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ORIGINAL ARTICLE

An eco-friendly method of synthesizing gold nanoparticles using an otherwise worthless weed pistia (*Pistia stratiotes* L.)

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A B S T R A C T

A biomimetic method of gold nanoparticles synthesis utilizing the highly invasive aquatic weed pistia (*Pistia stratiotes*) is presented. In an attempt to utilize the entire plant, the efficacy of the extracts of all its parts – aerial and submerged – was explored with different proportions of gold (III) solution in generating gold nanoparticles (GNPs). The progress of the synthesis, which occurred at ambient temperature and pressure and commenced soon after mixing the pistia extracts and gold (III) solutions, was tracked using UV–visible spectrophotometry. The electron micrographs of the synthesized GNPs revealed that, depending on the metal-extract concentrations used in the synthesis, GNPs of either monodispersed spherical shape were formed or there was anisotropy resulting in a mixture of triangular, hexagonal, pentagonal, and truncated triangular shaped GNPs. This phenomenon was witnessed with the extracts of aerial parts as well as submerged parts of pistia. The presence of gold atoms in the nanoparticles was confirmed from the EDAX and X-ray diffraction studies. The FT-IR spectral study indicated that the primary and secondary amines associated with the polypeptide biomolecules could have been responsible for the reduction of the gold (III) ions to GNPs and their subsequent stabilization.

Introduction

Metal nanoparticles have been the focus of a large body of scientific research due to the fact that their catalytic activity and their antimicrobial, electronic, optical, magnetic and medical properties are often significantly different from that of the bulk materials. Given that nanoparticles of different metals have several unique properties, and that these properties further depend on the morphology and size of the nanoparticles, it has become essential to develop methods with which nanoparticles of desired shape and sizes can be generated. The traditional methods of doing it revolve round chemical or physical techniques. Of these, the former often involve hazardous reagents and/or process conditions and lead to emission of pollutants. The latter are highly energy-intensive and expensive. In contrast, biological methods which employ biomolecules contained in microorganisms, algae, or vascular plants to generate nanoparticles in a way similar to that which occurs in nature – i.e. by biomimetics – are much cleaner and

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'greener'. This aspect has bestowed great relevance to the field of biomimetic nanoparticles synthesis [1–6].

The use of botanical species (henceforth referred to as 'plants') in the synthesis of nanoparticles has several advantages compared to methods relying on microorganisms as the agent brining about the synthesis. The latter require elaborate effort for maintaining microbial cultures and carry the hazard of leaks, which can endanger the environment and the human health. Microbial nanoparticle synthesis methods do not, also, lend themselves easily to large-scale processing. Moreover, the time required for microorganism-mediated nanoparticle synthesis can be very long, going up to 120 h [7,8]. The difficulties associated with maintaining the microbial cultures [9,10] further depreciates the value of this synthesis route in favor of plant-based procedures.

So far different authors have used about 130 species of plants to generate gold nanoparticles (GNPs). These species encompass fruits, flowers, vegetables, grains, cereals, spices, other foodstuff, medicinal plants, and beauty aids. For example, geranium, neem, gooseberry, aloe vera, coriander, guava, clove buds, mint, cinnamon, curry leave, aloe, horse gram, myrobalan, white gourd and citrus fruit that already have well-established uses, and entail substantial costs of production, have been explored [2,4,6,11,12]. Also, in the past, most authors have used only one or the other part of the plants (leaf/bark/seed/flower/fruit) for GNP synthesis. In contrast, the present study is based on the use of whole plant of a highly pernicious weed, pistia (*Pistia stratiotes*). It is a free-floating pleustonic macrophyte belonging to the Araceae family. It is one among the world's worst weeds and is now widespread in the lakes and ponds of the warmer parts of the world, seriously harming water quality and endangering biodiversity [13,14]. Given this context, the method presented here opens an avenue for the gainful utilization of pistia. The ability of the method to utilize the whole plant is significant because on one hand it enhances the utility value of each plant and on the other hand it makes the utilization of the invasive so potentially gainful that it may become remunerative to control the invasive through its harvesting and use. Hence, the present study can have far-reaching beneficial portent for the protection of large tracts of aquatic ecosystems currently plagued with pistia.

Experimental

All chemicals were of analytical grades unless specified otherwise. Deionized, double-distilled water was used throughout.

Preparation of aqueous extracts of the aerial and submerged parts of pistia

Pistia was collected from the ponds situated near the campus of Pondicherry University, Puducherry. The fresh, mature, and disease-free plant portions were washed thoroughly with water and then dipped in saline water to sterilize their surface, followed by washing liberally before blotting them dry. A known quantity of plant samples was dried at 105 °C to a constant weight [15]. On the basis of dry weight thus obtained, extracts for nanoparticle synthesis were made by boiling 1.0 g dry weight equivalent plant material with 100 ml of water for 5 min. The contents were filtered through a Whatmann number. A Whatman No. 42 filter paper and the filtrate were

Table 1 Wavelengths of absorption peaks (λ_{max}, nm) and corresponding absorbance of gold nanoparticle suspensions synthesized using extracts of pistia.

Plant part used for preparing the extract	Metal: extract concentration ratio	Reaction duration (h)									
		2		4		6		24		48	
		λ_{max}	Absorbance	λ_{max}	Absorbance	λ_{max}	Absorbance	λ_{max}	Absorbance	λ_{max}	Absorbance
Aerial	1:5	670	0.171	707	0.279	705	0.353	558	0.411	558	0.424
	1:6	644	0.247	792	0.344	600	0.455	552	0.522	543	0.455
						1018	0.508	1070	0.608	1023	0.503
	1:7	–	–	549	0.782	542	1.035	554	0.821	550	0.784
	1:10	–	–	539	0.739	543	0.789	549	0.754	550	0.727
	1:15	–	–	549	0.362	541	0.539	548	0.487	549	0.453
	1:30	531	0.189	535	0.216	535	0.225	539	0.238	540	0.208
Submerged	1:5	–	–	–	–	–	–	567	0.630	562	0.541
	1:6	–	–	–	–	–	–	568	0.609	562	0.514
	1:7	561	1.068	546	1.288	545	1.292	544	1.434	543	1.365
		912	1.189	985	1.752	960	1.795	909	2.021	877	1.893
	1:10	551	1.535	550	1.683	548	1.684	543	1.754	543	1.702
				686	1.438	675	1.451	655	1.518	645	1.478
	1:15	531	1.720	531	1.799	531	1.791	531	1.805	531	1.807
	1:30	531	1.135	530	1.159	529	1.153	528	1.202	530	1.224