Research Article

Biosynthesis of Silver Nanoparticles Using *Kedrostis foetidissima* (Jacq.) Cogn.

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Nanosilver was synthesized using the aqueous solution of solvent extracts of leaf and stem of *Kedrostis foetidissima*. Three different methods of formation of silver nanoparticles such as reaction at (i) room temperature, (ii) higher temperature, and (iii) sonication were employed in the present study. The synthesized silver nanoparticles were characterized by UV-visible spectroscopy, X-ray diffractometer, Scherrer's formula, scanning electron microscopy, and FTIR analysis.

1. Introduction

Nanoparticles have gained emergent interest due to their superior properties with functional versatility and serves as a potential tool for treating various diseases. Nanoparticles-based cellular delivery has been extensively used owing to their properties like accessibility, high functionality, and competence in targeting specific area for the release of drugs [1–4].

Silver nanoparticles have been the core vision of research nowadays, as it is implementing new findings in various fields of pharmaceuticals as antimicrobial agent due to their high specific surface to volume ratio, surface-enhanced Raman scattering and its optical properties pave a pathway to material sciences for developing biosensors, medical devices, electrical batteries, and solar cells production [5–10].

Kedrostis foetidissima (Jacq.) Cogn. is a traditional herb belonging to Cucurbitaceae family. The edible portions of the plant such as tubers, rhizome, and stem, are consumed by tribal people. As an ethnomedical plant, it can be used for treating ailments, common cold, diarrhea, and measles. The phytochemical analysis of petroleum ether extract of leaf and chloroform extract of stem revealed the presence of flavonoids, triterpenoids, phenols, steroids, and glycosides as reported in the literature [11, 12].

Silver nanoparticles are synthesized by several methods like chemical and biological methods. The biological method of synthesis of nanoparticles is largely superior compared to that of chemical methods due to its slower kinetics, better control over crystal growth, and reduced capital involved in production. Elimination of hazardous chemicals favours green synthesis as an ecofriendly method. Hence, research in this area is mainly motivated by the possibility of designing nanostructured materials that possess novel electronic, optical, magnetic, photochemical, and catalytic properties [13].

In the present study, an attempt has been made to biosynthesize silver nanoparticles using the aqueous solution of petroleum ether extract of leaf and chloroform extract of stem of *Kedrostis foetidissima*. The synthesized silver nanoparticles were characterized by UV-visible spectroscopy, XRD, FTIR and SEM analysis. The simple method of synthesis involved in this paper endorses green chemistry principles.

2. Materials and Methods

2.1. Extraction of Plant Materials. The crushed leaves and stem (each 100 g) of *Kedrostis foetidissima* (Jacq.) Cogn. were defatted with petroleum ether by refluxing for 6 hrs. Petroleum ether leaf and chloroform stem extract were

FIGURE 1: UV-visible absorption spectra of nanosilver synthesized using KFL (a) and KFS (b) extracts.

obtained by reflux (6 h) using 100 g of powdered leaves and crushed stem with 1 L of petroleum ether and chloroform (Brand-Merck), respectively. The process was repeated until minimum yield was obtained. The extracts were concentrated to dryness and the residues were refrigerated for performing various assays.

2.2. Preparation of the Aqueous Solution. Petroleum ether leaf extract (100 mg) and chloroform stem extract of *Kedrostis foetidissima* were weighed and sonicated with 100 mL of double distilled water for 15 min. The soluble aqueous portion of the solution was filtered and refrigerated at -4°C for further experiments. The presence of metabolites like terpenoids in the above extracts as noted from phytochemical colour tests prompted us to utilize these extracts for this study.

2.3. Synthesis of Silver Nanoparticles. The aqueous solution of petroleum ether leaf extract and chloroform stem extract of *Kedrostis foetidissima* was treated with (3 mM) silver nitrate solution under three different conditions such as (i) at room temperature, (ii) at higher temperature ($75\text{--}80^{\circ}\text{C}$), and (iii) sonication using ultrasonic bath. The reddish brown colour was indicative of the formation of silver nanoparticles. The nanosilver solution was centrifuged (Spectrofuze 7 M) at 13,000 rpm for 15 min before characterization.

2.4. Characterization of Synthesized Nanosilver. The completion of the formation of silver nanoparticles was confirmed by UV-visible spectroscopy (Double Beam Spectrophotometer 2202, Systronics). The synthesized nanosilver after centrifugation (Spectrofuze 7 M) at 13,000 rpm for 15 minutes was coated on the glass slide of size $2 \times 2\text{ cm}$. The slide was dried in an oven maintained at temperature of 80°C and analyzed by X-ray diffractometer (X'pert powder PANalytical). The particle size of nanosilver was also calculated using Debye-Scherrer's equation as follows:

$$D = \frac{k\lambda}{\beta \cos \theta}, \quad (1)$$

where k is dimensionless constant, λ is wavelength of X-ray ($\text{\AA}$), β is angular FWHM of the XRD peak at the diffraction angle (radian), and θ is diffraction angle (degrees).

The morphology of the synthesized silver nanoparticles fabricated on the glass substrate was characterized by scanning electron microscopy (TESCAN) provided with Vega TC software at an applied potential of 20,000 kV. Secondary sputtering was carried out for the samples before subjecting them to SEM analysis.

3. Results and Discussion

The aqueous solution of petroleum ether leaf extract (KFL) and chloroform stem extract (KFS) of *Kedrostis foetidissima* was treated with varying concentrations of silver nitrate (3 mM) solution in the ratios 5:1, 5:2, 5:3, 5:4, and 5:5 under room temperature, higher temperature, and sonication. The visible colour change from greenish yellow solution to reddish brown after 2 h and 3 h indicates the formation of silver nanoparticles at room temperature with KFL and KFS extracts, respectively. In higher temperature and sonication, the completion of formation of nanosilver takes place within 30 minutes for both the extracts. The UV-visible absorption spectrum shows an absorption band at 426 nm and 424 nm which is close to SPR bands and confirms the formation of nanosilver (Figure 1).

The XRD patterns of synthesized silver nanoparticles using KFL extract are shown in Figures 2(a), 2(b), and 2(c). The diffraction peaks appear at $2\theta = 32.16^{\circ}$, 38.02° , and 46.17° which correspond to (101), (111), (200), and (220) planes of face centered cubic (fcc) for room temperature condition. In higher temperature, the peaks at $2\theta = 38^{\circ}$, 44.13° , 64.46° , and 77.36° corresponding to the diffraction from (111), (200), (220), and (311) planes of silver lattice (JCPDS card number 04-0783) were shown in Figure 2(b), whereas only three peaks appearing at 32.12° , 38.20° , and 46.21° are observed which may be indexed to (101), (111), and (200) based on the face centered cubic structure of silver, respectively.

Figure 3 represents the XRD patterns of nanosilver synthesized from KFS extract. The XRD peaks of Bragg's reflections with 2θ values of 32.23° , 38.05° , and 46.23° (Figure 3(a)) for room temperature, in higher temperature the $2\theta = 32.20^{\circ}$, 38.07° (Figure 3(b)) whereas for sonication the two peaks at 32.18° and 38.14° (Figure 3(c)) are observed which may be indexed to (101), (111), and (200) set of lattice planes of silver nanoparticles, respectively.

FIGURE 2: XRD spectra of synthesized silver nanoparticles using KFL extract under room temperature (a), higher temperature (b), and sonication (c).

FIGURE 3: XRD spectra of synthesized silver nanoparticles using KFS extract under room temperature (a), higher temperature (b), and sonication (c).

The particle size of the nanosilver synthesized by KFL and KFS extracts that is determined by Debye-Scherrer's equation is given in Table 1.

The average particle sizes of the nanosilver are 52.59 nm and 31.32 nm, 30.42 nm and 24.43 nm, and 22.62 nm and 31.10 nm for room temperature, higher temperature, and sonication using KFL and KFS extracts, respectively. The SEM images of the nanosilver synthesized using KFL and KFS extract are shown in Figure 4. The particle size of nanosilver

is 80 nm in sonication, whereas in room temperature the size is 140 nm which was observed in KFL extract.

The size of the synthesized nanoparticles using KFS extract is 90 nm at room temperature but in sonication the particle size is 70 nm.

Table 2 represents the FTIR spectra peak values of the AgNPs synthesized from leaf extract (KFL) and stem extract (KFS) of *Kedrostis foetidissima*. The absence of peaks in the FTIR spectra of synthesized nanosilver compared to

TABLE 1: Determination of particle size of nanosilver using Debye-Scherrer's equation.

S. number	Extract	Conditions	2θ (degrees)	FWHM (degrees)	$D = k \lambda / \beta \cos \theta$ (nm)
1	KFL	Room temperature	32.16	0.0836	99.00
			38.02	0.5353	15.71
			46.17	0.2007	43.07
2	KFL	High temperature	38.00	0.1673	50.33
			44.13	0.8029	10.68
			64.46	0.5353	17.56
3	KFL	Sonication	77.36	0.8029	12.68
			32.12	0.2007	41.23
			38.20	0.8029	10.48
4	KFS	Room temperature	46.21	0.5353	16.16
			32.23	0.1338	61.95
			38.05	0.8029	10.47
5	KFS	High temperature	46.23	0.4015	21.54
			32.20	0.2678	30.91
			38.07	0.4684	17.96
6	KFS	Sonication	32.18	0.2007	41.24
			38.14	0.4015	20.96

FIGURE 4: SEM micrographs of nanosilver synthesized using KFL and KFS extracts under room temperature (a) and (b) and sonication (c) and (d), respectively.

TABLE 2: Frequency values of FTIR peaks for KFL and KFS extracts and synthesized nanosilver.

Sample	Stretching frequencies	Extract	Nanosilver
KFL	>N-H	3345.67 cm ⁻¹	3327.35 cm ⁻¹
		3298.42 cm ⁻¹	
	>C=O	1633.60 cm ⁻¹	1633.78 cm ⁻¹
		1638.78 cm ⁻¹	
	>C-H	2926.14 cm ⁻¹	—
KFS	>N-H	3336.03 cm ⁻¹	3332.17 cm ⁻¹
		3285.88 cm ⁻¹	
	>C=O	1639.56 cm ⁻¹	1635.71 cm ⁻¹
	>C-H	2931.93 cm ⁻¹	—
	>C-N	1223.89 cm ⁻¹	1220.99 cm ⁻¹

the spectrum of the plant extract confirms that the functional groups present in the aqueous extract might have been responsible for the mechanism of nanosilver formation.

4. Conclusion

A simple environmentally benign method of synthesis of silver nanoparticles was achieved using a common plant source. Three different methods of synthesis of nanosilver were adopted. The sonication method of synthesis of nanosilver results in faster reduction compared to other methods. The UV-visible spectroscopy confirms the formation of silver nanoparticles. The XRD, Scherrer's formula, and SEM analysis reveal that the size of the nanosilver was found to be less than 100 nm and to exhibit polydispersity. FTIR spectra support that the phytoconstituents in the plant extracts were responsible for the rapid reduction and formation of stable silver nanoparticles.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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