Cells, IET Nanobiotechnology 9 (6) (2015) 325–330.

[76] Gurunathan, Sangiliyandi, Jae Kyo Jeong, Jae Woong Han, Xi Feng Zhang, Jung Hyun Park, and Jin Hoi Kim. 2015. "Multidimensional Effects of Biologically Synthesized Silver Nanoparticles in Helicobacter Pylori, Helicobacter Felis, and Human Lung (L132) and Lung Carcinoma A549 Cells." Nanoscale Research Letters 2015 10:1 10 (1): 1–17.

[77] S. Hambardzumyan, N. Sahakyan, M. Petrosyan, M.J. Nasim, C. Jacob, A. Trchounian, Origanum vulgare L. extract-mediated synthesis of silver nanoparticles, their characterization and antibacterial activities, AMB Express 10 (2020) 1–11.

[78] S.N. Hawar, H.S. Al-Shmgani, Z.A. Al-Kubaisi, G.M. Sulaiman, Y.H. Dewir, J. J. Rikisahedew, Green synthesis of silver nanoparticles from Alhagi graecorum leaf extract and evaluation of their cytotoxicity and antifungal activity, Journal of Nanomaterials 2022 (2022) 1–8.

[79] He, Yan, Zhiyun Du, Shijing Ma, Shupeng Cheng, Sen Jiang, Yue Liu, Dongli Li, Huarong Huang, Kun Zhang, and Xi Zheng. 2016. "Biosynthesis, Antibacterial Activity and Anticancer Effects Against Prostate Cancer (PC-3) Cells of Silver Nanoparticles Using Dimocarpus Longan Lour. Peel Extract." Nanoscale Research Letters 11 (1).

[80] R. Heydari, M. Rashidipour, Green Synthesis of Silver Nanoparticles Using Extract of Oak Fruit Hull (Jaft): Synthesis and in Vitro Cytotoxic Effect on Mcf-7 Cells, International Journal of Breast Cancer (2015), 2015 (January.

[81] J. Huang, G. Zhan, B. Zheng, D. Sun, F. Lu, Y. Lin, Q. Li, Biogenic silver nanoparticles by Cacumen platycladi extract: synthesis, formation mechanism, and antibacterial activity, Industrial & Engineering Chemistry Research 50 (15) (2011) 9095–9106.

[82] W. Huang, M. Yan, H. Duan, Y. Bi, X. Cheng, H. Yu, Synergistic antifungal activity of green synthesized silver nanoparticles and epoxiconazole against Setosphaeria turcica, Journal of Nanomaterials 2020 (2020) 1–7.

[83] L.V. Hublikar, S.V. Ganachari, V.B. Patil, S. Nandi, A. Honnad, Anticancer Potential of Biologically Synthesized Silver Nanoparticles Using Lantana Camara Leaf Extract, Progress in Biomaterials 12 (2) (2023) 155–169.

[84] H.M. Ibrahim, Green synthesis and characterization of silver nanoparticles using banana peel extract and their antimicrobial activity against representative microorganisms, Journal of Radiation Research and Applied Sciences 8 (3) (2015) 265–275.

[85] A.R. Im, L. Han, E.R. Kim, J. Kim, Y.S. Kim, Y. Park, Enhanced antibacterial activities of Leonuri herba extracts containing silver nanoparticles, Phytotherapy Research 26 (8) (2012) 1249–1255.

[86] D. Inbakandan, C. Kumar, M. Bavanilatha, D.N. Ravindra, R. Kirubagaran, S. Ajmal Khan, Ultrasonic-Assisted Green Synthesis of Flower like Silver Nanocolloids Using Marine Sponge Extract and Its Effect on Oral Biofilm Bacteria and Oral Cancer Cell Lines, Microbial Pathogenesis 99 (October) (2016) 135–141.

[87] P. İpek, et al., Green synthesis and evaluation of antipathogenic, antioxidant, and anticholinesterase activities of gold nanoparticles (Au NPs) from Allium cepa L. peel aqueous extract, Biomass Conversion and Biorefinery 14 (9) (2024) 10661–10670.

[88] S. Jabeen, R. Qureshi, M. Munazir, M. Maqsood, M. Munir, S.S.H. Shah, B. Z. Rahim, Application of Green Synthesized Silver Nanoparticles in Cancer Treatment—a Critical Review, Materials Research Express 8 (9) (2021) 092001.

[89] J. Jalab, W. Abdelwahed, A. Kitaz, R. Al-Kayali, Green synthesis of silver nanoparticles using aqueous extract of Acacia cyanophylla and its antibacterial activity, Heliyon 7 (9) (2021).

[90] B. Javed, A. Nadhman, Optimization, characterization and antimicrobial activity of silver nanoparticles against plant bacterial pathogens phyto-synthesized by Mentha longifolia, Materials Research Express 7 (8) (2020) 085406.

[91] S. Jebril, R.K.B. Jenana, C. Dridi, Green synthesis of silver nanoparticles using Melia azedarach leaf extract and their antifungal activities: In vitro and in vivo, Materials Chemistry and Physics 248 (2020) 122898.

[92] M. Jeyaraj, M. Rajesh, R. Arun, D. MubarakAli, G. Sathishkumar, G. Sivanandhan, G.K. Dev, et al., An Investigation on the Cytotoxicity and Caspase-Mediated Apoptotic Effect of Biologically Synthesized Silver Nanoparticles Using Podophyllum Hexandrum on Human Cervical Carcinoma Cells, Colloids and Surfaces. b, Biointerfaces 102 (February) (2013) 708–717.

[93] A.S. Joshi, P. Singh, I. Mijakovic, Interactions of gold and silver nanoparticles with bacterial biofilms: Molecular interactions behind inhibition and resistance, International Journal of Molecular Sciences 21 (20) (2020) 7658.

[94] A.A. Kajani, A.K. Bordbar, S.H.Z. Esfahani, A.R. Khosropour, A. Razmjou, Green Synthesis of Anisotropic Silver Nanoparticles with Potent Anticancer Activity Using Taxus Baccata Extract, RSC Advances 4 (106) (2014) 61394–61403.

[95] T. Kalaiyarasu, N. Karthi, G.V. Sharmila, V. Manju, In vitro assessment of antioxidant and antibacterial activity of green synthesized silver nanoparticles from Digitaria radicosa leaves, Asian J Pharm Clin Res 9 (1) (2016).

[96] N. Kanipandian, R. Thirumurugan, A Feasible Approach to Phyto-Mediated Synthesis of Silver Nanoparticles Using Industrial Crop Gossypium Hirsutum (Cotton) Extract as Stabilizing Agent and Assessment of Its in Vitro Biomedical Potential, Industrial Crops and Products 55 (April) (2014) 1–10.

[97] I. Karmous, A. Pandey, K.B. Haj, A. Chaoui, Efficiency of the green synthesized nanoparticles as new tools in cancer therapy: insights on plant-based bioengineered nanoparticles, biophysical properties, and anticancer roles, Biological Trace Element Research 196 (2020) 330–342.

[98] J. Kaushal, J. Bhatti, P. Kumar, Green synthesis and physico-chemical study of silver nanoparticles extracted from a natural source Luffa acutangula, Journal of Molecular Liquids 224 (2016) 991–998.

[99] S. Kaviya, J. Santhanalakshmi, B. Viswanathan, J. Muthumary, K. Srinivasan, Biosynthesis of silver nanoparticles using Citrus sinensis peel extract and its antibacterial activity, Spectrochimica Acta Part a: Molecular and Biomolecular Spectroscopy 79 (3) (2011) 594–598.

[100] A. Keshari, R. Srivastava, S. Yadav, G. Nath, S. Gond, Synergistic activity of green silver nanoparticles with antibiotics, Nanomedicine Research Journal 5 (1) (2020) 44–54.

[101] A.T. Khalil, M. Ovais, J. Iqbal, A. Ali, M. Ayaz, M. Abbas, H.P. Devkota, Microbes-Mediated Synthesis Strategies of Metal Nanoparticles and Their Potential Role in Cancer Therapeutics Vol. 86 (2022) 693–705.

[102] M. Khan, S.T. Khan, M. Khan, S.F. Adil, J. Musarrat, A.A. Al-Khedhairy, H. Z. Alkhathlan, Antibacterial properties of silver nanoparticles synthesized using Pulicaria glutinosa plant extract as a green bioreductant, International Journal of Nanomedicine (2014) 3551–3565.

[103] L.N. Khanal, P.P. Dhakal, M.R. Kandel, D. Acharya, E.R. Baral, K. Chhetri, S. K. Kalauni, Stem Bark-Mediated Green Synthesis of Silver Nanoparticles from Pyrus pashia: Characterization, Antioxidant, and Antibacterial Properties, Inorganics 11 (6) (2023) 263.

[104] Y. Khane, K. Benouis, S. Albukhaty, G.M. Sulaiman, M.M. Abomughaid, A. Al Ali, N. Dizge, Green synthesis of silver nanoparticles using aqueous Citrus limon zest extract: Characterization and evaluation of their antioxidant and antimicrobial properties, Nanomaterials 12 (12) (2022) 2013.

[105] Z. Kiani, S. Mirjalili, K. Heydaryan, P. Mohammadparast, H. Aramjoo, F. Bahraini, S. Mortazavi-Derazkola, Harmonizing nature and nanotechnology: Phytoextract-mediated synthesis of Ag-doped ZnO nanoparticles using Lavandula stoechas extract for environmental and biomedical applications, Journal of Drug Delivery Science and Technology 96 (2024) 105708.

[106] C. Krishnaraj, E.G. Jagan, S. Rajasekar, P. Selvakumar, P.T. Kalaichelvan, M. Mohan, Synthesis of silver nanoparticles using Acalypha indica leaf extracts and its antibacterial activity against water borne pathogens, Colloids and Surfaces b: Biointerfaces 76 (1) (2010) 50–56.

[107] B. Kumar, K. Smita, R. Seqqat, K. Benalcazar, M. Grijalva, L. Cumbal, In Vitro Evaluation of Silver Nanoparticles Cytotoxicity on Hepatic Cancer (Hep-G2) Cell Line and Their Antioxidant Activity: Green Approach for Fabrication and Application, Journal of Photochemistry and Photobiology b: Biology 159 (June) (2016) 8–13.

[108] R. Kumari, G. Brahma, S. Rajak, M. Singh, S. Kumar, Antimicrobial activity of green silver nanoparticles produced using aqueous leaf extract of Hydrocotyle rotundifolia, Oriental Pharmacy and Experimental Medicine 16 (2016) 195–201.

[109] P. Kuppusamy, S.J.A. Ichwan, P.N.H. Al-Zikri, W.H. Suriyah, I. Soundharrajan, N. Govindan, G.P. Maniam, M.M. Yusoff, In Vitro Anticancer Activity of Au, Ag Nanoparticles Synthesized Using Commelina Nudiflora L. Aqueous Extract Against HCT-116 Colon Cancer Cells, Biological Trace Element Research 173 (2) (2016) 297–305.

[110] A. Laucht, F. Hohls, N. Ubbelohde, M.F. Gonzalez-Zalba, D.J. Reilly, S. Stobbe, J. Baugh, Roadmap on quantum nanotechnologies, Nanotechnology 32 (16) (2021) 162003.

[111] S. Logambal, T. Thilagavathi, M. Chandrasekar, C. Inmozhi, P.B.E. Kedi, F. A. Bassyouni, K. Kaviyarasu, Synthesis and antimicrobial activity of silver nanoparticles: incorporated couroupita guianensis flower petal extract for biomedical applications, Journal of King Saud University-Science 35 (1) (2023) 102455.

[112] K. Logaranjan, A.J. Raiza, S.C. Gopinath, Y. Chen, K. Pandian, Shape-and size-controlled synthesis of silver nanoparticles using Aloe vera plant extract and their antimicrobial activity, Nanoscale Research Letters 11 (2016) 1–9.

[113] P. Logeswari, S. Silambarasan, J. Abraham, Ecofriendly synthesis of silver nanoparticles from commercially available plant powders and their antibacterial properties, Scientia Iranica 20 (3) (2013) 1049–1054.

[114] P. Logeswari, S. Silambarasan, J. Abraham, Synthesis of silver nanoparticles using plants extract and analysis of their antimicrobial property, Journal of Saudi Chemical Society 19 (3) (2015) 311–317.

[115] S. Lokina, A. Stephen, V. Kaviyarasan, C. Arulvasu, V. Narayanan, Cytotoxicity and antimicrobial activities of green synthesized silver nanoparticles, European Journal of Medicinal Chemistry 76 (2014) 256–263.

[116] Y.Y. Loo, Y. Rukayadi, M.A.R. Nor-Khaizura, C.H. Kuan, B.W. Chieng, M. Nishibuchi, S. Radu, In vitro antimicrobial activity of green synthesized silver nanoparticles against selected gram-negative foodborne pathogens, Frontiers in Microbiology 9 (2018) 1555.

[117] J.L. López-Miranda, M. Vázquez, N. Fletes, R. Esparza, G. Rosas, Biosynthesis of silver nanoparticles using a Tamarix gallica leaf extract and their antibacterial activity, Materials Letters 176 (2016) 285–289.

[118] M.V.D.O.B. Maciel, A. da Rosa Almeida, M.H. Machado, W.C. Elias, C.G. da Rosa, G.L. Teixeira, P.L.M. Barreto, Green synthesis, characteristics and antimicrobial activity of silver nanoparticles mediated by essential oils as reducing agents, Biocatalysis and Agricultural Biotechnology 28 (2020) 101746.

[119] M. Madani, S. Hosny, D.M. Alshangiti, N. Nady, S.A. Alkhursani, H. Alkhaldi, G. A. Gaber, Green synthesis of nanoparticles for varied applications: Green renewable resources and energy-efficient synthetic routes, Nanotechnology Reviews 11 (1) (2022) 731–759.

[120] Majeed, Shahnaz, Mohd Syafiq bin Abdullah, Gouri Kumar Dash, Mohammed Tahir Ansari, and Anima Nanda. 2016. "Biochemical Synthesis of Silver Nanoprticles Using Filamentous Fungi Penicillium Decumbens (MTCC-2494) and Its Efficacy against A-549 Lung Cancer Cell Line." Chinese Journal of Natural Medicines 14 (8): 615–20.

[121] R.B. Malabadi, G.S. Mulgund, N.T. Meti, K. Nataraja, S.V. Kumar, Antibacterial activity of silver nanoparticles synthesized by using whole plant extracts of Clitoria ternatea, Research in Pharmacy 2 (4) (2015).

[122] S.B. Manjunatha, D.P. Biradar, Y.R. Aladakatti, Nanotechnology and its applications in agriculture: A review, J Farm Sci 29 (1) (2016) 1–13.

[123] N. Manosalva, G. Tortella, M. Cristina Diez, H. Schalchli, A.B. Seabra, N. Durán, O. Rubilar, Green synthesis of silver nanoparticles: effect of synthesis reaction parameters on antimicrobial activity, World Journal of Microbiology and Biotechnology 35 (2019) 1–9.

[124] A.D. Mare, C.N. Ciurea, A. Man, M. Mareș, F. Toma, L. Berța, C. Tanase, In vitro antifungal activity of silver nanoparticles biosynthesized with beech bark extract, Plants 10 (10) (2021) 2153.

[125] G. Marslin, R.K. Selvakesavan, G. Franklin, B. Sarmento, A.C. Dias, Antimicrobial activity of cream incorporated with silver nanoparticles biosynthesized from Withania somnifera, International Journal of Nanomedicine (2015) 5955–5963.

[126] R. Mie, M.W. Samsudin, L.B. Din, A. Ahmad, N. Ibrahim, S.N.A. Adnan, Synthesis of silver nanoparticles with antibacterial activity using the lichen Parmotrema praesorediosum, International Journal of Nanomedicine (2014) 121–127.

[127] A.K. Mittal, K. Thanki, S. Jain, U.C. Banerjee, Comparative Studies of Anticancer and Antimicrobial Potential of Bioinspired Silver and Silver-Selenium Nanoparticles, Journal of Materials NanoScience 3 (2) (2016) 22–27.

[128] F. Mohammadi, M. Yousefi, R. Ghahremanzadeh, Green synthesis, characterization and antimicrobial activity of silver nanoparticles (AgNPs) using leaves and stems extract of some plants, Advanced Journal of Chemistry-Section A 2 (4) (2019) 266–275.

[129] S. Mohammadi-Aghdam, F. Bahraini, S.M. Ghoreishi, In-vitro anticancer on acute lymphoblastic leukemia NALM-6 cell line, antibacterial and catalytic performance of eco-friendly synthesized ZnO and Ag-doped ZnO nanoparticles using Hedera colchica extract, Biomass Conversion and Biorefinery (2023) 1–16.

[130] R. Mohammadinejad, H. Maleki, E. Larraneta, A.R. Fajardo, A.B. Nik, A. Shavandi, V.K. Thakur, Status and future scope of plant-based green hydrogels in biomedical engineering, Applied Materials Today 16 (2019) 213–246.

[131] A.E. Mohammed, A. Al-Qahtani, A. Al-Mutairi, B. Al-Shamri, K. Aabed, Antibacterial and cytotoxic potential of biosynthesized silver nanoparticles by some plant extracts, Nanomaterials 8 (6) (2018) 382.

[132] Mohanta, Y. K., Biswas, K., Jena, S. K., Hashem, A., Abd_Allah, E. F., & Mohanta, T. K. (2020). Anti-biofilm and antibacterial activities of silver nanoparticles synthesized by the reducing activity of phytoconstituents present in the Indian medicinal plants. *Frontiers in Microbiology*, *11*, 1143.

[133] M. Mousavi-Khattat, M. Keyhanfar, A. Razmjou, A comparative study of stability, antioxidant, DNA cleavage and antibacterial activities of green and chemically synthesized silver nanoparticles, Artificial Cells, Nanomedicine, and Biotechnology 46 (sup3) (2018) 1022–1031.

[134] S. Mukherjee, D. Chowdhury, R. Kotcherlakota, B. Sujata Patra, M. P. Vinothkumar, B.S. Bhadra, C.R. Patra, Potential Theranostics Application of Bio-Synthesized Silver Nanoparticles (4-in-1 System), Theranostics 4 (3) (2014) 316–335.
[135] K. Murugan, B. Senthilkumar, D. Senbagam, S. Al-Sohaibani, Biosynthesis of silver nanoparticles using Acacia leucophloea extract and their antibacterial activity, International Journal of Nanomedicine (2014) 2431–2438.
[136] R. Naaz, V.U. Siddiqui, A. Ahmad, S.U. Qadir, W.A. Siddiqi, Study of antibacterial and antioxidant activities of silver nanoparticles synthesized from Tradescantia pallida (purpurea) leaves extract, Journal of Dispersion Science and Technology (2023) 1–11.
[137] A.S. Nadzirah, M. Salina, I.A. Latif, June). the Effect of pH, Temperature on Green Synthesis and Antibacterial Activity of Silver Nanoparticles from Polygonum minus Extract Vol. 2625, No. 1 (2023).
[138] A. Naghizadeh, Z.M. Mizwari, S.M. Ghoreishi, S. Lashgari, S. Mortazavi-Derazkola, B. Rezaie, Biogenic and eco-benign synthesis of silver nanoparticles using jujube core extract and its performance in catalytic and pharmaceutical applications: Removal of industrial contaminants and in-vitro antibacterial and anticancer activities, Environmental Technology & Innovation 23 (2021) 101560.
[139] J.R. Nakkala, R. Mata, A.K. Gupta, S.R. Sadras, Biological Activities of Green Silver Nanoparticles Synthesized with Acorous Calamus Rhizome Extract, European Journal of Medicinal Chemistry 85 (October) (2014) 784–794.
[140] Nallappan, Devi, Agustine Nengsih Fauzi, Balam Satheesh Krishna, Basivi Praveen Kumar, Avula Vijaya Kumar Reddy, Tasqeeruddin Syed, Cirandur Suresh Reddy, Nik Soriani Yaacob, and and Pasupuleti Visweswara Rao. 2021. "Green Biosynthesis, Antioxidant, Antibacterial, and Anticancer Activities of Silver Nanoparticles of Luffa Acutangula Leaf Extract." BioMed Research International, 1–28.
[141] S.I.Z. Naqvi, H. Kausar, A. Afzal, M. Hashim, H. Mujahid, M. Javed, S. Anjum, Antifungal Activity of Juglans-regia-Mediated Silver Nanoparticles (AgNPs) against Aspergillus-ochraceus-Induced Toxicity in In Vitro and In Vivo Settings, Journal of Functional Biomaterials 14 (4) (2023) 221.
[142] F. Okafor, A. Janen, T. Kukhtareva, V. Edwards, M. Curley, Green synthesis of silver nanoparticles, their characterization, application and antibacterial activity, International Journal of Environmental Research and Public Health 10 (10) (2013) 5221–5238.
[143] M. Ovais, A.T. Khalil, A. Raza, M.A. Khan, I. Ahmad, N.U. Islam, M. Saravanan, M. F. Ubaid, M. Ali, Z.K. Shinwari, Green Synthesis of Silver Nanoparticles via Plant Extracts: Beginning a New Era in Cancer Theranostics, Nanomedicine (london, England) 11 (23) (2016) 3157–3177.
[144] P. Palaniappan, G. Sathishkumar, R. Sankar, Fabrication of Nano-Silver Particles Using Cymodocea Serrulata and Its Cytotoxicity Effect against Human Lung Cancer A549 Cells Line, Spectrochimica Acta. Part a, Molecular and Biomolecular Spectroscopy 138 (March) (2015) 885–890.
[145] A.M. Pandian, C. Kumara, M.R. Karthikeyan, M.G. Dinesh, Synthesis of Silver Nanoparticle and Its Application, Ecotoxicology and Environmental Safety 121 (November) (2015) 211–227.
[146] S. Paosen, J. Saising, A.W. Septama, S.P. Voravuthikunchai, Green synthesis of silver nanoparticles using plants from Myrtaceae family and characterization of their antibacterial activity, Materials Letters 209 (2017) 201–206.
[147] K. Parvathalu, S. Chinmayee, B. Preethi, A. Swetha, G. Maruthi, M. Pritam, P. B. Bhaskar, Green synthesis of silver nanoparticles using Argyreia nervosa leaf extract and their antimicrobial activity, Plasmonics 18 (3) (2023) 1075–1081.
[148] A.R. Phull, Q. Abbas, A. Ali, H. Raza, M. Zia, I.U. Haq, Antioxidant, cytotoxic and antimicrobial activities of green synthesized silver nanoparticles from crude extract of Bergenia ciliata, Future Journal of Pharmaceutical Sciences 2 (1) (2016) 31–36.
[149] S. Pirtarighat, M. Ghannadnia, S. Baghshahi, Green synthesis of silver nanoparticles using the plant extract of Salvia spinosa grown in vitro and their antibacterial activity assessment, Journal of Nanostructure in Chemistry 9 (2019) 1–9.
[150] D. Prabhu, C. Arulvasu, G. Babu, R. Manikandan, P. Srinivasan, Biologically Synthesized Green Silver Nanoparticles from Leaf Extract of Vitex Negundo L. Induce Growth-Inhibitory Effect on Human Colon Cancer Cell Line HCT15, Process Biochemistry 48 (2) (2013) 317–324.
[151] Prasad, R., & Swamy, V. S. (2013). Antibacterial activity of silver nanoparticles synthesized by bark extract of Syzygium cumini. *Journal of Nanoparticles*, *2013*.
[152] R. Prasad, V. Kumar, K.S. Prasad, Nanotechnology in sustainable agriculture: present concerns and future aspects, African Journal of Biotechnology 13 (6) (2014) 705–713.
[153] R.I. Priyadharshini, G. Prasannaraj, N. Geetha, P. Venkatachalam, Microwave-Mediated Extracellular Synthesis of Metallic Silver and Zinc Oxide Nanoparticles Using Macro-Algae (Gracilaria Edulis) Extracts and Its Anticancer Activity against Human PC3 Cell Lines, Applied Biochemistry and Biotechnology 174 (8) (2014) 2777–2790.
[154] S. Raja, V. Ramesh, V. Thivaharan, Green biosynthesis of silver nanoparticles using Calliandra haematocephala leaf extract, their antibacterial activity and hydrogen peroxide sensing capability, Arabian Journal of Chemistry 10 (2) (2017) 253–261.
[155] Rajkuberan, Chandrasekaran, Kannaiah Sudha, Gnanasekar Sathishkumar, and Sivaperumal Sivaramakrishnan. 2015. "Antibacterial and Cytotoxic Potential of Silver Nanoparticles Synthesized Using Latex of Calotropis Gigantea L." Spectrochimica Acta. Part A, Molecular and Biomolecular Spectroscopy 136 Pt B (PB): 924–30.
[156] P.V. Rajkumar, A. Prakasam, S. Rajeshkumar, M. Gomathi, P.M. Anbarasan, R. Chandrasekaran, Green synthesis of silver nanoparticles using Gymnema sylvestre leaf extract and evaluation of its antibacterial activity, South African Journal of Chemical Engineering 32 (1) (2020) 1–4.
[157] S.M. Rakib-Uz-Zaman, E. Hoque Apu, M.N. Muntasir, S.A. Mowna, M.G. Khanom, S.S. Jahan, K. Khan, Biosynthesis of silver nanoparticles from Cymbopogon citratus leaf extract and evaluation of their antimicrobial properties, Challenges 13 (1) (2022) 18.
[158] C.H. Ramamurthy, M. Padma, R. Mareeswaran, A. Suyavaran, M.S. Kumar, K. Premkumar, C. Thirunavukkarasu, The extra cellular synthesis of gold and silver nanoparticles and their free radical scavenging and antibacterial properties, Colloids and Surfaces b: Biointerfaces 102 (2013) 808–815.
[159] M. Ramar, B. Manikandan, P.N. Marimuthu, T. Raman, A. Mahalingam, P. Subramanian, S. Karthick, A. Munusamy, "Synthesis of Silver Nanoparticles Using Solanum Trilobatum Fruits Extract and Its Antibacterial, Cytotoxic Activity against Human Breast Cancer Cell Line MCF 7". Spectrochimica Acta. Part A, Molecular and Biomolecular, Spectroscopy 140 (April) (2015) 223–228.
[160] Ratan, Zubair Ahmed, Mohammad Faisal Haidere, Md Nurunnabi, Sadi Md Shahriar, A. J.Saleh Ahammad, Youn Young Shim, Martin J.T. Reaney, and Jae Youl Cho. 2020. "Green Chemistry Synthesis of Silver Nanoparticles and Their Potential Anticancer Effects." Cancers 12 (4).
[161] P.R. Rathi Sre, M. Reka, R. Poovazhagi, M. Arul Kumar, K. Murugesan, Antibacterial and Cytotoxic Effect of Biologically Synthesized Silver Nanoparticles Using Aqueous Root Extract of Erythrina Indica Lam, Spectrochimica Acta. Part a, Molecular and Biomolecular Spectroscopy 135 (January) (2015) 1137–1144.
[162] V. Ravichandran, S. Vasanthi, S. Shalini, S.A.A. Shah, M. Tripathy, N. Paliwal, Green synthesis, characterization, antibacterial, antioxidant and photocatalytic activity of Parkia speciosa leaves extract mediated silver nanoparticles, Results in Physics 15 (2019) 102565.
[163] M. Reda, A. Ashames, Z. Edis, S. Bloukh, R. Bhandare, H. Abu Sara, Green synthesis of potent antimicrobial silver nanoparticles using different plant extracts and their mixtures, Processes 7 (8) (2019) 510.
[164] N. Reddy, D.N. Jayachandra, M.R. Vali, S. Sudha Rani, Evaluation of Antioxidant, Antibacterial and Cytotoxic Effects of Green Synthesized Silver Nanoparticles by Piper Longum Fruit, Materials Science and Engineering: C 34 (1) (2014) 115–122.
[165] W.R. Rolim, M.T. Pelegrino, B. de Araújo Lima, L.S. Ferraz, F.N. Costa, J. S. Bernardes, A.B. Seabra, Green tea extract mediated biogenic synthesis of silver nanoparticles: Characterization, cytotoxicity evaluation and antibacterial activity, Applied Surface Science 463 (2019) 66–74.
[166] P. Roy, B. Das, A. Mohanty, S. Mohapatra, Green synthesis of silver nanoparticles using Azadirachta indica leaf extract and its antimicrobial study, Applied Nanoscience 7 (8) (2017) 843–850.
[167] A. Said, M. Abu-Elghait, H.M. Atta, S.S. Salem, Antibacterial activity of green synthesized silver nanoparticles using lawsonia inermis against common pathogens from urinary tract infection, Applied Biochemistry and Biotechnology (2023) 1–14.
[168] A. Salayová, Z. Bedlovičová, N. Daneu, M. Baláž, Z. Lukáčová Bujňáková, Ľ. Balážová, Ľ. Tkáčiková, Green synthesis of silver nanoparticles with antibacterial activity using various medicinal plant extracts: Morphology and antibacterial efficacy, Nanomaterials 11 (4) (2021) 1005.
[169] M.A. Salih, T.S. Rashid, Screening for antibacterial activity in selected medicinal plant extracts against Xanthomonas euvesicatoria, Polytechnic Journal 12 (2) (2022) 215–219.
[170] A. Salleh, R. Naomi, N.D. Utami, A.W. Mohammad, E. Mahmoudi, N. Mustafa, M. B. Fauzi, The potential of silver nanoparticles for antiviral and antibacterial applications: A mechanism of action, Nanomaterials 10 (8) (2020) 1566.
[171] S. Samuggam, S.V. Chinni, P. Mutusamy, S.C. Gopinath, P. Anbu, V. Venugopal, B. Enugutti, Green synthesis and characterization of silver nanoparticles using Spondias mombin extract and their antimicrobial activity against biofilm-producing bacteria, Molecules 26 (9) (2021) 2681.
[172] Sankar, Renu, Arunachalam Karthik, Annamalai Prabu, Selvaraju Karthik, Kanchi Subramanian Shivashangari, and Vilwanathan Ravikumar. 2013. "Origanum Vulgare Mediated Biosynthesis of Silver Nanoparticles for Its Antibacterial and Anticancer Activity." Colloids and Surfaces. B, Biointerfaces 108 (August): 80–84.
[173] G. Sathishkumar, C. Gobinath, A. Wilson, S. Sivaramakrishnan, Dendrophthoe Falcata (L.f) Ettingsh (Neem Mistletoe): A Potent Bioresource to Fabricate Silver Nanoparticles for Anticancer Effect against Human Breast Cancer Cells (MCF-7), Spectrochimica Acta. Part a, Molecular and Biomolecular Spectroscopy 128 (July) (2014) 285–290.
[174] P. Sathishkumar, K. Vennila, R. Jayakumar, A.R.M. Yusoff, T. Hadibarata, T. Palvannan, Phyto-Synthesis of Silver Nanoparticles Using Alternanthera Tenella Leaf Extract: An Effective Inhibitor for the Migration of Human Breast Adenocarcinoma (MCF-7) Cells, Bioprocess and Biosystems Engineering 39 (4) (2016) 651–669.
[175] K. Satyavani, S. Gurudeeban, T. Ramanathan, T. Balasubramanian, Biomedical Potential of Silver Nanoparticles Synthesized from Calli Cells of Citrullus Colocynthis (L.) Schrad, Journal of Nanobiotechnology 9 (September) (2011).
[176] N. Savithramma, M.L. Rao, K. Rukmini, P.S. Devi, Antimicrobial activity of silver nanoparticles synthesized by using medicinal plants, International Journal of ChemTech Research 3 (3) (2011) 1394–1402.
[177] A. Saxena, R.M. Tripathi, R.P. Singh, Biological synthesis of silver nanoparticles by using onion (Allium cepa) extract and their antibacterial activity, Dig J Nanomater Bios 5 (2) (2010) 427–432.
[178] M.T. Shaaban, M.F. Ghaly, S.M. Fahmi, Antibacterial activities of hexadecanoic acid methyl ester and green-synthesized silver nanoparticles against multidrug-resistant bacteria, Journal of Basic Microbiology 61 (6) (2021) 557–568.

[179] M.R. Shaik, M. Khan, M. Kuniyil, A. Al-Warthan, H.Z. Alkhathlan, M.R. H. Siddiqui, S.F. Adil, Plant-extract-assisted green synthesis of silver nanoparticles using Origanum vulgare L. extract and their microbicidal activities, Sustainability 10 (4) (2018) 913.
[180] K. Sharma, S. Guleria, V.K. Razdan, Green synthesis of silver nanoparticles using Ocimum gratissimum leaf extract: characterization, antimicrobial activity and toxicity analysis, Journal of Plant Biochemistry and Biotechnology 29 (2020) 213–224.
[181] A.M. Shawkey, M.A. Rabeh, A.K. Abdulall, A.O. Abdellatif, Green Nanotechnology: Anticancer Activity of Silver Nanoparticles Using Citrullus Colocynthis Aqueous Extracts, Advances in Life Science and Technology 13 (2013) 60–70.
[182] M. Shirzadi-Ahodashti, Z.M. Mizwari, Z. Hashemi, S. Rajabalipour, S. M. Ghoreishi, S. Mortazavi-Derazkola, M.A. Ebrahimzadeh, Discovery of high antibacterial and catalytic activities of biosynthesized silver nanoparticles using C. fruticosus (CF-AgNPs) against multi-drug resistant clinical strains and hazardous pollutants, Environmental Technology & Innovation 23 (2021) 101607.
[183] G. Shumi, T.B. Demissie, R. Eswaramoorthy, R.F. Bogale, G. Kenasa, T. Desalegn, Biosynthesis of Silver Nanoparticles Functionalized with Histidine and Phenylalanine Amino Acids for Potential Antioxidant and Antibacterial Activities, ACS Omega. 8 (27) (2023) 24371–24386.
[184] A. Singh, B. Gaud, S. Jaybhaye, Optimization of synthesis parameters of silver nanoparticles and its antimicrobial activity, Materials Science for Energy Technologies 3 (2020) 232–236.
[185] C. Singh, S.K. Anand, R. Upadhyay, N. Pandey, P. Kumar, D. Singh, R. Tilak, Green synthesis of silver nanoparticles by root extract of Premna integrifolia L. and evaluation of its cytotoxic and antibacterial activity, Materials Chemistry and Physics 297 (2023) 127413.
[186] R. Singh, C. Hano, G. Nath, B. Sharma, Green biosynthesis of silver nanoparticles using leaf extract of Carissa carandas L. and their antioxidant and antimicrobial activity against human pathogenic bacteria, Biomolecules 11 (2) (2021) 299.
[187] J.K. Sohal, A. Saraf, K.K. Shukla, Green synthesis of silver nanoparticles (ag-nps) using plant extract for antimicrobial and antioxidant applications: A review, International Journal of Advanced Research in Science and Engineering 6 (10) (2017) 766–777.
[188] M.I. Sriram, S.B.M. Kanth, K. Kalishwaralal, S. Gurunathan, Antitumor activity of silver nanoparticles in Dalton's lymphoma ascites tumor model, International Journal of Nanomedicine (2010) 753–762.
[189] R. Sukirtha, K.M. Priyanka, J.J. Antony, S. Kamalakkannan, R. Thangam, P. Gunasekaran, M. Krishnan, S. Achiraman, Cytotoxic Effect of Green Synthesized Silver Nanoparticles Using Melia Azedarach against in Vitro HeLa Cell Lines and Lymphoma Mice Model, Process Biochemistry 47 (2) (2012) 273–1229.
[190] Q. Sun, X. Cai, J. Li, M. Zheng, Z. Chen, C.P. Yu, Green synthesis of silver nanoparticles using tea leaf extract and evaluation of their stability and antibacterial activity, Colloids and Surfaces a: Physicochemical and Engineering Aspects 444 (2014) 226–231.
[191] Z. Tabassum, A. Mohan, N. Mamidi, A. Khosla, A. Kumar, P.R. Solanki, M. Girdhar, Recent trends in nanocomposite packaging films utilising waste generated biopolymers: Industrial symbiosis and its implication in sustainability, IET Nanobiotechnology 17 (3) (2023) 127–153.
[192] G. Tailor, B.L. Yadav, J. Chaudhary, M. Joshi, C. Suvalka, Green synthesis of silver nanoparticles using Ocimum canum and their anti-bacterial activity, Biochemistry and Biophysics Reports 24 (2020) 100848.
[193] D.K. Takcı, M.S. Ozdenefe, S. Genc, Green synthesis of silver nanoparticles with an antibacterial activity using Salvia officinalis aqueous extract, Journal of Crystal Growth 614 (2023) 127239.
[194] S. Tarighi, M.S. Nejad, Ecofriendly fabrication of silver nanoparticles using quince petal extract and its antibacterial properties against fire blight disease, Journal of Natural Pesticide Research 4 (2023) 100026.
[195] M. Tesfaye, Y. Gonfa, G. Tadesse, T. Temesgen, S. Periyasamy, Green synthesis of silver nanoparticles using Vernonia amygdalina plant extract and its antimicrobial activities, Heliyon. 9 (2023) (2023) e17356.
[196] N. Thirumagal, A.P. Jeyakumari, Structural, optical and antibacterial properties of green synthesized silver nanoparticles (AgNPs) using Justicia adhatoda L. leaf extract, Journal of Cluster Science 31 (2) (2020) 487–497.
[197] S.K. Tiwari, V. Kumar, A. Huczko, R. Oraon, A.D. Adhikari, G.C. Nayak, Magical allotropes of carbon: prospects and applications, Critical Reviews in Solid State and Materials Sciences 41 (4) (2016) 257–317.
[198] M. Vanaja, G. Annadurai, Coleus aromaticus leaf extract mediated synthesis of silver nanoparticles and its bactericidal activity, Applied Nanoscience 3 (2013) 217–223.
[199] T. Varadavenkatesan, R. Selvaraj, R. Vinayagam, Dye degradation and antibacterial activity of green synthesized silver nanoparticles using Ipomoea digitata Linn. flower extract, International Journal of Environmental Science and Technology 16 (2019) 2395–2404.
[200] K. Vasanth, K. Ilango, R. MohanKumar, A. Agrawal, G.P. Dubey, Anticancer Activity of Moringa Oleifera Mediated Silver Nanoparticles on Human Cervical Carcinoma Cells by Apoptosis Induction, Colloids and Surfaces. b, Biointerfaces 117 (May) (2014) 354–1339.
[201] R. Veerasamy, T.Z. Xin, S. Gunasagaran, T.F.W. Xiang, E.F.C. Yang, N. Jeyakumar, S.A. Dhanaraj, Biosynthesis of silver nanoparticles using mangosteen leaf extract and evaluation of their antimicrobial activities, Journal of Saudi Chemical Society 15 (2) (2011) 113–120.
[202] B. Venkatadri, E. Shanparvish, M.R. Rameshkumar, M.V. Arasu, N.A. Al-Dhabi, V. K. Ponnusamy, P. Agastian, Green Synthesis of Silver Nanoparticles Using Aqueous Rhizome Extract of Zingiber Officinale and Curcuma Longa: In-Vitro Anti-Cancer Potential on Human Colon Carcinoma HT-29 Cells, Saudi Journal of Biological Sciences 27 (11) (2020) 2980–12296.
[203] B. Venkatesan, V. Subramanian, A. Tumala, E. Vellaichamy, Rapid Synthesis of Biocompatible Silver Nanoparticles Using Aqueous Extract of Rosa Damascena Petals and Evaluation of Their Anticancer Activity, Asian Pacific Journal of Tropical Medicine 7S1 (S1) (2014) S294–S300.
[204] K. Venugopal, H.A. Rather, K. Rajagopal, M.P. Shanthi, K. Sheriff, M. Illiyas, R. A. Rather, et al., Synthesis of Silver Nanoparticles (Ag NPs) for Anticancer Activities (MCF 7 Breast and A549 Lung Cell Lines) of the Crude Extract of Syzygium Aromaticum, Journal of Photochemistry and Photobiology. b, Biology 167 (February) (2017) 282–1229.
[205] T. Verano-Braga, R. Miethling-Graff, K. Wojdyla, A. Rogowska-Wrzesinska, J. R. Brewer, H. Erdmann, F. Kjeldsen, Insights into the Cellular Response Triggered by Silver Nanoparticles Using Quantitative Proteomics, ACS Nano 8 (3) (2014) 2161–2175.
[206] A. Verma, M.S. Mehata, Controllable synthesis of silver nanoparticles using Neem leaves and their antimicrobial activity, Journal of Radiation Research and Applied Sciences 9 (1) (2016) 109–115.
[207] L. Wang, Y. Wu, J. Xie, S. Wu, Z. Wu, Characterization, antioxidant and antimicrobial activities of green synthesized silver nanoparticles from Psidium guajava L. leaf aqueous extracts, Materials Science and Engineering: C 86 (2018) 1–8.
[208] Z. Wang, M. Guo, S.S. Lim, Recent advances in recognition of bioactive phytonutrients for specific targets in plant foods, Frontiers in Nutrition 9 (2022) 2456.
[209] Xia, Qian Hua, Yan Jun Ma, and Jian Wen Wang. 2016. "Biosynthesis of Silver Nanoparticles Using Taxus Yunnanensis Callus and Their Antibacterial Activity and Cytotoxicity in Human Cancer Cells." Nanomaterials (Basel, Switzerland) 6 (9).
[210] U. Yiğit, Y. Gürel, H. Ilhan, M. Türkkan, Antifungal activity and optimization procedure of silver nanoparticles green synthesized with Prunus laurocerasus L. (cherry laurel) leaf extract, International Journal of Life Sciences and Biotechnology 6 (1) (2023) 1–20.
[211] M. Younas, M.H. Rasool, M. Khurshid, A. Khan, M.Z. Nawaz, I. Ahmad, M. N. Lakhan, Moringa oleifera leaf extract mediated green synthesis of silver nanoparticles and their antibacterial effect against selected gram-negative strains, Biochemical Systematics and Ecology 107 (2023) 104605.
[212] Yousaf, Aliya, Muhammad Waseem, Aneela Javed, Sofia Baig, Bushra Ismail, Ayesha Baig, Irum Shahzadi, Shamyla Nawazish, and Iftikhar Zaman. 2022. "Augmented Anticancer Effect and Antibacterial Activity of Silver Nanoparticles Synthesized by Using Taxus Wallichiana Leaf Extract." PeerJ 10 (November).
[213] M. Zare-Bidaki, A. Ghasempour, P. Mohammadparast-Tabas, S.M. Ghoreishi, E. Alamzadeh, R. Javanshir, S. Mortazavi-Derazkola, Enhanced in vivo wound healing efficacy and excellent antibacterial, antifungal, antioxidant and anticancer activities via AgNPs@ PCS, Arabian Journal of Chemistry 16 (10) (2023) 105194.
[214] L. Zhang, L. Wu, Y. Mi, Y. Si, Silver nanoparticles induced cell apoptosis, membrane damage of Azotobacter vinelandii and Nitrosomonas europaea via generation of reactive oxygen species, Bulletin of Environmental Contamination and Toxicology 103 (2019) 181–186.
[215] H. Zulfiqar, A. Zafar, M.N. Rasheed, Z. Ali, K. Mehmood, A. Mazher, N. Mahmood, Synthesis of silver nanoparticles using Fagonia cretica and their antimicrobial activities, Nanoscale Advances 1 (5) (2019) 1707–1713.