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Green Synthesis of Nano Zerovalent Iron using *Anacardium Occidentale* Testa Extracts

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ABSTRACT
In the present study, nano-zerovalent iron is synthesized by environment friendly green synthesis method using the extracts of testa taken from Anacardium occidentale which is commonly known as cashew nut plant. Green synthesis method is simple as it requires only the precursor and the testa extract and no other external capping agent is required for stabilizing the nanoparticle as the polyphenol present in testa extracts gets adsorbed over the surface of nano particle during reduction and acts as stabilizing agents. This is clear from the FTIR spectra of the iron nano particle synthesized which shows the presence of polyphenolic groups in the nanoparticle responsible for the reduction and stabilization.

KEYWORDS : Anacardium occidentale, testa, polyphenols, catechin, epicatechin, capping agents

INTRODUCTION
Nanotechnology is making a big impact in the life of people now a days. Different approaches are used for the synthesis of nanoparticles such as chemical synthesis like chemical reduction, sol gel techniques etc. and physical methods such as thermal decomposition, microwave assisted synthesis, etc.[1] But these kind of nanoparticle synthesis have various drawbacks such as low production rate, high cost, high energy, use of toxic chemicals and most importantly, contamination of environment[1].

Hence, environment friendly techniques for the synthesis of nanoparticles are needed and green synthesis of nanoparticles is one of them which does not require use of toxic chemicals[2], high energy and complex equipments[3]. External chemical capping agents are also not required for stabilization as the active chemical components like polyphenols, tannins, gallic acid, aminoacids, etc. present in the plant extract themselves acts as capping agents for providing stabilization[2].

Anacardium occidentale belongs to Anacardiaceae family and are commonly known as Cashew. The cashew is commonly cultivated in the tropical regions of India, Brazil and Africa and its important part is its nut [4]. The cashew nut is completely covered by a brown colored skin, called testa. The testa of *Anacardium occidentale* contains hydrolysable tannins such as catechin, epicatechin and epigallocatechin and three phenolic acids, namely, syringic, gallic and p-coumaric acids were also present as the major constituents[5][6][7][8]. Owing to the presence of phenolic constituents, the testa of *Anacardium occidentale* shows excellent antioxidant activity[9]. This work involves the synthesis of iron nanoparticles(AO-Fe nanoparticles) from the the testa extract of *Anacardium occidentale* and its monitoring through change in pH, color and UV-Visible spectroscopy.

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MATERIALS AND METHODS

Reagents and Chemicals

All the chemicals used in this synthesis are of analytical reagent grade and are used as such without further purification. $FeCl_3.6H_2O$ was purchased from Merck, Germany. Merck Millipore water is used for making all the solutions and preparation of extract.

Preparation of Anacardium occidentale's testa Extract

Testa of *Anacardium occidentale* were obtained from Raipur District of Chhattisgarh. Testa of dried cashew nuts were removed, washed several times with Merck Millipore water and then dried. Dry testa were then crushed in to fine powder with the help of mortar and pestle. 0.5 g of powdered testa of *Anacardium occidentale* were taken with 50 ml Millipore water in an RB Flask and heated at 80°C with continuous stirring at 800 rpm for 1 h in Tarson's Digital Spinot. After cooling, solution was filtered with Whatmann filter paper no. 42. The orange colored extract obtained was stored at 4°C overnight for further synthesis of nanoparticles.

Green Synthesis of AO-Fe Nanoparticles from Anacardium occidentale extract

For green synthesis of AO-Fe Nanoparticle, 0.1 M $FeCl_3.6H_2O$ solution was prepared by adding 2.70 g of solid $FeCl_3.6H_2O$ in 100 ml of Millipore water. The solution of 0.1 M $FeCl_3.6H_2O$ was then added to *Anacardium occidentale* testa extract in the ratio of 4:1. The orange colored extract turned to black colored solution. Then it was heated at 80°C with stirring at 800 rpm for half an hour in Tarson's Digital Spinot. The solution was allowed to cool down to room temperature, then centrifuged at 10000 rpm for 30 minutes in Sigma 3-30 KS high speed centrifuge. The supernatant liquid was then decanted and the precipitate was washed with Millipore water and then with ethanol and then dried in hot air oven.

RESULTS AND DISCUSSION

Characterization of the synthesized Nanoparticles

During the synthesis of AO-Fe Nanoparticle, there is a sharp change in the color of extract from light orange to black with the decrease in the pH of the solution. Testa extract of *Anacardium occidentale* is having lower acidic pH 6.7 which changes to higher acidic pH 2.2 upon synthesis of the AO-Fe Nanoparticle.

Table 1. Change in color and pH during the synthesis of AO-Fe nanoparticle

Plant Extract		**Plant Part**	**Color and pH Change**	
			Before	**After**
Binomial Name	**Common Name**	Testa	Light Orange	Black
Anacardium occidentale	Cashew Nut		6.7	2.2

UV -Visible Spectral Analysis

UV Visible Spectral analysis of synthesized Ao-Fe nanoparticle was carried out through Labtronics Double Beam UV-Visible spectrophotometer at a range of 220 to 380 nm for monitoring the reduction of Fe(III) to Fe(0) nanoparticle. Excitation of surface Plasmon vibrations in AO-Fe nanoparticle solutions results in the absorption peak at 296 nm.

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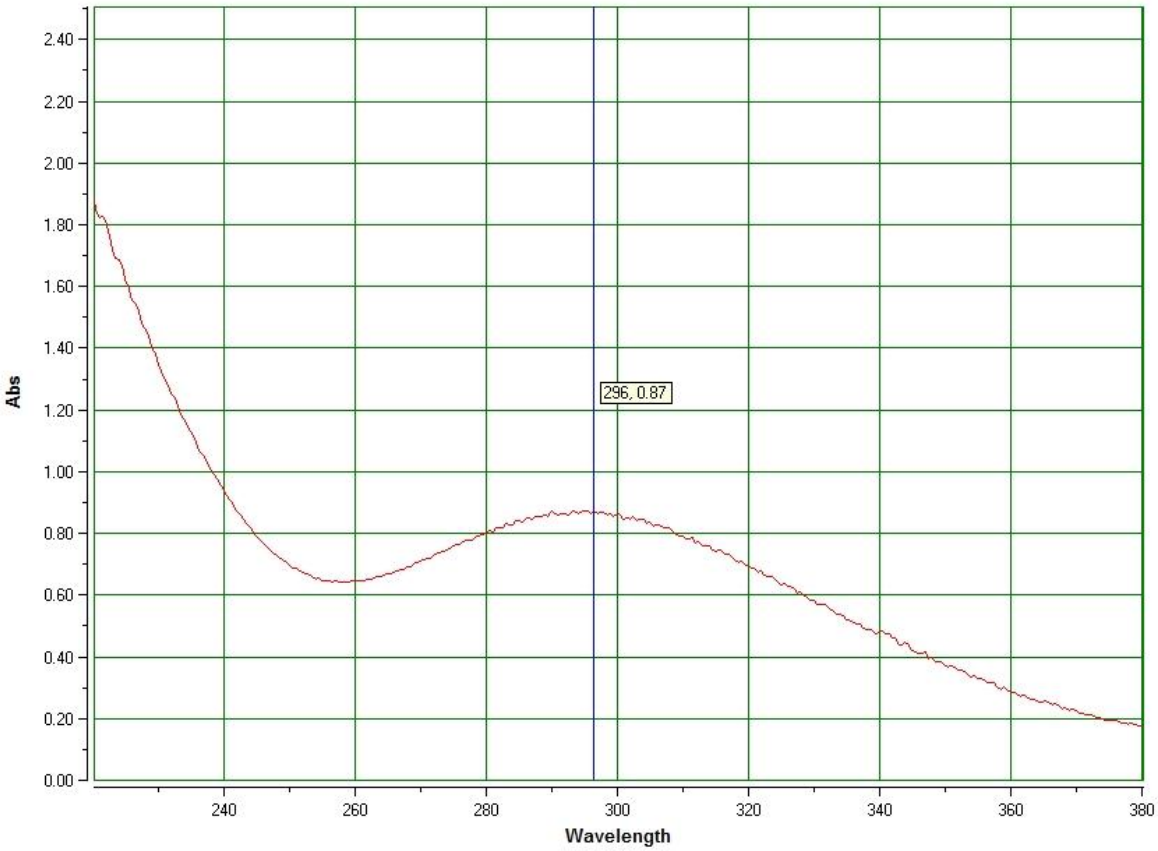

Fig.1: UV-Visible spectra of green synthesized AO-Fe Nanoparticle

FTIR Analysis

FTIR analysis of nanoparticle is carried out during the green synthesis so as to find out the groups which gets adsorbed to the surface of the nanoparticle during reduction and provide stability to the nanoparticle.

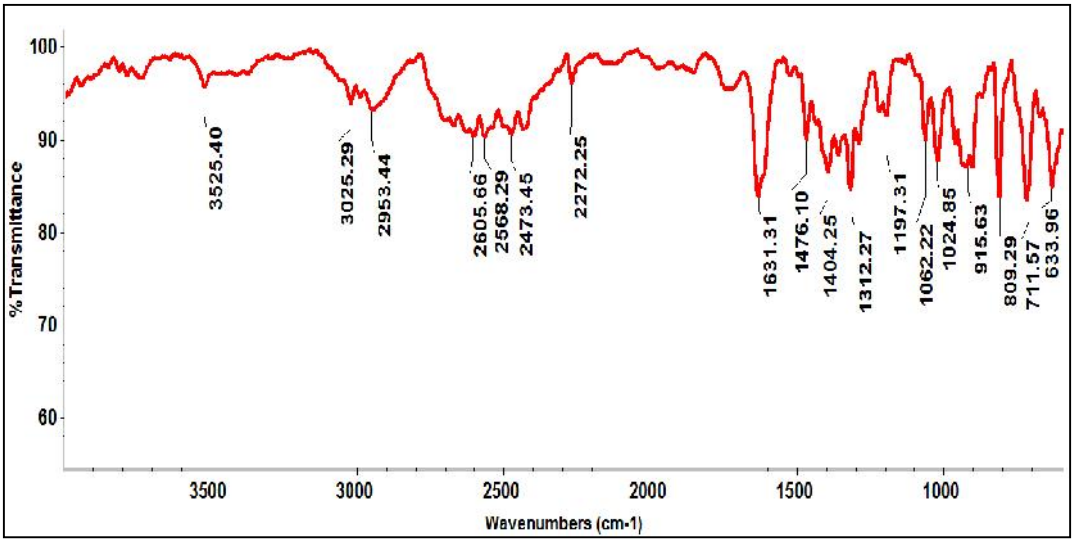

Fig.2: FTIR Spectra of synthesized AO-Fe Nanoparticle

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In *Anacardium occidentale*, various phytochemical constituents such as catechin, epicatechin and epigallocatechin and phenolic acids such syringic, gallic and p-coumaric acids are present[5][6][7][8] which are responsible for the reduction of Fe(III) to Fe(0) nanoparticle during the green synthesis and also gets adsorbed over its surface. A peak at 3525.30 cm^{-1} in the FTIR spectra shows the presence of hydrogen bonded –OH group of polyphenols which is not only responsible for reduction but also provide stability to the nanoparticle. Similarly, various peaks in the FTIR spectra of AO-Fe nanoparticle shows the presence of different functional groups of polyphenols and acids which provides stability to the nanoparticle by acting as capping agents.

Table 2. Prominent peaks and corresponding functional groups in FTIR spectra of AO-Fe Nanoparticle

GM-Fe Peaks(cm^{-1})	Intensity	Functional Groups	Compounds Indicated
3525.40	Str	O-H(H-bonded) stretch	Polyphenols
3025.29	Med	=C-H stretch	Aromatics
2953.44	Str	C-H stretch	Aromatics
2605.66	Str	O-H stretch	Acids
2568.29	Str	O-H stretch	Acids
1631.31	Var	C=C stretch	Alkene
1476.10	Var	C-H bend	Alkane
1404.25	Var	C-H bend	Alkane
1312.27	Str	C-O stretch	Acid
1197.31	Str	C-O stretch	Ether
1062.22	Str	C-O stretch	Ether
1024.85	Str	C-O stretch	Ether
916.63	Str	=C-H bend	Alkene
809.29	Str	=C-H bend	Alkene
711.57	Str	=C-H bend	Alkene
633.96	Str	=C-H bend	Alkene

SEM-EDX Analysis

SEM and EDX analysis are carried out using ZEISS EVO 18 Scanning Electron Microscope. Fig.3 shows the SEM and EDX images of the AO-Fe nanoparticle. The average size of the nanoparticle is around 90-100 nm which are scattered and irregular in shape and have many voids in between.

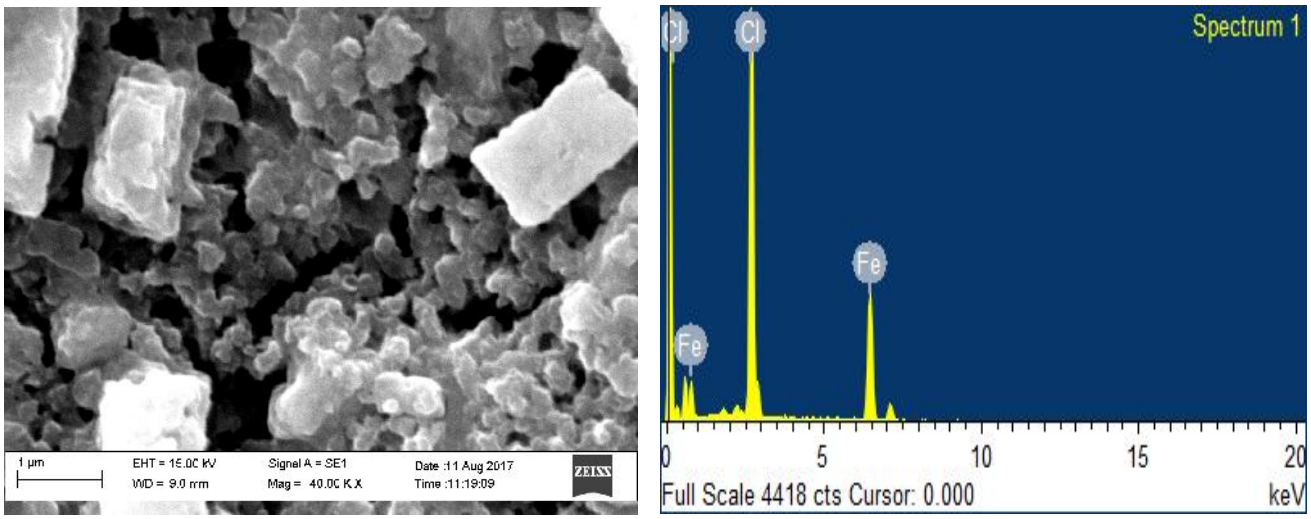

Fig.3: SEM-EDX of green synthesized AO-Fe Nanoparticle

CONCLUSION

Green synthesis of AO-Fe nanoparticle with the testa extracts of *Anacardium occidentale* is not only the cost effective method of nanoparticle synthesis but also does not cause any harm to the environment as no toxic chemicals are used during the synthesis. Also the method is simple as no complex equipments and methods are required for the synthesis and no external capping agent is required for addition as stabilizing agent because the phytochemical constituents in the extract containing polyphenolic groups themselves acts as capping agents as seen from their FTIR spectra.

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