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Green synthesis of silver nanoparticles with a long lasting stability using colloidal solution of cowpea seeds (*Vigna sp. L*)

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ABSTRACT

Silver nanoparticles (AgNPs), one of the most commercialized nanomaterials, are frequently used in various industries in medical devices to water purifiers. This study is the first to propose a low-cost and novel eco-friendly and reproducible synthesis to extract AgNPs using cowpea seeds (*Vigna sp. L*) with a long lasting stability. From a mixture of silver nitrate concentration of 10^{-3} M and 2.5 and 10 mL of seed extract, 2.19 and 1.09% spherical AgNPs were fabricated with diameters <70 nm and a maximum absorbance peak at 431 nm. The observed peaks in the extract, corresponding to carbonyl group, amide I, II and III, indicated the presence of carbohydrate and protein which stabilized the synthesized AgNPs for a period of 11 months. The carbohydrate and protein released from the aqueous extract cowpea seeds reduced the nitrate and acted as templates for silver nucleation sites to form silver nano-structures. Peptides and proteins also acted as capping agents to control the size and shape of the produced silver nanoparticles.

1. Introduction

Nanoparticles are synthesized using different methods including: reduction in solution [1], photochemical reduction [2], laser mediated technique [3], thermal decomposition [4], and microwave assisted method [5]. These conventional techniques have various limitations, e.g., complexity, high cost, low stability, toxicity, environmental unfriendliness, etc. These issues have persuaded researchers to develop simple, safe, eco-friendly and reliable methods to synthesize nanoparticles with a higher stability where organic systems are utilized as the preferred tailor green materials [6]. In this way, with a nano-bio-technological approach, biological systems have undergone physical and chemical processes to obtain nano-sized particles with desirable characteristics [7]. In fact, the *in-situ* green synthesized nanoparticles are often more stable compared with chemical nanoparticles. For example, the biogenic silver nanoparticles produced from *L. fermentum* was reported to be very persistent with a very good antimicrobial activity of up to 20 times higher, compared to chemically produced nanoparticles [8].

Green nanoparticle synthesis was reported by Gardea-Torresdey and his co-workers who investigated the formation of gold and silver nanoparticles from living plants [9]. Since then, many biological synthesis protocols have been reported using bacteria [10], fungi [11] and plants [12]. The potential of fungi for the nanoparticle synthesis, e.g., *Ureibacillus thermosphaericus*, was studied to produce nanoparticles with an average size of 1–100 nm [13],*ellipsoidal Neurospora crassa* with an average size of 11 nm [14], 2–4 nm *Trichoderma viride* [15] and spherical 10–40 nm spherical particles [16].

Silver nanoparticles (AgNPs) are one of the most commercialized nanomaterials with pharmaceutical values used in plant disease control, orthopedic/dental graft [17], antibacterial properties to hamper microbial growth [18], diagnostics, therapeutics [19] and wound dressing [20]. They are also used in textile products [21], home water purification systems, cosmetics, electronics [22], plasmonics [1] and optoelectronics [23].

Microorganisms such as bacteria, fungi and plants are used for the biological syntheses of silver nanoparticles due to their antioxidant or reducing properties typically responsible for the reduction of metal compounds in their respective nanoparticles. Among various biological methods of silver nanoparticle synthesis, microbe mediated synthesis is not of industrial feasibility due to the requirements of highly aseptic conditions and their maintenance [24]. Therefore, the use of plant extracts is potentially advantageous over microorganisms due to the ease of

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Table 1
The synthesis of silver nanoparticles in solutions using green sources (mostly plants).

References	Temperature	Reduction time	Average size of silver nanoparticles	Primary source
Ghorbani [34]	–	30 min	50–150 nm	*Cell extract of bacterium Salmonella typhirium*
Elavazhagan and Arunachalam [35]	–	3 h	50–90 nm	*Memecylon edule leaf extract*
Abdel-Aziz et al. [36]	40 °C	24 h	30–50 nm	*Chenopodium murale leaf extract*
Jha et al. [37]	40 °C	10 min	2–5 nm	*plant exracts*
Obaid et al. [38]	30 °C	30 min	8–40 nm	*Oriental plane leaves extract*
Nabikhan et al. [39]	–	24 h	5–20 nm	*Leaf callus extract Sesuvium portulacastrum*
Prathap et al. [40]	50–95 °C	–	106 nm	*Leaf extract Abutilon indicum (L.) sweet*
Kumar et al. [27]	60 °C	30 min	–	*Leaves extract Mangifera Indica and Syzygium cumini*
Banu et al. [41]	40 °C	24 h	3–20 nm	*Fung Rhizopus stolonifer*
Donda et al. [29]	60 °C	15 min	11–20 nm	*Leaves and fruit extract of Securinega leucopyrus*
Jha and Prasad [30]	Warming up on the steam bath	10 min	2–6 nm	*Cycas Leaf*
Subramani et al. [42]	Room temperature under dark condition	15 min	80 ± 90 nm	*Medicinal plants such as Mukia maderaspatana, Kedrostis foetidissima and Cayratia pedata*
Bala and Arya [43]	Temperature variation (0°, 37° and 100 °C) at different conditions like pH variation (9, 10 and 11)	–	–	*Aqueous extract of endophytic fungus Aspergillus fumigatus*
Salisu et al. [44]	Room temperature in the dark	Overnight	–	*Leaf extract of Lemon grass (Cymbopogon citratus)*
Jancy and Inbathamizh [45]	Room temperature and direct boiling, exposed to different conditions like sunlight radiation, UV radiation, and several short burst of microwave)	Room temperature with 48 h	20–40 nm	*Leaf extract of Morinda pubescens*
Firdhouse and Lalitha [46]	3 methods: room temperature, temperature of 70–75 °C and sonicated using an ultrasonic bath	1 h	< 60 nm	*Aqueous extract of Portulaca oleracea*
Kaviya et al. [47]	Room temperature (25 °C) and 60 °C	1 and 18 min for 10^{-3} M $AgNO_3$ 1 h and 40 min for 10^{-4} M $AgNO_3$	50 nm and 35 nm using 10^{-3} M $AgNO_3$ at 25 °C and 60 °C, respectively 20 nm and 15 nm using 10^{-4}M $AgNO_3$ at 25 °C and 60 °C, respectively	*Leaf Extract along with D-Sorbitol of Polyalthia longifolia*
Iravani and Zolfaghari [48]	Different temperatures (25 °C, 50 °C, 100 °C, and 150 °C)	–	10–40 nm	*Pinus eldarica bark extract*
Amutha et al. [49]	(i) Room temperature, (ii) higher temperatures (75–80 °C), and (iii) sonication	2 h and 3 h at room temperature with KFL and KFS extracts, and 30 min at higher temperatures and sonication	20–140 nm	*Leaf and stem of Kedrostis foetidissima*
Ariff et al. [50]	Room temperature	2 h	2–47 nm	*Aqueous extract from Orthosiphon stamineus leaves*
Bar et al. [51]	80 °C	15 min	15–50 nm	*Seed extract of Jatropha curcas*
This work	Room temperature (23 °C) and 60 °C	20 min	24 nm	*Seed extract of Cowpea (Vigna sp. L)*