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A review on multifarious medicinal potential of green synthesized silver nanoparticles

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Abstract

Momentous advancement in nanotechnology has greatly participated in bringing transformations in various challenges of society like energy production, information technology, health and environment. Out of all the challenges society is currently facing, health is the major issue. Cancer, Bacterial, Fungal and other numerous diseases are there which we need to encounter with the best possible methods. Nanoparticles owing to their better size to area ratio act as good drug delivery agents. Synthesis of nanoparticles (NPs) has already travelled a long pathway and researchers are looking for green synthesis of NPs which is non-toxic and non-hazardous pathway of NPs synthesis. Green synthesis of NPs can be performed using bacteria, fungi, algae, virus, plant extracts etc. Green synthesis is preferable because of its cost-effectiveness, energy-efficient nature, bio-compatibility and being therapeutically significant. Biological media tend to have antioxidant properties preferably plant resources which when incorporated with metal, transport same property to such nanoparticles synthesized. Since ancient times, it has been read and well-researched that silver accounts various health benefits. Therefore, silver NPs (AgNPs) are looked upon for their novel use in therapies and treatment against numerous diseases as anticancer, anti-fungal, antibacterial. This review commentates on therapeutic activity of green synthesized AgNPs, their mode of action, and potential medicinal use against many diseases as well as their antioxidant potential.

Keywords: Silver nanoparticles [AgNPs]; Plant extract; Green synthesis; Antioxidant

1. Introduction

Nanotechnology infers to the word for mustering, embodying, regulating and usage of structures to regulate the dimension and structure at the nanoscale. Nanotechnology owns a good relationship with various disciplines of science and therefore has enormous applications in daily life including diagnosis and treatment of diseases [1]. Elements derived from a group of atoms with various dimensions in size range of 1-100 nm are called NPs. They possess high responsiveness as compared to bulk materials owing to their high surface area to volume ratio. Among all kind of NPs metal NPs own high value due to their uniform size distribution [2]. Among all, precious metal NPs like gold [3], iridium [4], osmium [5], platinum [6], palladium [7], rhenium [8], rhodium [9], and silver [10] along with multifarious stabilizing agents are useful due to their catalytic activity, air/water treatment, and medicinal applications. Various capping agents, solvents, reducing agents, metal salts and varying temperature ranges are used to tune the properties of NPs [11]. AgNPs are extensively studied and highly commercialized as they are much cheaper than Gold NPs (AuNPs) and widely used in consumer products, such as personal care products, cosmetics, medicinal devices, textile industries, and cleansing

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agents [12]. Silver is abundant in nature and has many useful properties like good conductivity, optical activity, non-liner catalytic effect, enhanced Raman scattering, high thermal conductivity. It has wide biomedical potential also as it can act as an antiseptic, antimicrobial, and larvicidal agent, used in medical and surgical devices, a content of various medicines, used in drug delivery, present in various cosmetic products, and also present in food preservatives [13]. Recent advancement in nanotechnology has manifested new approaches for AgNPs and it has become an essential and dominant innovation in recent years [14, 15].

Given the advancements made in science and technology in modern times , cancer is among the hardest problems that human race currently encounters. Cancer and metastasis occur by unbridled cell division and ensuing spread to adjacent healthy cells and tissues [16]. Mutated proto-oncogenes and tumour suppressor genes are the major cause of cancer. Both external and internal triggers may induce cancer. Traditional cancer treatment methods have certain flaws like non-specificity, low bio-availability, rapid clearance and toxicity. Cancer nanobiotechnology owns propitious capability to enhance the detection, diagnosis and medication of cancer [17]. With advancement in science, bacterial strains have developed resistance against antibiotics available which needs a new class of antibacterial drugs. Nano silvers own high reactivity against broad spectrum of microbes and parasites, even in low doses [18]. Fungal infections are also a major concern these days and interaction of silver nanoparticles with moulds is also widely discovered. Green resources specially some plant parts have potential anti-fungal activity. These plant parts when tuned with silver while fabrication of silver nanoparticles, impart their medicinal activity into synthesized particles as well. Anti-fungal potential is also a very well explored of medicinal application of silver nanoparticles. Antioxidants are agents that check oxidative reactions occurring in body. Advanced medical science has provided us synthetic antioxidants but these are harmful for us. Due to redox-active radical-scavenging properties metal nanoparticles behave as good antioxidants [19]. Therefore, in this review we have discussed about the current technology which includes AgNPs as one of the major tools for their medicinal applications and antioxidant properties.[20]

2. Synthesis of NPs

There are three main approaches to synthesize metal NPs – Physical synthesis, chemical synthesis, and biological (Green) synthesis of metal NPs [figure 1] and there are two major routes to synthesize NPs [Figure 2] namely, Bottom up and Top-down approaches [21, 22]. In physical synthesis, top-down approach is normally used while in chemical or plant-mediated synthesis, the bottom-up technique is employed. Implementing a bottom-up technique delivers a mono-dispersed nanostructure with fewer blemishes [21]. Physical method of synthesis of NPs includes few steps as grinding, milling and thermal ablation etc. This route of synthesis needs quite high amount of energy which makes it slightly non feasible. Also, low yield through physical method of synthesis of NPs is a major drawback of this pathway [23]. Though chemical method of synthesis of NPs consumes lesser amount of energy and also yields particles with precise shape and size [24] but, the use of precarious chemicals which are potent to cause carcinogenicity, genotoxicity, and cytotoxicity [25, 26] make them hazardous for environment. Generally, nanoparticles are synthesized via those techniques which involve hazardous solvents and toxic chemicals used in pyrolysis, sol-gel technique, chemical vapour deposition, etching and supercritical fluid approach [27]. Other extensively used techniques to synthesize metal nanoparticles are micropatterning [28, 29], attrition [30], nanolithography [32], mechanical milling [33], sputtering and thermal decomposition [33].

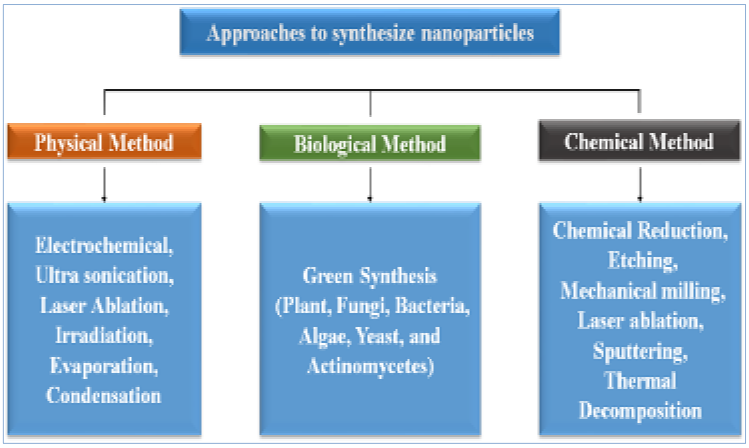

Figure 1 Approaches to synthesize nanomaterials

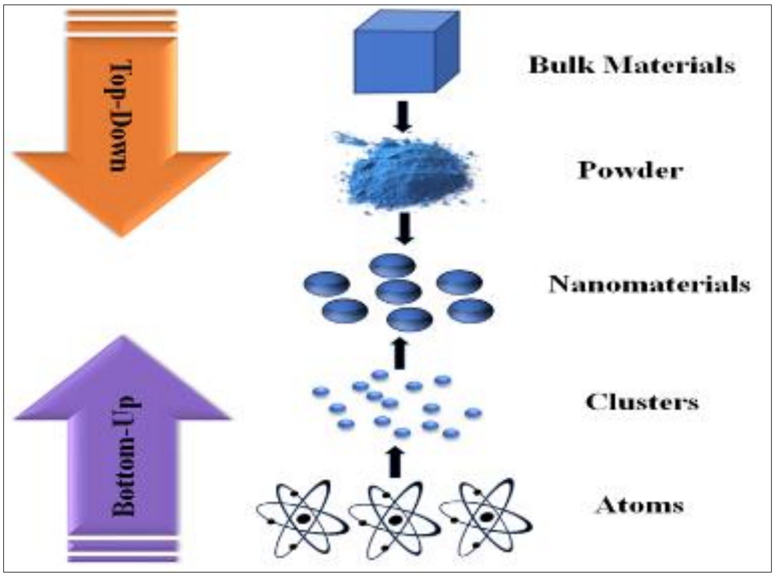

Figure 2 Routes to synthesise NPs

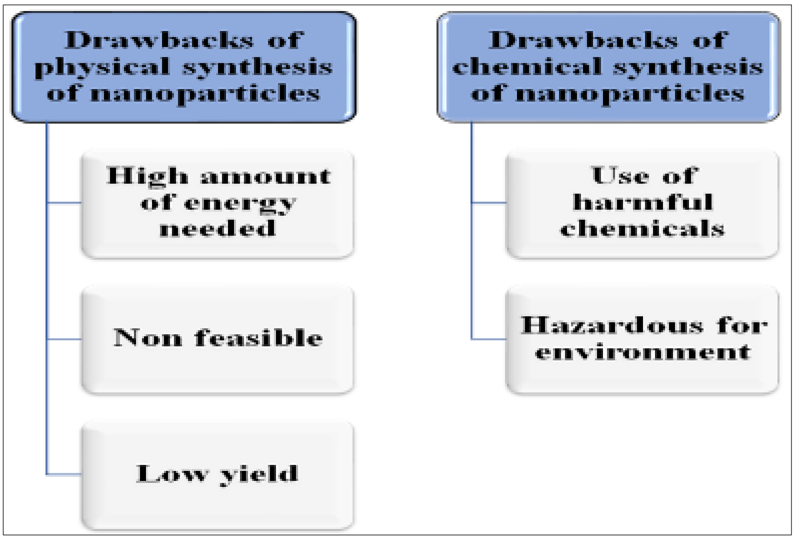

Figure 3 Drawbacks of physical and chemical Synthesis of Nanoparticles

Both physical and chemical methods are the fundamental methods of NPs synthesis but due to several limitations and drawbacks [figure 3], these are overtaken by green synthesis of metal NPs [32]. Green synthesis, being biocompatible and environmentally safe is considered as the most feasible approach for NPs synthesis [34]. Blending green chemistry with nanotechnology has extended the assortment of metal nanoparticles that are consistent with life and cellular physiology.

3. Clean Fabrication of AgNPs: Research Assessment

The domain of 'green chemistry' is very expansive and entails among other entities microorganisms, algal cells and vegetation [15]. Metallic nanoparticles are produced and anchored using these. Silver nitrate along with a naturally occurring reducing agent are vital for the ecologically sound fabrication of silver nanoparticles [35]. These reducing agents are available in the environment such as humic acid which has a broad occurrence. Its reducing tendency is due to quinines, ketones, aldehydes, phenolic and hydroxyls attached in its structure [14]. In green synthesis water is used as solvent with eco-friendly and renewable materials as capping and reducing agents [36]. AgNPs started out utilizing botanical extracts from *Salvia spinosa* cultured in vitro [37]. Sharma et.al's [38] investigated AgNPs synthesis using glucose [39], tea and coffee extract [40], unicellular algae extract [41] and bacteria [42].

According to a recent study, the bacterial cell-free supernatant with extracellular and intracellular approaches were beneficial for the synthesis of silver NPs [43]. The earliest AgNPs were produced by Klaus et. al. exploiting the biomass of *Pseudomonas stutzeri* AG259 bacterium [44]. Kalimuthu et. al synthesized silver NPs by intermixing aqueous solution of silver nitrate including *Bacillus lichenoformis* biomass [45]. Culture supernatants of *Staphylococcus aureus* was used by Nanda and Saravanan for synthesizing AgNPs [46]. Large scale production of NPs is mainly governed by the choice of bacteria and methods of synthesis [47]. To synthesize AgNPs beyond the cells *Penicillium citrinum* wholly extracted from soil was used [48], and Al-Bahrani et al. employed aquous extract of *Pleurots stratus* basidiocarp to develop AgNPs in sustainable manner [49]. Yeast strains were used by Eugenio et al. to synthesize AgNPs [50]. Antifungal efficacy and production of silver nanoparticles formed from *Fusarium oxysporum* has been researched by Regiel Futyra et al.[51].

Synthesis of silver nanoparticles have also been done using plant resources for instance, generation of AgNPs through *Jatropha curcus* latex serving as capping and reducing agent [52], usage of pineapple juice (*Ananas comosus*) as a reducer and stabilizer for AgNP production [53], using leaf extract of *Ocimum sanctum,* and curry leaves (*Murraya koenigii*) for synthesis of antibacterial AgNPs [54, 55], use of peanut shell extract for synthesis of antifungal AgNPs (that are comparable with the commercial AgNPs) [56], use of leaf extract of *Acalypha hispida* for Mn^{2+} detection [57], use of fruit extract of papaya [58], and leaf extract of *Moringa olifera* for antimicrobial capacity of AgNPs has also been reported [59]. In the process of green synthesis of AgNPs, it is observed that the protein metabolites [60] and chlorophyll [61] act as a stabilizing agent. Innocuous synthesis of NPs can be best explored with the aid of phyto nanotechnology. There are numerous secondary metabolites occurring in plants that are likely to be absent in microbes which validate that metals are reduced to their respective oxides, forming NPs of utterly novel shapes and sizes [62]. Plant mediated synthesis of nanoparticles occur in three phases·

- Reduction phase – It includes reduction of metal ions to non-valent metal atoms through electron transfer reduction method.
- Growth phase – In growth phase, the reduced zero valent metal atoms get aggregated into non-metallic particles with various shapes.
- Termination phase – This is the last phase in which the phytoactive components having antioxidant properties get ornamented around the nanomaterials concerning their stability [60, 63]

Biodegradable waste can also be incorporated into the process of synthesizing NPs [64]. This not only saves our environment but also prevents exhaustion of any natural resource. For instance, Skiba et al., synthesized silver NPs using orange peel extract obtained by plasma chemical extraction technique and methylene blue degradation under solar irradiation [65]. Human hair derived keratin, aqueous extract of tea waste [66], aqueous extract of waste corn-cob [67], cauliflower waste [68], aqueous extract of Mahua oil cake (as reducing and capping agent for silver NPs synthesis) [69], waste extract of plant food waste [70] and pomelo peel extract has also been used to synthesize silver nanoparticles [71].

4. Therapeutic Activity of AgNPs

4.1. Combat Cancer with silver nanoparticles

According to World Health organization (WHO) cancer is the foremost cause of death and it is the most widespread disease across the globe. Cancer is procured by changes in genes that control growth and division of cells. Cancer cells tend to grow even in absence of growth signalling. These have tendency to invade into neighbouring areas and spread across them. Initial stage of cancer is called 'Tumour'. Tumours are of two types namely cancerous tumours and benign tumours. Cancerous tumours spread into surrounding areas and undergo metastasis whereas benign tumours do not undergo metastasis and do not grow back. Based on the origin, cancer disease is classified as cervical cancer, breast cancer, thyroid cancer, prostate cancer, bladder cancer, kidney cancer, pancreatic cancer, melanoma and leukemia etc. [72]. Depending on the type of cell in which it is caused, cancer can be categorized as Carcinoma, Sarcoma, Leukemia, Lymphoma, Multiple myeloma, Melanoma, Brain & Spinal cord tumors, Germ cell tumors, Neuroendocrine tumors, and carcinoid tumors [73]. Cancer treatment pathway depends on numerous factors like location and type of cancer, extent of infection and recovery rate of patient [74, 75]. Some conventional pathways to treat cancer include surgery, radiation therapy, chemotherapy, immunotherapy [76-78], hormonal therapy [79, 80], endocrine therapy [81] and cancer stem cell therapy. Out of these treatments, hormone therapy and immunotherapy are not widely used because they tend to cause abnormality along with some sort of side effects including destruction of healthy cells, organs due to deterioration in life quality [82]. AgNPs are proclaimed to illustrate competent anticancer behaviour with high individuality and efficient against cancerous cells in a dose dependent way. Sumptuous versatility of AgNPs owes their biological compatibility towards phytochemicals that come from plant source. Furthermore, based on recent researches plant mediated AgNPs have proven their cancer curative properties by lowering the proliferation rate of cancer causing cells by halting the cell cycle [83]. Plant mediated AgNPs have exhibited intriguing anticancer activities over cells implicated with various carcinoma cells [84]. Anticancer potential has been proven by AgNPs produced by banana leaves against A549 and MCF7 cell lines [85], AgNPs facilitated by *Mangifera indica* seeds against Hela and MCF7 [86], AgNPs generated by *Heliotropium bacciferum* contrary to HCT-116 [87], and AgNPs employing *Zingiber officinale* against AsPC-1, PANC-1 and MIA PaCa-2 cell line [88].

A brief outlook of mode of action of silver nanoparticles counter to cancer cells can be given as- show cytotoxic behaviour by elevating ROS generation against cancer cells associated, upregulating the expression of pro-apoptopic and down regulating the expression of anti-apoptopic genes [89]. For instance, human epidermal laryngeal cancer cell lineages are cytotoxically impacted by AgNPs synthesized from *Citrullus colocynthis* [90], AgNPs synthesized from resveratrol and combined with gemcitabine are used in treating ovarian cancer which also enhances apoptopic activity [91] and cytotoxic against breast cancer cell lines and induces oxidative stress and apoptosis. [92]. Sreekanth et. al. used *Saccharina japonica* extract for synthesizing AgNPs which were cytotoxic against cervical carcinoma cells [93]. Jeyaraj et. al. synthesized spherical silver nanoparticles employing Podophyllum hexandrum Royal leaf extract which showed cytotoxic activity against human carcinoma cells [94]. Silver nanoparticles produced from *Cryptococcus laurentii* have anticancer properties against breast cancer cell lines [95]. Nanoengineered drug vehicles are better treatment methods due to having fluorescent and magnetic properties [96]. NPs exhibiting fluorescence are called quantum dots that help in identifying the cell attached to a particular nanocarrier [97]. The table 2 summarizes the anticancer activity of some green synthesized AgNPs.

Table 1 Green synthesized AgNPs against cancer

Reducing agent	Size of NP	Shape of NP	Activity	IC_{50} value	Reference
Ginkgo biloba leaves extract	40nm	Spherical-oval	Cervical cancer cells proliferation and growth is inhibited	3μg/ml for HeLa and SiHa cells	[98]
Cyperus conglomeratus root extract	468nm	Spherical	Destructive to human breast cells but not to healthy fibroblasts	5μg/ml	[99]
Walnut green husk extract with water	31nm	Spherical	Lethal to fibroblast cell lineages and carcinoma of the breast	60 μg/mL	[100]
Teucrium polium extract	100nm	Spherical	Cytotoxic in a dose dependent way towards human gastric cancerous cells.	68.2μg/ml for MNK45 cell line	[101]
Taxus yunnanensis extract	27nm	Crystal	Enables human hepatoma cancer cell lineages to go through apoptosis	81.39 μg/mL on HL-7702 cells	[102]
Cucumis prophetarum leaf extract in water	90nm	Spherical	Cytotoxic to human pumonary cells, hepatoma cells and triple negative breast cancer cells	105.8 μg/ml on A549, 81.1 μg/ml on MDA-MB-231, 94.2 μg/ml on HepG2, and 65.6 μg/mL on MCF-7 cell lines	[103]
Talaromyces purpurogenus extracellular pigment	41nm	-	Hostile to human embryonic kidney cell lines, human liver cancer and human cervical carcinoma	154.88 μg/mL	[104]
Nocardiopsis sp. MBRC-1	45nm	Spherical	Toxic to human cervical carcinoma in a dose-dependent manner	200 μg/mL	[105]
Alternanthera sessilis extract	50nm	Spherical	Cytotoxic in a time and dose dependent way against carcinoma of breast and prostatic cells	250.21μg/ml	[106]

Lyngbya majuscula strain	149nm	Spherical	Reduces human leukemic cell lines' viability in a dose and time dependent manner	1000 ± 4.38 μg mL^{-1}	[107]
Dimocarpus Longan Lour., extract from peel	32nm	Cubic	Detrimental to human prostate carcinoma cells	-	[108]
Actinobacterial strain SH11	16nm	Spherical	Deleterious in a dose dependent manner against macrophage cells and breast cancer cells	-	[109]
Artemisia vulgaris extract	25nm	Spherical	Cytotoxic to human cervical and breast carcinoma	-	[110]
Penicillium shearii AJP05	8nm	Spherical	Lethality of human hepatic carcinoma along with osteosarcoma cell lines by apoptosis and ROS release.	-	[111]

4.2. Antibacterial activity of silver nanoparticles

Resistance of bacterial strains towards antibiotics is a major concern while treating bacterial diseases which calls for new antibacterial agents [112]. Since ancient times, silver has been used as disinfectant, especially for wound healing [113]. Effectiveness of silver nanoparticles against bacterial disease depends on ambience where it has to act as well as on interaction between bacterial cell and the silver nanoparticles.

Table 2 Antibacterial activity of Green synthesized AgNPs

Reducing agent	Size of NP	Shape of NP	Activity	MIC value	Reference
Fenugreek leaves	20-30 nm	Spherical	*E. coli* bacteria	6.25μg/ml	[114]
			S. aureus bacteria	12.5μg/ml	
Justicia adhatoda	20 nm	Spherical	*Pseudomonas aeruginosa*	-	[115]
Emblica Officinalis fruit extract	15 nm	Spherical	*E. coli*	-	[116]
			K. pneumonia		
			S. aureus		
			B. subtilis		
Berberis vulgaris	75.7 ± 17.1 nm	Spherical	*coli*	89.21 ± 6.48	[117]
Brassica nigra	14.7 ± 7.9 nm	Spherical	*E. coli*	83.31 ± 3.45	
Capsella bursa-pastoris	16.2 ± 8.4 nm	Spherical	*E. coli*	80.76 ± 2.94	
Lavandula angustifolia	37.8 ± 10.7 nm	Spherical	*E. coli*	82.77 ± 1.03	
Origanum vulgare	46.1 ± 19.7 nm	Tunacted Octahedral	*E. coli*	-	
Pedalium murex leaf extract	14 nm	Spherical	*E. coli*	-	[118]
			P. aeruginosa		
			M. flavus		
			B. subtilis		
			B. pumilus		
			S aureus		
			K. pneumoniae		

Gymnema sylvestreleaf extract	20-30 nm	Spherical	*Staphylococcus aureus*	-	[119]
			Escherichia coli		
Aloe Vera	35-55 nm	Spherical	*Bacillus subtilis*	-	[120]
			Klebsiella pneumoniae		
			Salmonella typhi		
Datura stramonium leaf extract	18 nm	Spherical	*Staphylococcus aureus*	-	[121]
			Escherichia coli		
Olive leaf extract	30 ± 6 nm	Spherical	*Staphylococcus aureus*	-	[122]
			Escherichia coli		
Artocarpus heterophyllus Lam. seed extract	10.78 nm	Irregular shape	Gram positive (*B. cereus, B. subtilis* and *S. aureus*)	-	[123]
			Gram negative *(P. aeruginosa*)		
Coffea arabica seed extract	10-40 nm	Irregular shape	*Staphylococcus aureus*	-	[124]
			Escherichia coli		

4.3. Anti-fungal activity of silver nanoparticles

Anti-fungal drug resistance is not as much challenging as antibacterial drug resistance yet a need of better and well-developed drugs is always searched in medicine sector. AgNPs are found useful for anifungal activities at a good extent.

Table 3 Anti-fungal activity of green synthesized AgNPs

Reducing agent	Size of NP	Shape of NP	Activity	MIC value	Reference
Aspergillus Foetidus MTCC8876	104.9 nm	Roughly spherical	*Aspergillus niger, Fusarium oxysporum, Aspergillus Oryzae, Aspergillus parasiticus, Aspergillus foetidus, Aspergillus flavus*	-	[125]
Olive Leaf Extract	13.85 nm	Spherical and semi spherical shape	*Aspergillus aculeatus* strain N (MW958085), *Fuserium oxysporum* (MT550034), and *Alternaria tenuissiuma* (MT550036)	-	[126]
Kiwi peels extract	-	Spherical	*C. albicans, C. haemulonii, C. lusitaniae, C. krusei and C. glabrata*	-	[127]
Capsicum annum LeavesExtracts	18.6 nm	Spherical	*C. Albicans*	1.6	[128]
			A. niger	3.0	
			R. oryzae	2.6	
			A. pahariSticus	2.8	
			A. flavus	3.0	
Avena fatua Extract	25-40 nm	Spherical	*F. oxysporum*	-	[129]
leaf extract of *J. regia*	20.67 nm	Spherical	*Aspergillus ochraceus, Aspergillus melleus, and Aspergillus flavus*	-	[130]
Ascomycetes fungi	21.8-35.8 nm	Spherical	*Candida albicans, Candida krusei, Candida glabrata, Candida parapsilosis, Candida tropicalis*, and *Candida guilliermondii,*	-	[130]

			Fusarium oxysporum, Fusarium phaseoli, Fusarium sacchari, Fusarium subglutinans, Fusarium verticillioides, and *Curvularia lunata*		
			Yeast	1.25-40 μM	
Arctium lappa leaves	40 nm	Spherical	*Phytophthora infestans* and *Alternaria*	-	[132]
Zygophyllum album	6.64 nm-54.82nm	Spherical	*Fusarium oxysporum*	-	[133]
Cinnamomum camphora		Spherical	*Fusarium oxysporum*	154.39 μg/mL	[134]

4.4. Antioxidant properties of silver nanoparticles

Medicinal plants own antioxidant properties which make them very useful from medicinal aspect. Promising antioxidant properties of such herbs make them beneficial for health. These when incorporated with silver metal , impart same property on synthesized nanoparticles as well. Strong antioxidant property displayed by few nanomaterials is breaching intriguing potential to cultivate new administration with improved and intented actions. Some phytometabolites as flavanoids, anthocyanins and phenols are natural and potent resources of antioxidants. Flavanoids, remarkably, are secondary plant phenols with promising antioxidant potential [19]. Among natural antioxidants, flavanoids, tocopherols, cinnamic acids are most notable ones [128].

Table 4 Antioxidnat properties of green synthesized AgNPs

Reducing agent	Size of NP	Shape of NP	Reference
Blighia sapida	-	Spherical	[19]
L. angustifolia	10-30	Spherical	[135]
Olive Leaf Extract	13.85 nm	Spherical and semi spherical shape	[126]
Kiwi peels extract	-	Spherical	[127]
leaf extract of *J. regia*	20.67 nm	Spherical	[130]
Zygophyllum album	6.64 nm-54.82nm	Spherical	[133]

5. Viable bioactive mechanism of green synthesized AgNPs

Biosynthesized AgNPs have a knack to modulate the transmembrane potential of mitochondria by producing free radicals in excess , thereby causing cell death due to apoptosis [136]. At level of cells, these NPs can control cancer growth or cause cancer cell death by autophagy or apoptosis through different signaling pathways like nuclear factor-κB, COX-2 along with PI3K/AKT/ mTOR course [137, 138]. NPs attributed to cancer treatment have three parts i.e., as a targeting agent that connects to biomarker, as an imaging agent like the quantum dots [139] and as the drug carrier that releases drug into the body. Size of NPs conjointly plays an imperative role in drug delivery. AgNPs show "trojan-horse" type mechanism on cancer cells [140] where AgNPs are collected in endosomes after their intake. Later the organelles are directed to lysosomal functions which cause increased discharge of silver ions consequently that may lead to unbalanced cellular homeostasis and can instigate cell death [140]. By increasing their communication with metalloproteinases (MMPs) AgNPs may cease the propagation of malignant cells , terminate the cell cycle and develop a variety of morphological alterations and modulate pro-apoptopic and anti-apoptopic protein expressions [141, 142]. AgNPs can target the cancer cells either actively or passively. The rationale for passive attack is the anatomy of cancerous tissues, where neo-angiogenesis results in an aberrant endothelial layer and fenestrated vasculature. These anatomical characteristics in combination with impeded lymphatic drainage direct the infiltration and anticipation of nanoscale substances into cancerous cells [143]. The term "Enhanced Permeability and Retention" (EPR) effect describes this phenomena[144] while active targeting is a viable approach to increase cancer specificity of AgNPs. When actively targeted, a moiety peculiar to cancer cells is attached to NP surface to facilitate the nanomaterial uptake by desired cells [145]. Orlowski et al., demonstrated that absorption of AgNPs may be governed by heterogeneous uptake mechanism [146]. However, this trait has a detriment that AgNPs may be eradicated from circulation prior to reaching the tumor by reticuloendothelial cells' phagocytic cells.This problem can be resolved by PEGylating the AgNPs which inhibits opsonization [147, 148].

Additionally, it has been noted that silver ions affect ROS production which ends up resulting in significant oxidative stress and prompts cellular processes that eventually culminate in cell death [149-151] and in turn help in performing well in medicinal purpose. AgNPs activate MAP kinases to initiate an array of signaling pathways, including the DNA-damage response and anti-proliferative signaling [152]. Modern therapy works on intercepting autophagic flux by AgNPs [153] that can inflect autophagy in cells [154, 155]. Autophagy induction is the key feature of AgNPs to show cytotoxicity infected cells [156, 157]. It has been proven that smaller AgNPs than larger AgNPs produce more robust radioenhancement and release more silver ions, thus are more effective [158]. NPs also assist in targeted drug delivery for site specific drugs [159] and they also act as excellent vaccine carriers [160]. Nanoparticles have shown to increase antifungal and antibacterial activity of drugs when in combination with them. This makes them highly potential for such treatment. Along with this therapeutic activity, since biota holds a very promising antioxidant behaviour therefore, silver nanoparticles when synthesized in their combination are also blessed with good antioxidant behavior.

6. Possible Adverse Effects of Nanomaterials

In 21st century, nanotechnology has become apparent as one of the most important technologies and a fast-growing discipline. Nanomaterials have tremendous applications in medicinal sector and in different domains such as cosmetics, textiles, diagnostic materials, food, energy, personal care products, paints, pharmaceuticals, computers, portable telephones and science [161-167]. Global impact of nanomaterials is clearly reflected by the increasing number of related patents, heavy investments in research and development in the highly advanced nations, and the availability of nano-products in the market. Though, future prospects of the applications of nano-materials are unlimited, but now, for the last few years, scientists are thinking rationally about the possible adverse effects to human health, ecology and environment due to exposure of nano-materials in the natural environment [168-170]. Concerns over environment, health and ecology have limited the future applications of nano-materials in different fields. Therefore, efforts must be made to assess the toxicity risks with the exposure of nano-materials in working environment and propose its future impacts on a global level.

7. Conclusion

Nanomaterials have multiple beneficial applications in medicinal, environmental and economic areas. The size, shape and fabrication factors of metallic nanoparticles can all influence their curative properties. NPs of size less than 100nm are considered better therapeutic agents since they are stable, bio-compatible, have an EPR effect and are well transmitted. The intrinsic features of elements , their potential for surface functionalization, their size, and their morphology could all influence the fluctuations in the curative abilities of metal based NPs. Main difference midst silver nanoparticles and conventional drugs is based on nano nature of AgNPs which decreases the severe side effects. AgNPs synthesized via green route show more prominent selective cytotoxicity and antioxidant properties.

Green synthesized NPs tend to be cost effective treatment against cancer, fungi -mediated as well as bacteria-mediated diseases. AgNPs can be considered as not only better option for direct bio-active reagents but also better delivery platforms for various cytotoxic drugs. They may also be incorporated to enhance anti-cancer activity in chemo or radiotherapy. Studies about bio-active activities of green synthesized AgNPs may pave a new path to decrease the required dose for therapy. Application of nanotechnology has potential to increase the efficiency of therapy by providing solutions to problems related with pharmaceutical solubility, toxicities, bioavailability, immunocompatibility, and cellular intake. Therefore, this review summarizes that AgNPs obtained from different green pathways are functional towards different kinds of anticancer, antifungal and antibacterial cells along with owing antioxidant features.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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