ISSN : 0974 - 7494 Volume 8 Issue 12

Nano Science and Nano Technology
An Indian Journal

Full Paper

NSNTAIJ, 8(12), 2014 [475-481]

Biosynthesis and characterization of gold nanoparticles from *Gracilaria corticata*

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ABSTRACT

In the present study, gold nanoparticles were synthesized from the aqueous solution of red seaweed *Gracilaria corticata* using gold precursor. The formation of gold nanoparticles was primarily confirmed by the colour change from pale yellow to red. The biologically synthesized gold nanoparticles were characterized by UV-Vis spectrophotometer, FTIR, X-ray diffraction, FE-SEM, EDX, and HR-TEM. HR-TEM and FE-SEM analyses revealed the size and shape of the nanoparticles. FTIR showed that nanoparticles were capped with alga compounds. X-ray diffraction pattern and UV-Vis spectrum showed the peaks corresponding to gold nanoparticles. Thus, physiochemical characteristic results suggest that gold nanoparticles will have biomedical applications in different area such as drug delivery, tissue engineering, biosensor, etc.
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KEYWORDS

Gracilaria corticata;
Gold nanoparticle;
UV (Visible);
FTIR;
Transmission electron microscopy;
Scanning electron microscopy;
X-ray diffraction.

INTRODUCTION

Bionanotechnology is an interdisciplinary field that combines the biological processes and the technology to build nano sized materials or particles for various biological applications. The use of biological process in nanotechnology can have an impact in the production, function and properties of the synthesized nanomaterials or nanoparticles. Nanobiotechnology is one of the most promising areas in modern nanoscience and technology. This emerging area of research interlaces various disciplines of science such as physics, chemistry, biology and material science[13]. Gold is one of the precious, inert, and less toxic metals, and it is utilized for curing various diseases. Gold nanoparticles play a vital role in nanobiotechnology as biomedicine because of convenient surface bioconjugation with biomolecular probes and remarkable plasmon resonant optical properties[4,23,7]. Gold nanoparticles have an important function in the delivery of nucleic acids, proteins, gene therapy, in vivo delivery, targeting, etc[21].

Generally, metal nanoparticles are synthesized and stabilized through chemical and mechanical methods[22], electrochemical techniques[14], photochemical reactions in reverse micelles and nowadays via green chemistry methods[20]. A wide variety of physical and chemical processes have been developed for the synthesis of metal nanoparticles[8], but these methods are expensive and require the use of toxic and aggressive chemicals as reducing and/or capping agents[9]. Therefore, green

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chemistry should be integrated into nanotechnologies especially when nanoparticles are to be used in medical applications, which include imaging, drug delivery, disinfection, and tissue repair[1].

The green biosynthesis of nanoparticles can be achieved via the selection of an environmentally acceptable solvent with eco-friendly reducing and stabilizing agents[6]. Therefore, biological approaches to nanoparticle synthesis have been suggested as valuable alternatives to physical and chemical methods[11]. The literature survey found that the marine red algae are rich sources of phenolic compounds especially bromophenols. Phenolic substances were reported to possess a wide range of biological effects, including antioxidant, antimicrobial, anti-inflammatory and vasodilator actions. Furthermore, tannis and flavonoids are defined as naturally occurring seaweed polyphenolic compounds which have been found only in marine algae[10].

In the present study, the red seaweed *Gracilaria corticata* was used to synthesis gold nanoparticles by the reduction of aqueous $HAuCl_4^-$ into nanoparticles. The synthesized gold nanoparticles were characterized by UV-Vis spectrophotometer, FTIR, X-ray diffraction, FE-SEM, EDX, and HR-TEM.

MATERIALS AND METHODS

In the present study *Gracilaria corticata* were collected from Kovalam, 50 km from Chennai, Tamilnadu, India. The algae were cleaned thoroughly in double distilled water and shade dried for 3 to 5 days, ground with mortar and pestle and seived to a mesh size of <0.5mm. The dried biomass powder was used for the synthesis of gold nanoparticles. About 30 mg of seaweed powder was added with 10 ml of 10^{-3} M aqueous $HAuCl4^-$ solution in a 20 ml test tube and incubated at room temperature. The colour change from yellow to deep red colour indicates the formation of gold nanoparticles. The optical property of synthesized gold nanoparticles was characterized using a ultraviolet–visible (UV–vis) spectrophotometer; morphological characters was studied by performing TEM and SEM; crystalline nature was analyzed using X-ray diffraction (XRD) patterns; and functional molecules involved in the reduction process were comprehensively studied using Fourier transform-infrared (FTIR) spectroscopy.

RESULTS AND DISCUSSION

The colour change from yellow to deep red was the visual inspection of reduction of gold ions to gold nanoparticles. The gold ions exhibits yellow colour in double distilled water (Figure1a), when it is exposed to seaweed powder it turns to dark pink (Figure1b) after 2 hours of incubation. Mukherjee *et al*., (2002) reported that the appearance of the purple colour clearly indicates the formation of gold nanoparticles in the reaction mixture during the studies carried out on *Fusarium oxysporum*. Synthesized gold nanoparticles were extracted by centrifugation with 5,000 rpm for 15 min at 4ºC.

Figure 2 shows the UV-Vis spectra recorded at 546 nm corresponding to the formation of gold nanoparticles. The reaction was optimized since the size and shape of nanoparticles depend on bio-extract concentration[3]. Rajathi *et al*. (2012) reported the formation of gold nanoparticles using *Stoechospermum marginatum* (kützing) confirmed by the presence of an absorption peak at 550 nm. In this present study, the colour change and absorption peak at 530 nm was an evidence for the bioreduction of gold ions extracellularly. The Plasmon resonance for gold nanoparticles

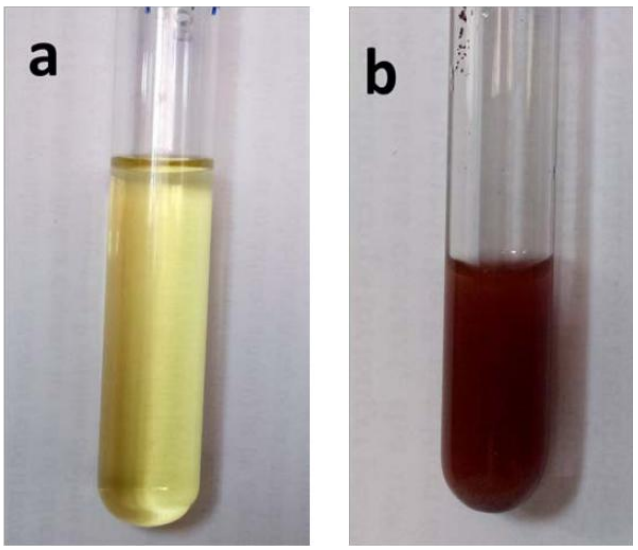

Figure 1 : (a) Aqueous solution of 1×10^{-3} M chloroauric acid in double distilled water (b) Deep red colour due to the addition of seaweed powder to the choroaurate solution after 2 hours incubation

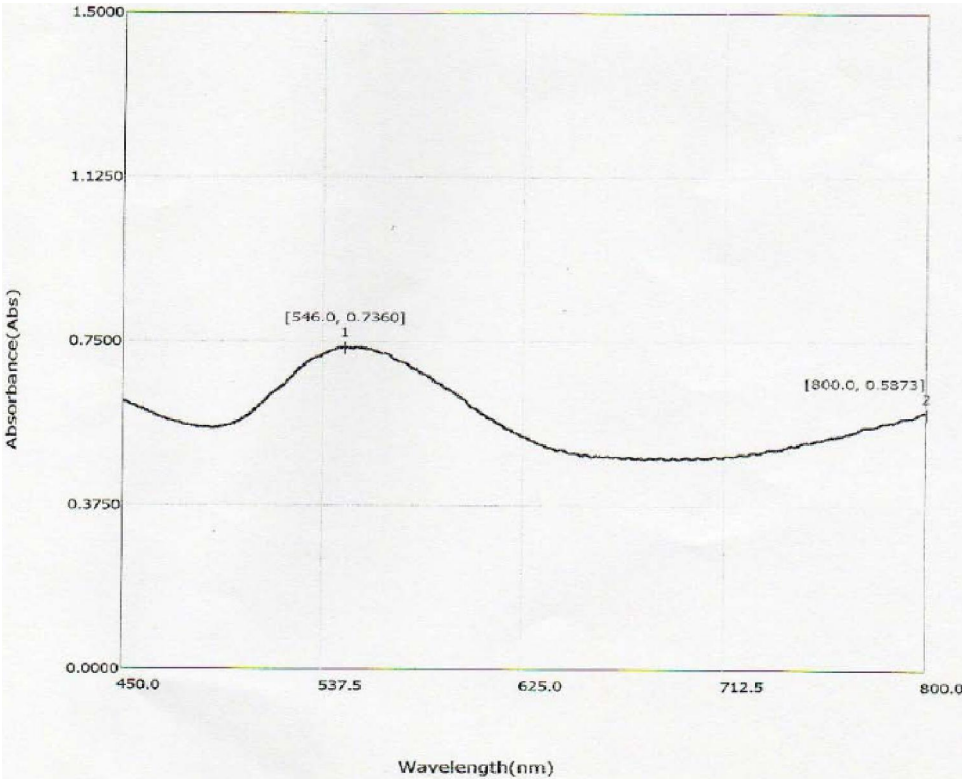

Figure 2 : UV-Visible range spectrum of gold nanoparticles showing the surface Plasmon band

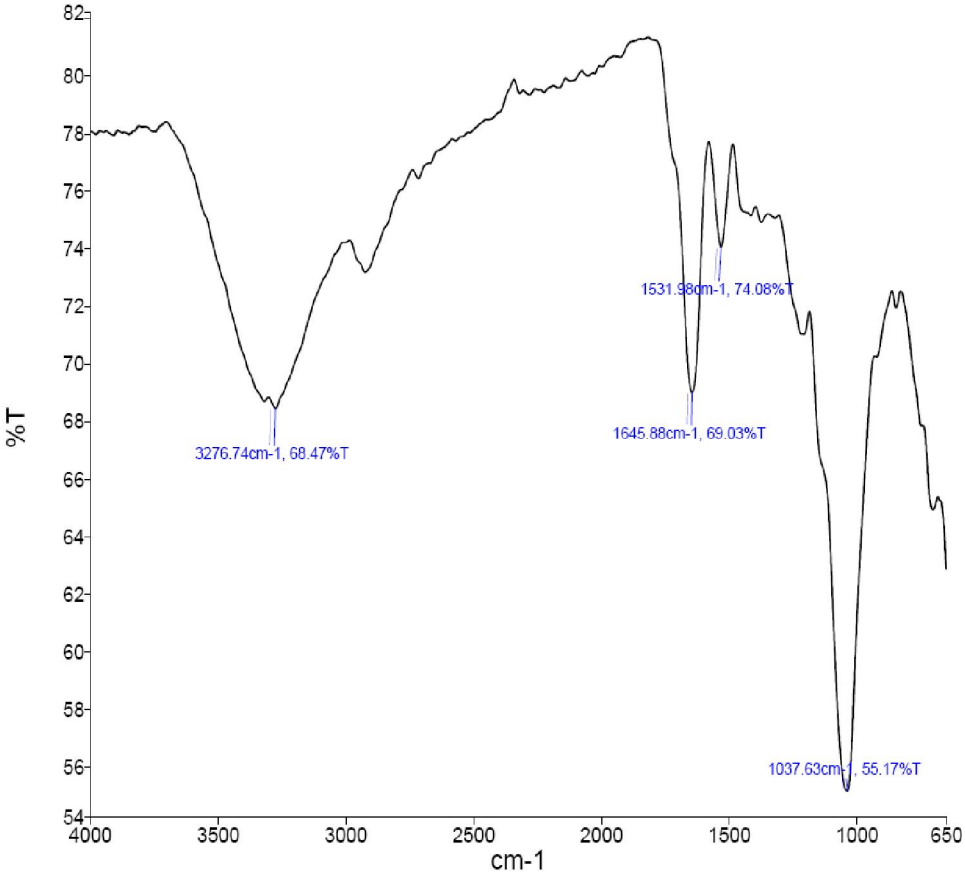

Figure 3 : FT-IR spectrum of gold nanoparticles synthesized by *G. corticata*

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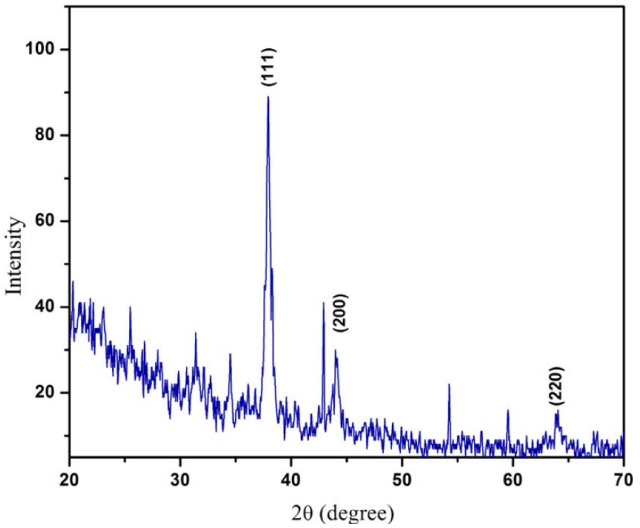

Figure 4 : X-ray diffraction pattern of the gold nanoparticles obtained from *G. corticata*

in aqueous solution appeared at approximately 540 nm and changed according to the size of the nanoparticles[16].

FTIR spectrum analysis of gold nanoparticles showed intense absorption bands at 3276.74, 1645.88, 1531.98 and 1037.63 cm^{-1} (Figure 3). The intense broad absorbance peak at 3276.74 cm^{-1} (O-H stretch) is the characteristic of the hydroxyl functional group in alcohols and phenolic compounds. The band at 1645.88 cm^{-1} (C=C stretch) can be assigned to the functional group alkenes. The intense medium absorbance at 1531.98 cm^{-1} (N-O asymmetric stretch) is the characteristic of nitro compounds. The intense absorbance at 1037.63 cm^{-1} (C-N stretch) may be assigned as aliphatic amines group. A previous report reveals that the hydroxyl group (O–H) has a strong ability to interact

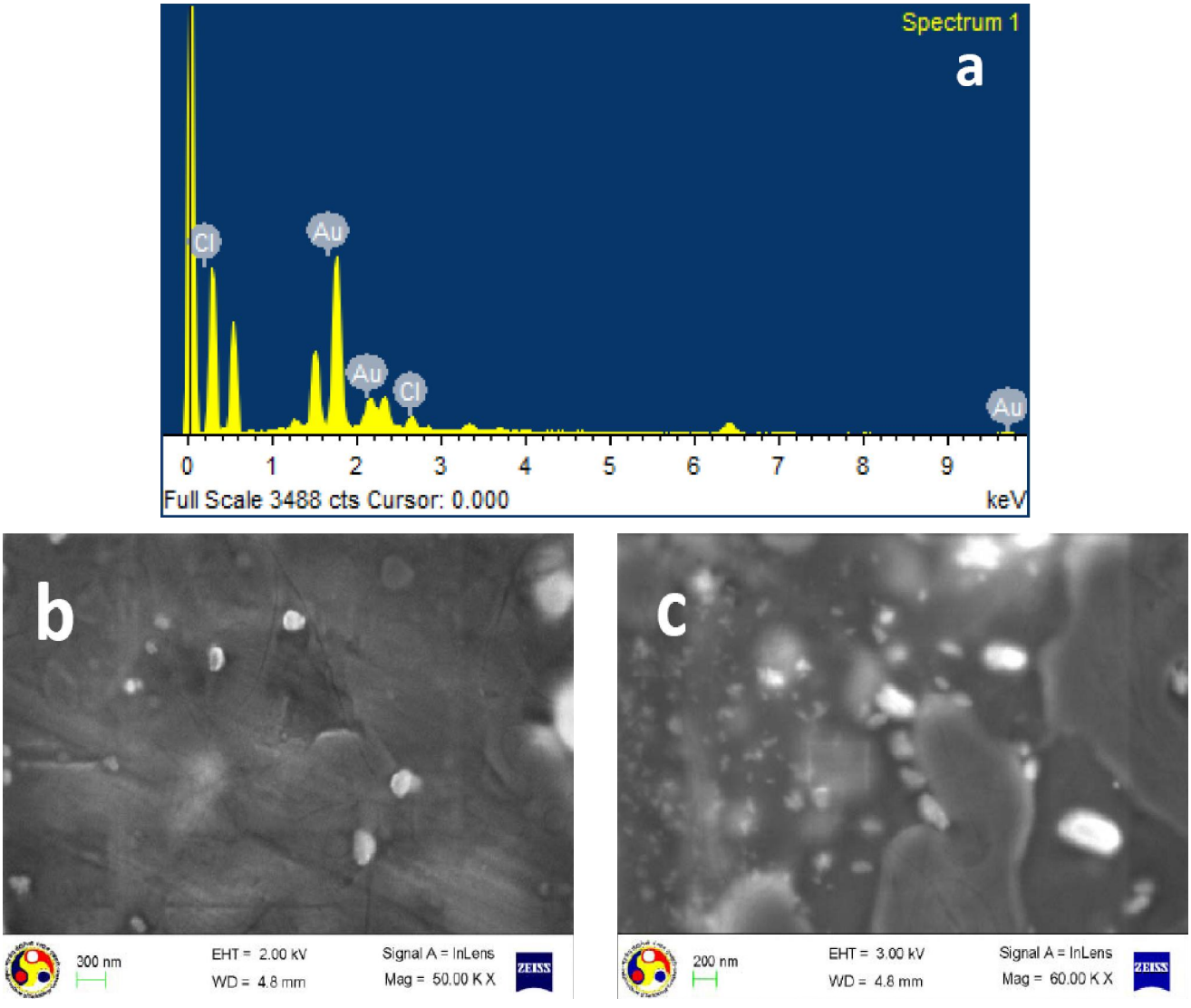

Figure 5 : (a) EDX analysis of gold nanoparticles synthesized by *G. corticata* and (b&c) FE-SEM images of gold nanoparticles

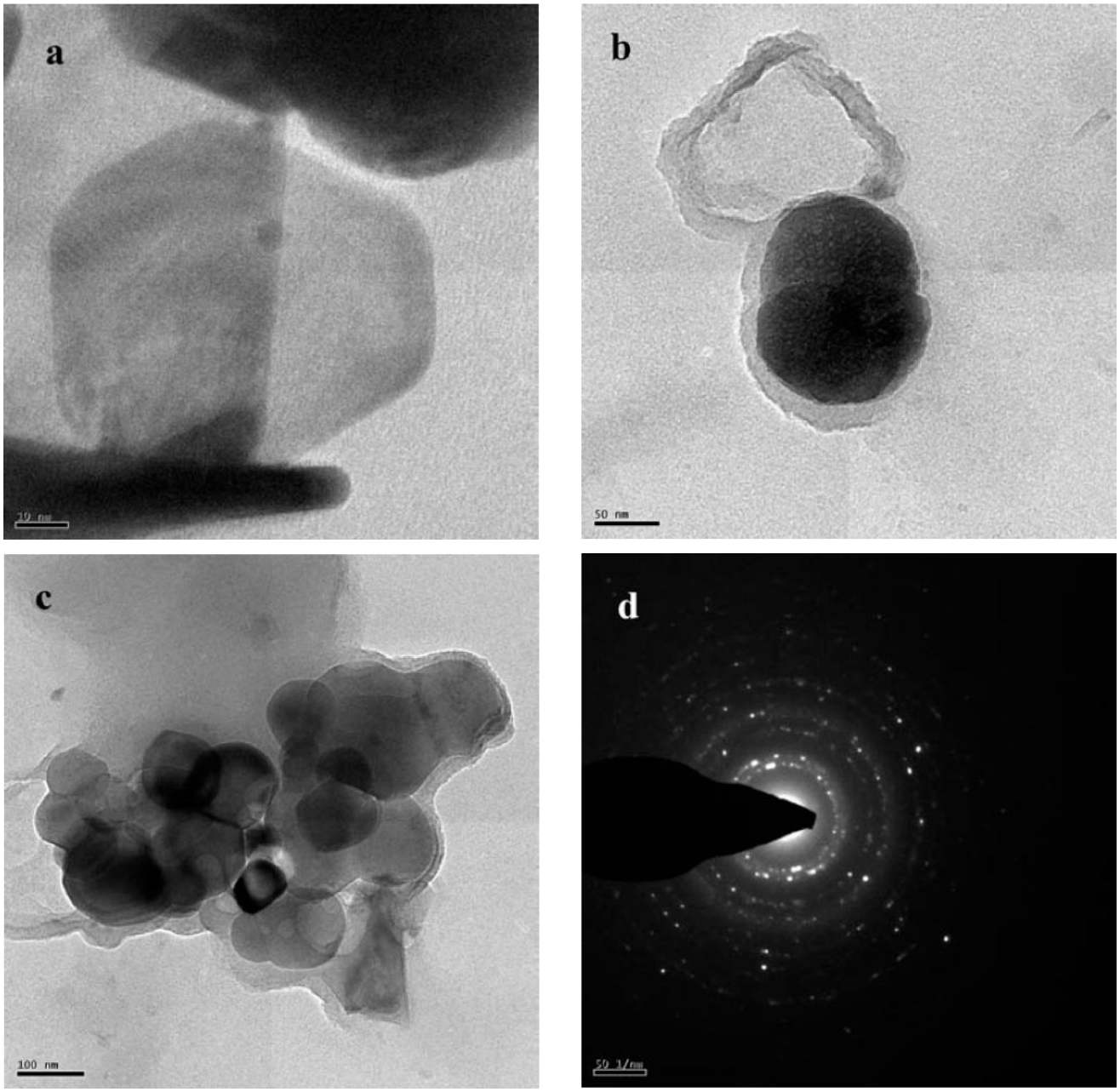

Figure 6 : HR-TEM images of gold nanoparticles formed by reduction of gold ions using *G. corticata* (a) 10 nm scale (b) 50 nm scale (c) 100 nm scale and (d) selected area diffraction pattern

with nanoparticles[19,2,5].

The crystalline nature of synthesized gold nanoparticles of *G. corticata* was analysed using XRD patterns as observed by Singh *et al*., (2013) in *Padina gymnospora*. Figure 4 shows the XRD pattern of gold nanoparticles synthesized using red seaweed. The XRD patterns revealed that gold nanoparticles corresponded to the crystalline gold fcc phase. The diffraction peaks obtained at 2θ= 37.92° (1 1 1), 44.01° (2 0 0), and 64.13° (2 2 0) are identical with those reported for the standard gold metal (Au^0) (Joint Committee on Powder Diffraction Standards-JCPDS, USA). The presence of these three intense peaks corresponding to the nanoparticles was in agreement with the Bragg's reflections of gold identified with the diffraction pattern[17]. The other unidentified peaks reveals the association of algal biomass with the synthesized gold nanoparticles.

FE-SEM micrographs show gold nanoparticles at 200 to 300 nm range (Figure 5b and 5c). A few larger

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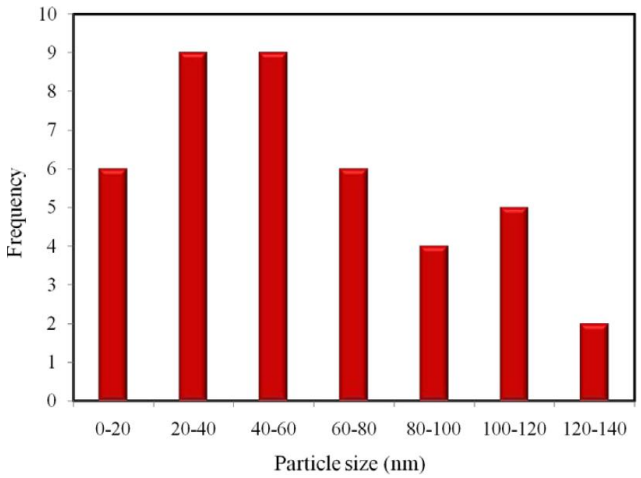

Figure 7 : Particle size distribution obtained from HR-TEM micrograph

particles are formed by the aggregation of smaller particles. In EDX, strong signals were observed for the gold atoms and weak signals for carbon, oxygen and chloride. This weaker signals indicate the presence of biomolecule of *G. corticata* (Figure 5a)

The TEM study gives clear shape and size of the nanoparticles. The diameter of the nanoparticles ranges from 5 to 135 nm. The nanoparticles synthesized were hexagonal and spherical shaped (Figure 6a-d). The particle size distribution histogram constructed from the TEM micrograph is shown in Figure 7. The size distribution varies from 10 to 140 nm with an average particle size of 75 ± 41.83 nm. The reason behind the aggregation of the gold nanoparticles may be the change of the pH during the synthesis of the nanoparticles.

CONCLUSION

In the present study, we have used economically important red seaweed *G. corticata* which is a rich marine source available in abundance. The biomolecules present in the algae must be responsible for the reduction of gold ions to gold nanoparticles. This biological method of synthesis of gold nanoparticles is less time consuming, ecofriendly, non-toxic and single-step process. The nanoparticles thus formed are spherical and hexagonal shaped with smooth edges. Hence, this has high potential in biomedical applications. This method is inexpensive and highly recommended for large-scale production of gold nanoparticles.

ACKNOWLEGEMENT

We acknowledge UGC, New Delhi for funding this work which is a part of Major Research Project.

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