Chapter

Increasing Trend of Silver Nanoparticles as Antibacterial and Anticancer Agent

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Abstract

Silver nanoparticles (AgNPs) synthesis from plants that already have been reported for medicinal purposes demonstrated better efficacy for curing diseases. Recently, a number of researches have been reported where AgNPs act as promising antibacterial and anticancer agent. Biosynthesized silver nanoparticles (AgNPs) are a type of environmentally friendly, cost-effective, and biocompatible substance that has gotten a lot of attention in treatment of cancer and inhibition of pathogenic microbes. In this chapter, a comprehensive report on the recent development of AgNPs as nanomedicine synthesized from plant extracts. The role and mechanism of AgNPs as antibacterial and anticancer agent was reported that leads towards development of targeted nannomedicines to treat infectious diseases and world most challenging disease like cancer. Reported literature give imminence importance of AgNPs and demonstrated more potency to treat cancer and bacterial infections.

Keywords: silver nanoparticles, biolabeling, conjugation, phagocytosis, polydispersity

1. Introduction

Silver has been used widely from ancient times as it is a noble metal. Hippocrates advocated for the use of silver in the treatment of sickness and for healing purposes [1]. Silver is found abundantly in nature with multiple biological and biochemical properties making silver most suitable candidate for the biomedical applications, can be used as an antiseptic, part of medicines, antimicrobial efficacy, pharmaceutical industry, Food preservation, cosmetics, biolabelling, and optical properties. AgCl and AgNO3, ionic forms of silver, caused cardiac alterations in rats, such as left ventricular hypertrophy, hypersensitivity, and inhibition of normal fibroblast function [2]. Silver nanoparticles (AgNPs) are comparatively safe and more effective in medical treatment to silver ions [3].

Recently, nanotechnology has played a critical role in biomedical, diagnosis, treatments, the industrial sector, scientific purpose, and environmental protection [4]. Nanomaterials have a size range of 1–100 nm, or particles with at least one dimension smaller than 100 nm [4]. Due to unique physicochemical and biological characteristics, such as large surface area to volume ratio, excellent surface plasmon resonance, conjugation with various ligands to obtain desired property, inhibition against microbes, potent toxicity towards cancer cells, catalytic operations, silver nanoparticles are one of the most widely studied metal nanoparticles for a variety of scientific purposes. Due to very small size they penetrate the blood capillaries and tissues and become more effective in cancer treatment. Moreover they carry the multiple drugs on their large surface area and have capability to modify and combine chemically. Antimicrobial and anticancer activities of green synthesized AgNPs is due to phytoconstituents attached on their surface [5]. Several research studies have been conducted a green method to synthesize a range of metallic nanoparticles in concern with growing worldwide burden of cancer that showed potential anticancer effect against a range of cancer cell types [6]. Unicellular or multicellular living organisms are typically with 10 μm, so AgNPs in small size (1–100 nm) can interact with cell wall of bacterial, viral, and fungal pathogens and their active nano-complexes can penetrate and break the external capsule. The permeability of the plasma membrane to small-sized AgNPs permits them to accumulate in cell compartments. Phagocytosis, endocytosis, or micropinocytosis is the uptake mechanisms of nanoparticles in eukaryotic cells [7].

The rising applications of AgNPs in field of oncology and microbiology, present chapter emphasizes the significant antibacterial and anticancer properties of AgNPs synthesized by the green approach, recent developments and finding new perspectives in nanomedicine. In comparison with other methods, Ram Prasad's methods have been shown to be better due to their slow kinetics and ability to manipulate crystal growth and stabilization in a better way. The biogenetic synthesis uses plant extracts in aqueous form to create noble nanoparticles, as the extracts contain more reducing agents than plants. The availability of silver nanoparticles and their various metabolites makes plant-mediated silver nanoparticle synthesis a preferable method [8]. There are several phyto-constituents that are believed to reduce silver ions, including tannins, terpenoids, flavonoids, ketones, aldehydes, amides, and carboxylic acids. Plant extracts (chemical composition, amount, conjugation method) and nanoparticles (type, size, shape, polydispersity, etc.) play an influential role in the properties of a bioconjugate method [9].

In addition to being expensive to manufacture, the silver ion method has not been demonstrated to be clinically effective in randomized controlled trials and cannot be used with oxidizing solutions such as hypochlorite or H_2O_2 [10]. There are several drawbacks to the generation of silver nanoparticles (AgNPs) using a tube furnace, including the fact that it occupies a large space, consumes a lot of energy, raises the temperature in the surrounding environment, and requires a lot of time to achieve thermal stability. To achieve a stable operating temperature, a tube furnace typically requires several kilowatts and several time of preheating [11]. The polysaccride method is very temperature sensitive because the binding between the silver nano particles is very weak. If the temperature is increased slightly then the reversible reaction is started and the separation of the silver nano particles is started so the nano particles are unstable [12].

2. Applications and importance of silver nanoparticles

Nanoparticles and nano-composites synthesized from plants containing noble metals, silver nanoparticles are widely used metal due to incredible potential and significant usage. The diverse chemical and physical nature of AgNPs suggests

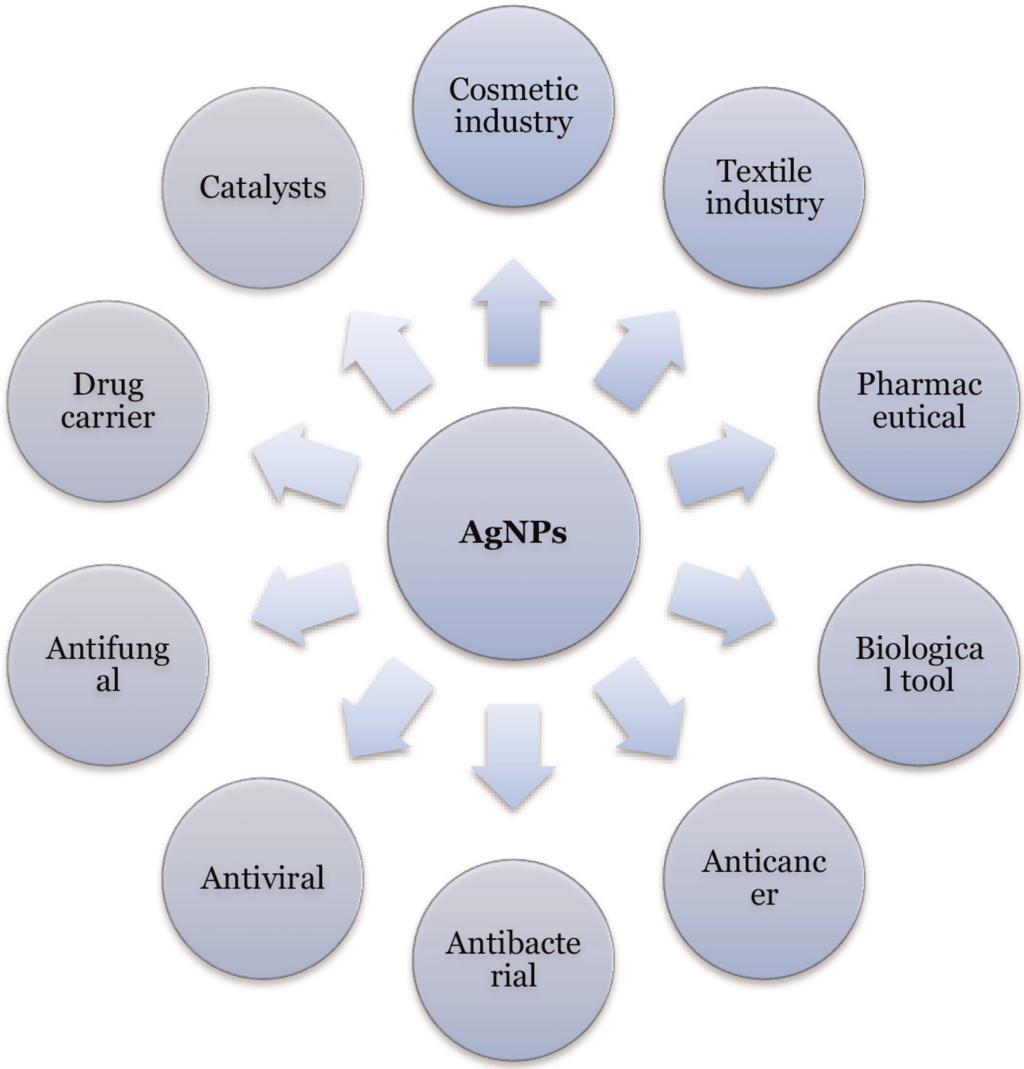

Figure 1.
Applications of AgNPs.

potential uses in the environment and for the well being of human life, promoting one health program for example cover the field of agriculture, food industry, medicine, and for the better human health (**Figure 1**) [13–15]. In the treatment of cancer cells, AgNPs are used as therapeutic agents due to cellular oxidative and apoptotic potential [15, 16]. AgNPs offer new uses due to their size-dependent actions and capacity to form various complexes with natural or synthetic molecules [17–19].

AgNPs are the most studied zero-dimensional nanoparticles for their remarkable and unparalleled uses in pharmaceutical science, infectious problems, wound care, antimicrobial, food packaging, and the cosmetic sector [20]. In recent years, biosynthesized AgNPs have shown potent larvicidal, bactericidal, fungicidal, antioxidant, antiviral, antidiabetic, and anticancer activities [21]. There are approximately 383 commercialized nano silver-based products on the market worldwide, accounting for 24% of all nano products [22].

2.1 Silver nanoparticles as anticancer agent

Cancer is one of the most challenging diseases to treat, and defined as the uncontrollable division of altered cells. It is the leading cause of mortality and about 70%

deaths in middle and low income countries and 68% population suffer due to cancer [23]. Globally cancer burden will be rise up to 27 million by 2040 [24]. Cancers most commonly diagnosed in the human population include lung, thyroid, cervical, liver, stomach, brain tumors, prostate, uterine, and breast cancers [19]. The most predominantly prevalent cancer are breast and prostate cancer that effect women and men, respectively. The field of cancer nanobiotechnology has provided new direction to detect, diagnose, and treat cancer [25]. AgNPs produced through green method with phytochemical covering give them more efficacy than AgNPs produced through chemical method. The ability to combine AgNPs inherent anticancer property with the pharmacological anticancer effects could be the key to treating malignancies that have stopped responding to chemotherapy or radiotherapy. Metal-based AgNPs have been found to be pro-oxidative in a variety of cancer cell types. The phytoconstituents berberine isolated from plants in combination with AgNPs showed synergistic anticancer activity [26]. Several studies in the published literature have looked into the methods by which AgNPs exhibit anticancer action. Among studied cancer cell lines most of the silver nanoparticles are studied against breast cancer cell line MCF-7. The size of AgNPs evaluated for anticancer ranged from 5 to 100 nm; with varying shapes such as spherical, cubical and hexagonal. The IC50 values of green synthesized AgNPs extracts against studied cell lines ranged from 6 to 1200 μg/mL. Some important studies regarding *in vitro* evaluation of AgNPs on cancerous cell lines represented in **Table 1**. AgNPs synthesized from *Mentha species* possess inhibitory effect against

Plant used	Part used	Size (nm) and shape of AgNPs	Cancer cell line	IC_{50} value (μg ml − 1)	Reference
Avicennia marina	Leaves	10 (spherical)	A549 lung cancer cells	15	[27]
Litchi chinensis	Leaves	59 (spherical)	MCF-7	40	[28]
Fagonia indica	Whole plant	10–60 (spherical)	MCF-7	12.3	
Ganoderma neo-japonicum	Fruit	5–8 (spherical)	MDA-MB-231	6	[29]
Putranjiva roxburgi	leaves	8 (spherical)	MDA-MB-231, HCT-116 and PANC-1	0.54–0.00025	[30]
Jasminum officinale	Rhizome	9.2 (spherical)	MCF-7, Bladder (5637)	9.3–1,13.0	[31]
Noctiluca scintillans	callus	4.2 (spherical)	MDA-MB-231	50	[32]
Euprenolepisprocera	Leaves	60 (spherical)	MCF-7	9.63	[19]
Nostoclinckia	Whole	9.39–25.89 (spherical)	MCF-7	27.79	[33]
Solanumtrilobatum	Seed coat	41.90 (spherical)	MCF-7	30	[34]
Elephantopusscaber	Peel	59 (spherical and polygonal)	Colo-259	17.4	[35]
Zingiberofficinale	seed	20–51 (spherical)	HT-29	150.8	[36]
Chlorophytumborivilianum	peel	52 (spherical)	HT-29	7	[37]
Oleachrysophylla, Lavandula dentate	Aerial parts	328.6–284.5 (spherical)	HCT116	99.35	[38]

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Plant used	Part used	Size (nm) and shape of AgNPs	Cancer cell line	IC_{50} value (μg ml − 1)	Reference
Mentha arvensis	Leaves	100 (spherical)	HCT116	1.7	[39]
Zanthoxylumrhesta	Leaves	10–68 (spherical)	A549	65.17	[40]
Punicagranatum	leaves	6–45 (spherical)	A549	5	[41]
Derris trifoliate	leaves	16.92 (spherical)	A549	86.23	[42]
Dimocarpuslonganlour	Peel	8–22 (spherical)	H1299	5.33	[43]
Neptadeflersiana	Aerial parts	33 (cubical)	HeLa	23	[44]
Detariummicrocarpum	Leaf	81 (cubical)	HeLa, PANC-1	31.5–1.84	[45]
Ginkgo biloba	leaf	40 (spherical)	HeLa, SiHa	Dose dependent	[46]
Rhizophoraapiculata	leaf	>100 (spherical)	HEK-293, HeLa	0.062–1.98	[47]
Punicagranatum	leaf	46.1 (spherical)	HeLa	100	[41]
Allium sativum	leaf	100–800 (spherical)	HePG2	31.25	[48]
Biergavuaerecta	leaf	15.9 (spherical)	PA-1	25	[46]
Alternantherasessilis	Whole plant	30–50 (spherical)	PC3	6.8	[49]
Dimocarpuslongan	Peel	9–32 (cubical)	PC3	10	[43]
Perillafrutescens	Leaf	25.71 (spherical and cubical)	COLO205, LNCaP	39.28–24.33	[50]
Salvia miltiorrhiza	leaf	100 (spherical and hexagonal)	LNCaP	50	[51]
Zingiber officinale	Leaf	18.93 (spherical)	AsPC-1PANC-1	312–1295	[36]
Punicagranatum	leaf	35–69 (spherical)	HePG2	70	[41]
Elephantopusscaber	leaf	59 (spherical)	MCF-7, A-549 and SCC-40	10	[35]
Tamarindus indica	Fruit shell	20–30 (spherical)	MCF-7	120	[24]
Chaetomorphalinum		Smaller size (spherical)	HCT-116	48.84	[52]
Andrographis paniculata	Stem	Small size u-shaped	Vero cells	31.25	[53]
Phyllanthus niruri	Leaf			125	
Tinospora cordifolia	Leaf			250	
Conocarpus Lancifolius	Fruits	21 to 173 nm	MDA MB-231	16.8 μg/ml.	[54]
Tridax procumbens	Leaf	11.1–45.4	A459	42.70	[55]
Sambucus ebulus	Leaf	35–50	AGS and MCF-7	240	[56]
Parthenium hysterophorus	Leaf	20 spherical	HepG2	50	[57]
Cleome viscosa	leaf	20–50	A549 and PA1	28 and 30 μg/mL	[58]
Bee pollens	Leaf	44	MCF-7	90	[59]
chitosan,	Leaf	23	MDA-MB–231	4.6	[60]

Plant used	Part used	Size (nm) and shape of AgNPs	Cancer cell line	IC_{50} value (μg ml − 1)	Reference
Mimusops elengi	Fruit	43 spherical shape	HT-29 and MCF7	155 and 179	[61]
Gloriosa superba	Stem	7nm–14 spherical	A549	46.54	[62]
Luffa acutangula,	Leaves	8 spherical	MCF-7	90	[63]
			MDA-MB-231	65	
			U87	80	
			DBTRG,	90	
(Pistacia terebinthus)	Leaves	32 spherical shape	MCF-7	25	[58]
Hypericum Perforatum	Leaves	100	HeLa	7.71	[64]
			Hep G2	12.44	
Alternanthera sessilis	Aerial part	10–30 nm/ spherical	MCF-7	3.04	[65]
Alternanthera tenella	Leaf	48 nm/—	MCF-7	42.5	[55]
Andrographis echioides	Leaf	68.06 nm/cubic, pentagonal, hexagona	MCF-7	31.5	[65]
Achillea biebersteinii	Flower	12 nm/spherical, pentagonal	MCF-7	20 μg/mL	[66]
Azadirachta indica	Leaf	40 nm/spherical	MCF-7	10	[59]
oriandrum sativum	Leaf	37 nm/spherical, rod, triangular, hexagonal	MCF-7	30.5	[67]
Citrullus colocynthis	Leaf	7.39 nm/spherical	MCF-7	2.4 μg/mL	[68]
Dendrophthoe falcata	Leaf	5–45 nm/spherical	MCF-7	7	[57]
Erythrina indica	Root	20–118 nm/ spherical	MCF-7	23.89	[60]
Melia dubia	Leaf	7.3 nm/irregular	MCF-7	31.2	[69]
Olax scandens		30–60 nm/ spherical	MCF-7	30	[70]
Piper longum	Root	46 nm/spherical	MCF-7	67	[71]
Quercus (genus)	Fruit hull	46 spherical	MCF-7	50	[34]
Rheum emodi	Root	27.5 nm/spherical	MCF-7	28	[47]
Sesbania grandiflora	Leaf	22 nm/spherical	MCF-7	20	[72]
Solanum trilobatum	fruit	41.90 nm/ spherical, polygonal	MCF-7	30	[46]
Syzygium cumini	Fruit	40 nm/spherical	MCF-7	10	[73]
Syzygium aromaticum	Fruit	5–20 nm/spherical	MCF-7	70	[74]
Tabernae montana divaricate	Leaf	Mean 22.85 nm/ spherica	MCF-7	20	[75]

Plant used	Part used	Size (nm) and shape of AgNPs	Cancer cell line	IC_{50} value (μg ml − 1)	Reference
Taxus baccata	Needles	Mean 75.1 nm/ spherical	MCF-7	0.25	[76]
Ulva lactuca	Whole	56 nm/spherica	MCF-7	37	[71]
Butea monosperma	LEAF	20–80 nm/ spherical	HNGC2	67	
Azadirachta indica	Leaf	2–18 nm/ triangular, hexagonal	shia	4.1	[77]
Melia azedarach	Leaf	78 nm/cubical, spherical	HeLa	300	[78]
Citrullus colocynthis	Leaf	16.57 nm/Spherical	HCT-116	30	[79]
Gymnema sylvestre	Leaf	Spherical	HT29	85	[80]

Key: A-549; H1299; lung cancer, MCF-7, MDA-MB-231; breast cancer cell lines, SCC-40; oral cancer, HCT-116, HT-29; colon cancer, PANC-1; pancreatic cancer, Bladder (5637); bladder cancer, HeLa & SiHa; cervical cancer, HEK-293; human embryonic kidney cells, HepG2; liver cancer, PA-1; ovarian teratocarcinoma cell, PC3; prostate cancer, and LNCaP; prostate adenocarcinoma.

Table 1.
Anticancer activities of silver nanoparticles (AgNPs) synthesized from plants.

HCT116 colon cancer cells in human by inhibiting the cell division and reducing G1 phase [18]. In another study green synthesized AgNPs by using plant extract showed potent cytotoxicity against lung cancer [23]. AgNPs synthesized from fruit of *Tamarindus indica* and *Nepeta deflersiana* resulted into apoptosis and cytotoxicity for human breast cancer and cervical cancer, respectively. A dose dependent anticancer effect was observed may be induced due to oxidative stress that leads to mitochondrial and DNA impairment [24]. Cell lines from liver, gastric, and prostate cancer showed cytotoxic effects against AgNPs from lotus plants [26]. AgNPs prepared from *Crataegus microphylla* (fruit) and *Gossypium hirsutum* (leaf) showed considerable distortion of gastric adenocarcinoma cells [81]. It has been reported that AgNPs target the lung adenocarcinoma cells breaking DNA helix, chromosomal instability, and damage the mitochondria of cancerous cells [81]. When AgNPs applied to MCF-7, it changes the morphological parameter modifications, inhibition of cell growth and significant loss of plasma membrane integrity.

Although AgNPs of large size >100 nm can be more effective but small size <10 nm penetrate the cell, get localized inside the nucleus easily and can induce cytotoxicity at greater level as reported by Avalos et al. that smaller size nanoparticles exhibit more cytotoxicity than larger size in MTT assay and lactate dehydrogenase assays [82]. The mechanism involved behind inducing cytotoxicity is (i) interruption in cellular respiration and DNA replication due to uptake of free silver ions (ii) production of free silver radicals and reactive oxygen species (ROS) (iii) damage to cell membrane [83]. AgNPs induce ROS production and reduce glutathione (SGH), nuclear factor kB (NF-kB) and tumor necrosis factor-alpha (TNF-1) levels within cells). Increasing levels of superoxide radicals disrupt the mitochondrial signal transduction pathway, resulting in apoptosis [84]. The increase level of reactive oxygen species and decrease glutathione elicit damage to different components of cell such as breaking of DNA, peroxidation of lipid membrane and protein carbonylation. Apoptosis occurs when caspases 3 and 9 are activated as a result of changing mitochondrial membrane potential. After that, it activates c-Jun NH2terminal kinase (JNK), which causes DNA breaks to cause cell cycle arrest and the creation of apoptotic bodies [85]. AgNPs prepared from plants increase the sub-G1 phases of cell cycle and exhibit potent cytotoxicity. Chang et al. demonstrated link between sub-G1 arrests in cancer cells treated with curcumin showed more apoptosis suggested that AgNPs induced apoptosis in cancerous cells by prolonged sub-G1 phase [86]. This implies that the enhanced sub-G1 arrest of cancerous cells, which is connected to the induction of apoptosis, may be resulting in the death of cancer cells due to AgNPs application. In addition, green synthesized AgNPs prevented the formation of new cells induced by vascular endothelial growth factor (VEGF). After penetrating into the cell, AgNPs inhibited VEGF and through Src-dependent pathway the vascular permeability 1 L-1βinduced occured. [87]. Due to this anti-angiogenic efficacy AgNPs recommended as a new gateway of treatment for cancer. Another mechanism suggested for the anticancer potential of AgNPs is autophagy-induced cell breakdown, which results in cell death. Additionally, because autophagolysosomes accumulate in cancer cells and are more prevalent there, greenly produced AgNPs encourage autophagy, which ultimately results in cell death [30].

2.2 Silver nanoparticles as antibacterial agent

Silver nanoparticles have antibacterial properties and they auspiciously appear to be more potent and efficient antimicrobial agents than other nanomaterials from noble metals, due to their unique properties such as a large surface to volume ratio, toxicity, interaction with phosphorus and sulfur compounds in the cell [88]. These characteristics make them excellent agents for treating a variety of microbial infectious complaints, as well as for overcoming microbial resistance to conventional medicines, whether used in single or in combination with other therapeutic formulations [89]. The synergistic action of nano-silver and a broad variety of phytoconstituents exhibit wide range of antibacterial qualities, as silver nanoparticles are easily manufactured from plant extracts with extraordinary stability and eco-friendly approach. According to a report antimicrobial agent containing silver ions can damage the external membrane of targeted cell by reacting with proteins (thiol group) resulted in inactivation of bacterial enzymes. Silver reduces DNA replication and uncouples electron transport from oxidative phosphorylation when applied. As a result it interferes with membrane permeability and inhibits the respiratory chain enzymes and kills the microbes at very low concentration [90, 91]. AgNPs have suppressed the growth of bacteria at the minimum inhibitory concentration (MIC) for example; *Cestrum nocturnum*at at 0.25 μg/ml concentration showed 36 mm zone of inhibition against *Citrobecter* which support the above statement. At a dosage of 10 μg/ml, *B. vulgaris* and *B. nigra* demonstrated substantial antibacterial activity against *S. aureus* (93 mm) while *Ceratonia siliqua* leaves showed 8 mm inhibitory zone against *E. coli* (**Table 1**). *Ocimum sanctum* at 5 μg/ml concentration showed 11 mm zone of inhibition against *E. coli.* When tested at minimum inhibitory concentrations, AgNPs showed excellent permeability through bacterial cell walls and plasma membranes. AgNPs interacting with plasma membranes and releasing Ag + ions into cell cytoplasm, Thus, respiratory mechanisms and ion exchange processes were disrupted in bacterial membranes and mesosomes, and the obstruction of sulfur-containing protein synthesis on ribosomes [92]. When biologically produced nanoparticles and

$AgNO_3$ solutions were combined, the cytotoxic action was enhanced [93]. The addition of Ag + ions to the culture media reduced the production of biofilms by bacteria during growth. In biological experiments, AgNPs were found to have anti-biofilm formation properties against Gram positive (*Enterococcus faecalis* and *S. aureus*) and Gram negative (*Shigella sonnei* and *Pseudomonas aeruginosa*) [94]. All of these mechanisms of action show that AgNPs have antibacterial capabilities and that they can be used as anti-pathogenic drugs to reduce microorganism proliferation (**Table 2**).

Plant used	Concentration (μg/ml)	Bacteria	ZI (mm)	Reference
Coptis chinensis	12.50	*E. coli*	12	[95]
Cestrum nocturnum	0.25	*Citrobacter*	36	[94]
	1	*S. typhi*	28	
	2	*E. faecalis*	15	
	4	*E. coli*	23	
	8	*P. vulgaris*	26	
	16	*V. cholerae*	41	
B. vulgaris	10	*P. aeruginosa*	77.57	[96]
		E. coli	89.21	
		S. aureus	93.64	
B. nigar	10	*P. aeruginosa*	73.83	
		E. coli	83.31	
		S. aureus	93.12	
C. burspastoris	15.50	*P. aeruginosa*	92.62	
		E. coli	80.76	
		S. aureus	96.03	
Ceratonia siliqua	10	*E. coli*	8	[97]
Helictere sisora	12.5	*E. coli*	2	[98]
	100	*V. cholerae*	6	
Ocimum sanctum	5	*E. coli*	11	[99]
		S. aureus	10	
Acalypha indica	10	*E. coli*		[100]
Citrus aurantiifolia		*E. coli*	7	[101]
Citrus sinensis			8	
Citrus limetta			6	
Citrus aurantiifolia		*K. pneumoniae*	6	
Citrus sinensis			8	
Citrus limetta			5	
Citrus aurantiifolia		*S. aureus*	5	
Citrus sinensis			5	
Citrus limetta			4	

Plant used	Concentration (μg/ml)	Bacteria	ZI (mm)	Reference
Citrus aurantiifolia		S. typhimurium	6	
Citrus sinensis			6	
Citrus limetta			4	
Zingiber officinale	100	Staphylococcus spp	6.5	[102]
Coffea arabica	0.05	E. coli	2.3	[103]
	0.1		3.1	
	0.05	S. aureus	2.1	
	0.1		2.7	
Chlorophytum borivilianum	15	S. aureus	10	[37]
	30		17	
	60		29	
	15	P. aeruginosa	9	
	30		11	
	60		14	
Ficus sycomorus	50	E. coli	9	[104]
		S. aureus	11	
		P. aeruginosa	11	
		K. pneumoniae	18	
		S. typhi	30	
		S. flexneri	16	
Zataria multiflora	20	S. aureus		[105]
		P. aeruginosa		
Malva verticillata	100	A. hydrophila n	12.44	[106]
		A. salmonicida	28.64	
Camilla sinensis	50	E. coli	12.5	[107]
Rhizophora apiculata	21	B. subtilis	11	[108]
		E. coli	14	
		K. pneumoniae	14	
		P. vulgaris	14	
		P. aeruginosa	12	
		S. typhi	14	
Dryopteris crassirhizoma	100	B. cereus	2	[109]
	150	P. aeruginosa	3	
Acacia leucophloea	25	S. aureus	15	[110]
	50	B. cereus	17.50	
	75	S. flexneri	17	
Olea europaea	7	S. aureus	2.7	[111]

Plant used	Concentration (μg/ml)	Bacteria	ZI (mm)	Reference
Conocarpus Lancifolius	2.5	*s. aureus*	4	[54]
	5		7.5	
	10		11	
	20		14	
	50		22	
	2.5	*s. pneumoniae*	3.8	
	5		7	
	10		10	
	20		11	
	50		19	
Tridax procumbens	20	*E. coli*	11	[55]
		Shigella. ssp	15	
		Pseudomonas aeruginosa	20.66	
		Pseudomonas aeruginosa	15.33	
		Candida tropicalis	20	
Cleome viscosa	10	*s. aureus*	11	[101]
	20		13	
	30		14	
	40		17	
	10	*B. subtilis*	10	
	20		12	
	30		13	
	40		14	
	10	*E. coli*	10	
	20		13	
	30		15	
	40		16	
Bee pollen	100 μg/mL	*B. subtilis*	18	[59]
		P. aeruginosa	18	
		S. aureus	17	
		E. coli	11	
Parthenium hysterophorus	60	*E. coli*	17	[60]
		P. aeruginosa	18	
		B. subtilis	12	
		E. feacali	11	
		S. aureus	15	

Plant used	Concentration (µg/ml)	Bacteria	ZI (mm)	Reference
Gloriosa superba	40	*Enterococcus faecalis*	29	[62]
		Bacillus subtilis	24	
		Staphylococcus aureus	23	
Luffa acutangula	5	*B. subtilis*	7.2	[63]
		S. aureus	7.9	
		E. coli	7.4	
P. americana	25	*P. vermicola*	24	[102]
		A. caviae	17	
	50	*E. coli*	10	[103]
		Bacillus subtilis	8	
Taxus baccata Linn	25	*Shigella dysenteriae*	10	[77]
		E. coli	12	
		Salmonella typhi	08	
Gardenia thailandica	50	*S. aureus*	12	[103]

Table 2.
Antibacterial activity of silver nanoparticles (AgNPs) from plants.

2.3 Antifungal activity of silver Nano particles

Drug resistance by pathogenic fungi has been continuously increasing, so it is necessary to develop new antifungal agent. The antifungal agent was present in the form of the chemically, physically and, biologically. The green plants which caring affective metabolites and particles which use against the fungus disease. There are the many nano particles which use against the fungi but Silver nano particles have the drastic affect against the many disease which is caused by the fungi [25]. In many study reported that the AgNPs as antifungal agent in treating fungal infectious diseases [112]. This disease badly affected the human and the plants as well. Silver nanoparticle are very effective against the four pathogens *R. solani, F. oxysporum, S. sclerotiorum,* and *S. rolfsii* which caused the disease in the vegetable and horticulture. Silver nanoparticles activity was checked at the four different concentration against these fungus species [113]. Silver nano particles was seen the most activity against the candida albican species include *C. tropicalis*, *C. glabrata*, *C. parapsilosis. C. glabrata* at different concentration (0.01 µg −300 µg) with different zone of inhibitions (05–70) [114] (**Table 3**).

Plant name	Concentration µg	Fungus		Reference
Garcinia kola pulp	75	*Candida tropicalis*	13	[115]
		Fusarium oxysperium	15	
Taxus baccata Linn	90	*T. purpureogenus*	22	[77]
Juniperus procera	50	*C. albicans* ATCC885653	14.3	
	50	*C. neoformans* ATCC16620	9.80	

Plant name	Concentration µg	Fungus		Reference
red curran	30	*Fusarium oxysporum*	12	[116]
		Botrytis cinerea	26	
		Pestalotiopsis mangiferae	50	
E. tirucalli	923.4	*B. cinérea*	1.9	[117]
		R. stolonifera	3.5	
B. lanzan Spreng	50 ppm	*Rhizoctonia solani*.	47	[118]
	100 ppm		52	
Allium fistulosum	0.32 mg/mL	*Aspergillus niger*	08	[119]
	10 mg/mL		11	
	0.32 mg/mL	*Candida albicans*	07	
	10 mg/mL		10	
Cynara cardunculus	1.8 mg/mL	*C. albicans*	26.6	[120]
Glycosmis pentaphylla	11	*A. alternata*	15.5	[121]
		F. moniliforme	14.5	
		Colletotrichum lindemuthianum	9.5	
		Candida glabrat	12	
O. vulgare	5 µL	*Aspergillus flavus*	7.7	[122]
	10 µL		11	
	5 µL	*Fusarium moniliform*	7	
	10 µL		10	
	5 µL	*Candida albicans*	10	
	10 µL		18	
Borago officinalis	100	*Candida albicans*	7	[123]
Alhagi graecorum	0.01 mmol\ml	*C. albicans*	14	[124]
		C. glabrata	18	
		C. parapsilosis	22	
		C. tropicales	21	
		C. krusei	15	
	0.02 mmol\ml	*C. albicans*	16	
		C. glabrata	21	
		C. parapsilosis	27	
		C. tropicales	25	
		C. krusei	17	
Malva parviflora L	15 µg /mL	*F. solani*	81.1	[125]
		A. alternata	83	
		H. rostratum	88.6	
		F. oxysporum	80	

Plant name	Concentration µg	Fungus		Reference
Allium ampeloprasum	25 µg /mL	*C. albicans*	20.1	[126]
		C. glabrata	20.6	
		C. krusei	15.1	
		C. tropicalis	16.4	
		C. parapsilosis	18.4	
Melia azedarach	20 µg /mL	*Verticillium dahliae*	87	[127]
Teucrium polium L	50 µg /mL	*F. oxysporum*	46	[128]
	100 µg /mL		54	
	150 µg /mL		54	
plant essential oil	20 µg /mL	*Aspergillus niger*	11.33	[129]
	20 µg /mL	*Aspergillus flavus*	13.27	
		Candida albicans	9.87	
		Candida tropicalis	14.66	
		Candida kefyr	15.17	
maize	25	*C. albicans*	0.021	[130]
Maize	47 g	*Candida albicans*	62.5	[131]
Ferulago macrocarpa	250 µg/mL	*Candida albicans*	34	[132]
Lotus lalambensis	6.25	*Candida albicans*	10	[133]
	12.5		13	
	25		16	
	50		19	
Grass waste	2	*F. solani*	20	[134]
	5		38	
	10		60	

Table 3.
Antifungal activity of silver nanoparticles (AgNPs) from plants.

3. Conclusions

Due to the vast range of activities and unique physical and chemical characteristics, silver nanoparticles are currently the subject of in-depth research. AgNPs are effective anticancer agents because they affect the cell cycle, prevent the growth of cancer cells, cause oxidative stress, and promote apoptosis [135, 136]. They protect against bacterial infections and showed potent antibacterial effect at minute concentrations. Due to the weakened immunological resistance of cancer patients, such antimicrobial protection is preferred during chemo- and radiotherapy. Most of the literature for use of AgNPs as antibacterial and anticancer agent is quite reported recently in present century showing that nanomedicine has made many advances in ongoing years and still there need to explored this field [137–139]. In order to gain unique insights and improve silver NP characteristics, additional research on AgNPs needs to be done.

Future applications may involve certain contentious concerns, like dose for various tissues; side effects from therapy, tissue-specific biocompatibility, or microbial resistance to NPs. AgNPs have some actions that seem to be dual or even contradictory depending on the situation. Examples include anti- or pro-oxidative, biosensing or bioresisting activity depending on the type of cell or living organism. Before being added to cells, NPs must be thoroughly described and their physical and chemical characteristics must be understood. These characteristics are mostly the product of various AgNP synthesis techniques, and only nontoxic ones should be favored in bioassays involving living models.

Author contributions

Muhammad Adnan and Ruqia Nazir, Sakina Mussarat conceived the idea of chapter, helped in writing and provide useful suggestions. Sakina Mussarat and Attique ur Rehman Khan participated in writing of the manuscript, and performed all literature surveys, designed the figures and reviewed the literature. All authors were involved in revising the chapter content, read, and approved the final draft.

Conflict of interest

The authors declared no potential conflicts of interest.

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