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SYNTHESIS AND CHARACTERISATION OF IRON NANO PARTICLES USING *ARTOCARPUS HETEROPHYLLUS* TENDER LEAF EXTRACT AND EVALUATION OF CYTOTOXIC ACTIVITY

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ABSTRACT

The iron nanoparticle synthesized using *Artocarpus heterophyllus* tender leaf extract was characterized using UV-Vis spectroscopy, FTIR spectroscopy, Scanning electron microscope (SEM) and Transmission electron microscopy (TEM) analyses. Results obtained from the above analyses revealed the efficient capping and stabilization properties of these nanoparticles. SEM results showed that the particles synthesized using the plant extract are in nano size varies between 560.36 and 461.74 nm. This also supported by the shifts and difference in the areas of the peaks obtained in the FTIR analysis. TEM results also showed that the iron nanoparticles are in cubical shape and the mean diameter size of this nanoparticle was found to be 51 nm. FTIR spectroscopy confirms that *Artocarpus heterophyllus* tender leaf extract has the ability to act as reducing agents and stabilizers of the iron nanoparticles. The FTIR spectra shows the presence of O-H, C-H, C=O, C-O-C and Fe-O bonds. As the size of the nanoparticles decreases, the band gap increases and thus the optical absorbance increases as compared to that of the bulk particles and therefore their color changes. The absorption maxima of thus synthesized nano particles is in the range of 220-240nm. From the optical absorbance data the optical energy band gap has been calculated. It was found to be about 2.3 eV. For iron nanoparticles the optical energy band gap is in between 2 to 2.5 eV. This further confirmed the formation of iron nanoparticles. From the cytotoxicity analysis, it is observed that the formed iron nanoparticle has the ability to destroy the cells which are formed from the abnormal growth of tumour cells. It opened a new way to the nano medicinal field for the drug designing against cancer.

KEYWORDS: *Artocarpus heterophyllus*, green synthesis, iron nanoparticles, cytotoxicity, drug designing.

INTRODUCTION

Artocarpus heterophyllus is the tree that is commonly seen in South East Asia and found occasionally in pacific island home gardens. The succulent, aromatic and flavorful fruit is eaten fresh or preserved in myriad ways. The nutritious seeds are boiled or roasted and eaten like chestnuts, added to flour for baking, or cooked in dishes. It is also known for its remarkable, durable timber, which ages to an orange or red-brown color. Many parts of the plant including the bark, roots, leaves and fruits are attributed with medicinal properties. Wood chips yield a dye used to give the famous orange-red color to the robes of the Buddhist priests. The tree can provide many environmental services too. It is highly wind tolerant and therefore makes a good component in wind break or border planting. *Artocarpus heterophyllus* is designed as multipurpose tree and has great economic importance for its fruits and timber. In South and South East Asia ripe fruits are in particular demand particularly as source of energy for villagers and working peoples. The fruiting perianths have a strong sweet, aromatic odour, fine structure and rich appetizing taste. The perianths are rich in sugar; a fair amount of carotene is also present. Seeds and unripe fruits are mostly used as popular vegetables, which are starchy and contain fair amounts of protein, calcium and thiamin and have good pectin content. Leaves and remnants of the fruit are good source of nutrient fodder. The plant produces a moderately hard wood, which is widely used in many purposes such as construction of houses and furniture. The timber polishes well and does not wrap and spilt. It is an important source of compounds like Morin, -Dihydromorin, Cynomacurin, Artocarpin, Isoartocarpin, Cyloartocarpin, Artocarpesin, Oxydihydroartocarpesin, Artocarpetin, Norartocarpetin, Cycloartinone, Betulinic Acid, Artopanone and Heterophlol which have therapeutic properties.[1]

Jackfruit seeds can be used as cough medicine and tonic. Jackfruit seeds can be processed into flour which is used as a raw material for food industry. Jackfruit wood is considered as superior to teak for furniture manufacture, turning to building construction, masts, musical instruments etc. sap of the bark has also been used as drug fever and also as anti-inflammatory drug worms. Chemical constituents in wood are Morin, Sianomaklurin, Flavonoids, and Tannins.[2]

All parts of the plants have medicinal properties. The root is a remedy for skin disease and asthma and the extract is taken in the cases of fever and diarrhea. The tender jackfruit leaves and flowers are cooked and served as vegetables. The ashes of the leaves are burned together with corn and coconuts are used alone or with coconut oil to heal ulcers. Mixed with vinegars the latex promotes healing of abscesses, snakebite and glandular swellings. Heated leaves are alone placed on wounds and the bark is made into poultices. The seed starch is given to relieve biliousness and the roasted seeds are regarded as aphrodisiac. In Chinese medicine the pulp and seeds are considered as tonic and nutritious. The studies conducted by Mohana Priya and co-workers[3] showed that various parts of *Artocarpus heterophyllus* have been used in traditional medicine. The leaves of this plant are recommended by ayurvedic medicine as an anti diabetic drug because jackfruit leaves extract has hypoglycemic effect. Diabetes mellitus is a chronic disease that affects 5% of world population. It is caused by an inherited or acquired deficiency of insulin secretion that results in an increased blood glucose level, which in turn produces adverse effects on different body systems. There are limitations to currently available drugs, which merit the consideration of new agents with the potential for greater efficiency or fewer side effects. It is estimated that different species of plants are used as folk medicines to treat diabetes. Among them *Artocarpus heterophyllus* sounds the most. Different classes of flavonoids are abundant in the jack fruit plant. Several reports have cited the diabetic effects of jack fruit extracts, which could be attributed to its high proanthocyanidin and flavonoid contents through inhibition of lipid peroxide formation, and through aα-amylase inhibitory effect, indicating that it could act as a starch blocker to decrease postprandial glucose level.

Nazli Shahin and co-workers[4] carried out the pharmacognostical standardization and diabetic activities of *Artocarpus heterophyllus* lam. The investigation was carried out to focus on the hypoglycemic effect of the leaves of *Artocarpus heterophyllus* in normal and streptozocin induced diabetic rats. This study clearly demonstrated that the plant is having potential hypoglycemic activity which may be beneficial for the management and treatment of diabetes mellitus. Studies were conducted by Fernado and co-workers[5] on the effect of *Artocarpus heterophyllus* leaves and *Asteracanthus longfolia* on glucose tolerance in normal human subjects and in maturity onset diabetic patients.

In addition, it was reported that *Artocarpus heterophyllus* extract possess anti-inflammatory and antibacterial activity.[6] Antioxidant and antibacterial activities on foodborne pathogens of

Artocarpus heterophyllus lam leaves extract were studied by Loizzo and coworkers.[7] *Artocarpus heterophyllus* leaves extract demonstrated interesting biological properties that suggest its use as a new potential source of natural antioxidant and antimicrobial agents.

Antibacterial and antifungal activities of the silver nanoparticles synthesized using *Artocarpus heterophyllus* leaves extract were conducted.[8] The biostabilised silver nanoparticles were characterized by UV-Visible spectroscopy, SEM, EDS, XRD and FTIR. The silver nanoparticles demonstrated potent antibacterial activity against *Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtilis*. The nanoparticles also demonstrated antifungal activity against *Aspergillus Niger* and the yeast *Pichiapastoris*.

Studies were conducted by Sirtapetaweej and co-workers[9] on the antimicrobial activity of a 48-kDa protease (AMP48) from *Artocarpus heterophyllus* latex. It was found that the purified protease has the antimicrobial activity. Evaluation of the antioxidant capacity of phenol content in jackfruit (*Artocarpus heterophyllus* Lam.) fruit pulp was conducted by Umesgh Jagtap co-workers.[10] The antioxidant capacity of jackfruit (*Artocarpus heterophyllus* Lam.) fruit pulp was determined by evaluating the scavenging activity using 1, 1-diphenyl-2picrylhydrazyl. Jackfruit pulp was analysed for total phenolic content and total analysed content and the antioxidant activity of jackfruit pulp was correlated with the total phenolic and total analysed content. The results showed that the jackfruit pulp is one natural source of antioxidant compounds.

Synthesis of silver nanoparticles using various plant extracts and evaluation of their potential antibacterial properties was done by Zia-ur-Rehman co-workers.[11] Green mediated synthesis of zinc oxide nanoparticles for the photo catalytic degradation of Rose Bengal dye is done by Vidhya and co-workers.[12] *Artocarpus heterophyllus* leaves extract has been proved to have potential photo constituents for green mediated synthesis of zinc oxide nanoparticles. The synthesized zinc oxide nanoparticles were highly potential towards photo catalytic degradation of Rose Bengal dye, a main water pollutant released by textile industries, under UV light. The characterization results confirmed that zinc oxide nanoparticles can be effectively synthesized using *Artocarpus heterophyllus* leaf extract as stabilizer and photo degradation results proved the efficiency of green synthesized zinc nanoparticles for the degradation of Rose Bengal dye.

Isolation of tyrosinose inhibitors from *Artocarpus heterophyllus* and use of its extract as antibrowning agent was conducted by Zong-Ping Zheng and coworkers.[13] A new furanoflavone 7-(2,4-dihydroxy phenol)-4-hydroxy-2-(2-hydroxy propan-2-yl)-2,2-dihydrofuro (3, 2-g) chromen-5-one (artocarpfuranol, together with 14 known compounds, dihydromorin, steppogenin, norartocarpetin, artocarpanone, artocarpesin, artocarpin, cycloartocarpin, cycloartocarpesin, artocarpetin, brosimone I, cudraflavone B, carpachromene, isoartocarpesin and cyanomaclurinwere isolated from the wood of *Artocarpus heterophyllus.* Their structures were identified by interpretation of mass spectroscopy, ^{1}H-NMR, ^{13}C-NMR, HMQC and HMBC spectroscopic data. Among them compound artocarpesin showed strong mushroom tyrosinase inhibitory activity with IC_{50} values lower than 50µM, more potent than kojic acid, a well-known tyrosinase inhibitor. In addition, the extract of *Artocarpus heterophyllus* was evaluated for its anti browning effect on fresh cut apple slices. It was discovered that the fresh cut slices treated by dipping in the solution of 0.03 or 0.05% of *Artocarpus heterophyllus* extract with 0.5% ascorbic acid did not undergo any substantial browning reaction after storage at room temperature for 24hour. The results provided preliminary evidence supporting the potential for its natural extract as anti browning agents in food systems. Phyo-chemical changes in fresh-cut jackfruit (*Artocarpus heterophyllus*) bulb during modified atmospheric storage were conducted by Alok Saxena and co-workers.[14]

Structure-activity relationship of prenyl substituted polyphenols from *Artocarpus heterophyllus* as inhibitors of melanin biosynthesis in cultured melanoma cells were studied by Enos Tangke Arung and coworkers.[15] Prenylated, flavones based polyphenols compounds were isolated from the woods of *Artocarpus heterophyllus*. These compounds which have previously been not to inhibit tyrosinase were found to be active inhibitors of the in vivo melanin biosynthesis in B16 melanoma cells with little or no toxicity.

Comparative study on the chemical composition and mineral content of *Artocarpus heterophyllus* and *Treculia* analysed seeds and seed oils were conducted by Ibironke Adetolu Ajayi.[16] It was found that the physicochemical properties of two seeds are comparable of those of conventional oil seeds such as groundnut and palm kernel oils and could be used for nutritional and industrial purposes. Studies were conducted by Kazuki Shinomiya and co-workers[17] to prepare Diels-alder adduct from *Artocarpus heterophyllus.* A new natural Diels-Alder type adducts, artonin X along with two known Diels-Alder type adducts were

isolated from the bark of *Artocarpus heterophyllus.* A novel serene protease with human fibrino (geno) tic activities from *Artocarpus heterophyllus* latex were produce by Siritapetaawee co-workers.[18] In this work, the protease enzyme was characterized for biochemical and medicinal properties.

Aroma volatiles from two fruit varieties of jackfruit (*Artocarpus heterophyllus* Lam.) were studied by Jose Guilherme S Maia and co-workers.[19] The aroma volatiles from two fruit varieties of jackfruit (*Artocarpus heterophyllus*) growing in the Amazon were synthesised by simultaneous distillation-extraction and were analysed by gas chromatography and mass spectroscopy. It was found that the major components in the aroma concentrate of "hard jackfruit" variety were isopentyl isovalerate (28.4%) and butyl isovalerate (25.6%). The aroma concentrate of "soft jackfruit" was dominated by isopentyl isovalerate (18.3%), butyl acetate (16.5%), ethyl isovalerate (14.4%), butyl isovalerate (12.9%) and 2-methylbutyl acetate (12.0%). Analysis of volatile compounds in five jackfruit (*Artocarpus heterophyllus* L.) cultivars using solid-phase micro extraction (SPME) and gas chromatography-time-of-flight mass spectrometry (GC-TOFMS) were conducted by Ong and co-workers.[20]

Inhibitory effect of Artocarpanone from *Artocarpus heterophyllus* on Melanin biosynthesis was done by Enos Tangke Arung co-workers.[21] They isolated artocarpanone by the fractionation of *Artocarpus heterophyllus* wood extract and discovered that artocarpanone inhibited both mushroom tyrosinase activity and melanin production in B16 melanoma cells. They also found out that artocarpanone can be used as a remedy for hyper pigmentation in human skin.

Studies were conducted by Ying-zhi Li[22] on the genetic diversity within a jackfruit *Artocarpus heterophyllus* lam germplasm collection in china. In this study, genetic diversity of 50 jackfruit accessions from three provinces in China was analysed based on amplified fragment length polymorphic (AFLP) markers. A total of 320 unambiguous bands were produced by eight primer combinations, and 65 (20.3%) of them were polymorphic. This study has provided useful information for collection and preservation of jackfruit germplasm worldwide.

Characterisation of antiproliferative activity constituents from *Artocarpus heterophyllus*were done by Zong-Ping Zheng and co-workers.[23] This study identified 8 new phenolic compounds, artoheterophyllins E–J (1–6), 4-geranyl-2′,3,4′,5-tetrahydroxy-*cis*-stilbene (7),

and 5-methoxymorican M (8) and 2 new natural compounds (9 and 10), 2,3-dihydro-5,7-dihydroxy-2-(2-hydroxy-4-methoxyphenyl)-4*H*-benzopyran-4-one and 6-[(1*S*,2*S*)-1,2-dihydroxy-3-methylbutyl]-2-(2,4-dihydroxyphenyl)-5-hydroxy-7-methoxy-3-(3-methyl-2-buten-1-yl)-4*H*-1-benzopyran-4-one, together with 23 known compounds (11–33), from the ethanol extract of the wood of *Artocarpus heterophyllus*. The structures of the eight new compounds (1–8) and two new natural compounds were established by extensive 1D- and 2D-NMR experiments. The anticancer effects of the isolated compounds were examined in MCF-7, H460, and SMMC-7721 human cancer cell lines by MTT assay. Compounds 5, 11, 12, and 30 significantly reduced the cell viabilities of these cell lines. Especially, compounds 11 and 30 resulted in more potent cytotoxicity than the positive control, 5-fluorouracil (5-Fu), in SMMC-7721 cell line, with IC_{50} values of 15.85 and 12.06 μM, whereas compound 30 exhibited more potent cytotoxicity than 5-Fu in NCI-H460 cell line, with an IC_{50} value of 5.19 μM. In addition, this study suggests that compounds 11 and 30 from the wood of *Artocarpus heterophyllus* have anticancer potential.

Based on review of literature no reports are available regarding the green synthesis of iron nanoparticles and evaluation of the cytotoxic potential of the iron nanoparticles synthesized using the *Artocarpus heterophyllus* tender leaf extract. In this work, iron nanoparticles were synthesized using *Artocarpus heterophyllus* tender leaf extract and characterized using TEM, SEM, UV and IR. The cytoxicity of the nanoparticles were evaluated by trypan blue dye exclusion method. The results showed that the green synthesized iron nano particle has the ability to destroy the tumour cells and this will open a new way for drug designing in cancer treatment.

MATERIALS AND METHODS

Plant Material and preparation of plant extracts

Fresh and healthy tender leaves of *Artocarpus heterophyllus* were collected from Shornur village of Palakkad district, Kerala. It was rinsed thoroughly washed first with tap water and then by distilled water to remove all the dust and unwanted visible particles. Tender leaves were cut into small pieces and dried in room temperature. About 50g of these finely incised tender leaves were weighed and transferred into a 250ml beaker containing 150ml distilled water and boiled for 20 minutes. The extract was then filtered thrice using Whatmann No. 1 filter paper to remove particulate matter and to get clear solutions. The solution was then

concentrated to 50ml, which was then refrigerated (4^0C) in 250ml Erlenmeyer flasks for further experiments.

Preparation of Iron nanoparticles

Mixed 50ml of 0.1M $FeCl_2$ and 100ml of 0.1M $FeCl_3$ in a conical flask it was heated to 80^0C and stirred using a magnetic stirrer for about 10 minutes. Then 50ml of the plant extract was added to the mixture and stirred for another 5 minutes at 80^0C. Then the yellow color of the solution gets changed to a reddish brown color. Then 10 or 20ml of 0.1M Na OH solution was added with a rate of 3ml per minute. It was again stirred for 5 minutes. The solution was cooled and the froth was removed. It was decanted and the plant residue was removed. The decanted solution was the centrifuged and then residue obtained was washed using sterile distilled water (at least 3 times). The nanoparticles obtained are dried are used for further analysis.

Characterization of Iron nanoparticles

The band gap of the iron nanoparticles was studied by UV spectral analysis. The capping of the iron nanoparticles by the functional group present in the plant extract was identified using FTIR. The size and morphology of the iron nanoparticles were analysed by Transmission Electron Microscopy (TEM) and Scanning Electron Microscope (SEM). The *in vitro* cytotoxicity of iron nanoparticles was also studied.

Cytotoxicity analysis

In this work the green synthesized iron nanoparticles were analyzed for a short term in vitro cytotoxicity using Dalton's lymphoma ascites cells (DLA). Scanning electron microscopic studies revealed that ascites Dalton's lymphoma cells are distributed singly or in groups of 2-3 cells and 5 or more cells connected together. The percentage of single cells and groups of 2-3 or more cells changes with tumor growth. In this work the tumor cells aspirated from the peritoneal cavity of tumor bearing mice were washed thrice with PBS or normal saline water. For this the test compound was dissolved in water. The cell viability was measured by trypan blue exclusion method. Viable cell suspension (1 X 10^6 cells in0.1 ml) was added to tubes containing various concentration of the test compound and the volume was made up to 1ml using phosphate buffered saline (PBS). Control tube contained only cell suspension. These assay mixture were incubated for 3 hours at 37^oC.[24]

Further cell suspension was mixed with 0.1 ml of 1% trypan blue and kept for 2-3 minutes and loaded on a haemocytometer. Dead cells take up the blue colour of the trypan blue while the dead cells do not take up the dye the number of the stained and unstained cells were counted separately the equation used for calculating the percentage of cytotoxicity is

$$\% \text{ Cytotoxicity} = \frac{\text{Killed target cells}}{\text{Killed target cells} + \text{Live target cells}} * 100$$

RESULTS AND DISCUSSION

UV Spectral Analysis

UV-Visible spectroscopy refers to absorption spectroscopy in UV-Visible spectral region. The optical absorbance of iron nanoparticles prepared by the green synthesis using the tender leaves of *Artocarpus heterophyllus* has measured by UV-Visible spectroscopy in the range of 200 to 800 nm. It is generally recognized that UV-visible spectroscopy could be used to examine size and shape controlled nanoparticles in aqueous suspensions. Here, tender leaf extract of *Artocarpus heterophyllus* changed the color of ferric chloride solution from transparent to dark yellow brown due to the reduction of Fe^{3+} to Fe^{2+} within commencement of the reaction. This colour changes arise because of the excitation of surface plasmon vibrations with the iron nanoparticles.[25]

From the optical absorbance results the optical energy band gap has been determined. It was calculated by plotting $(\alpha\ h\surd)^2$ as a function of photon energy $(h\surd)$, the optical energy band gap for direct method can be determined. The result shows that the photon energy of the green synthesized iron nanoparticle is in between 2 to 2.5 eV. This means that the formed particles are iron nanoparticles.[26]

FTIR Analysis

FTIR analysis was performed in order to determine the functional groups and predict their role in the synthesis of iron nanoparticles. FTIR spectroscopy is used to find out the functional group of the active compound based on the peak value in the region of infrared radiation. It displays strong absorption bands at 3388.82cm^{-1}, 1622.31cm^{-1}, 1430.23cm^{-1}, 1071.60cm^{-1}, 552.61cm^{-1}. The strong absorption peak at 3388.82cm^{-1} is due to the OH functional group. Absorption peak at 1622.31 may be assigned to the amide bond of proteins arising due to carbonyl stretch in proteins The spectrum at 1430.23cm^{-1} shows CH symmetrical mode stretching the absorption peak at 1071.60cm^{-1} shows single bond C-O

stretching vibration of C-OH group. The formation of iron nanoparticles is characterized by the absorption band at 552.66 cm^{-1} which corresponds to the Fe-O bond**.** From this result it was concluded that the soluble elements present in *Artocarpus heterophyllus* tender leaves extract could have acted as capping agents preventing the aggregation of iron nanoparticles in the solution, thus playing a relevant role in their extracellular synthesis and shaping.[27]

Scanning Electron Microscopy (SEM) Analysis

The prepared iron nanoparticles were analyzed by Scanning Electron Microscopy (SEM) to know its morphology. Figures shown below are the SEM images of iron nanoparticles prepared from 100 ml of 0.1 M $FeCl_3$ and 50 ml of 0.1 M $FeCl_2$ with 50 ml of aquous solution of *Artocarpus heterophyllus* leaf extract. SEM image shows the clear morphology of iron nanoparticles. Figure 1 is observed at 500X magnification. Figure 2 is at 1500X, figure 3 at 5000X and figure 4 is at 10000 magnification. Figure 5 is the zoomed image of figure 4. All of the images are taken with an accelarating voltage of 20kV. Figure 1 shows the low magnification SEM image of iron nano particles.

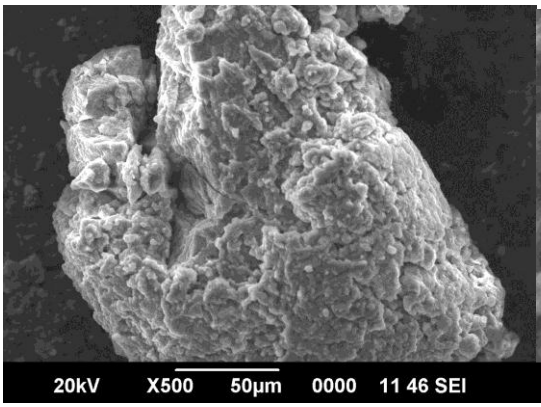


Fig. 1

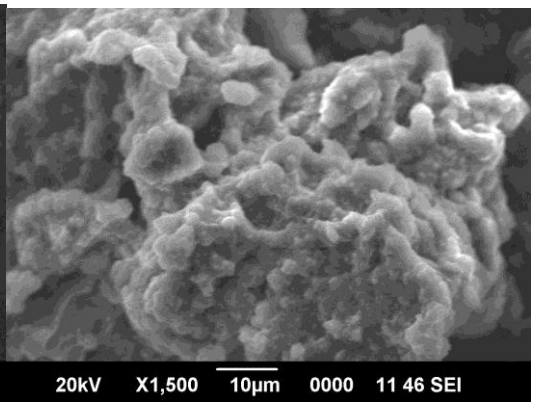


Fig. 2

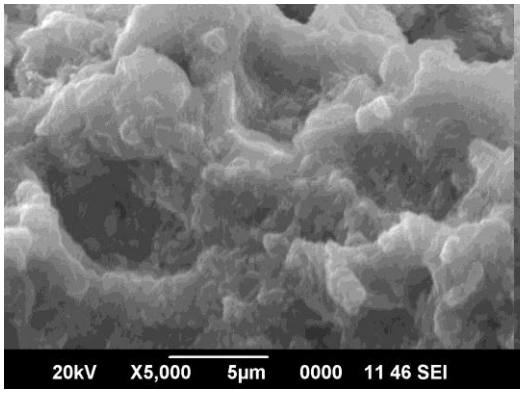


Fig. 3

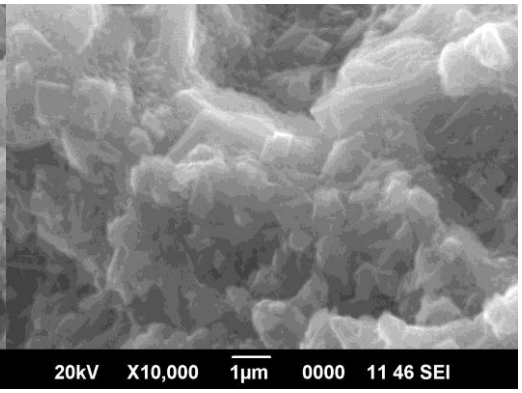


Fig. 4

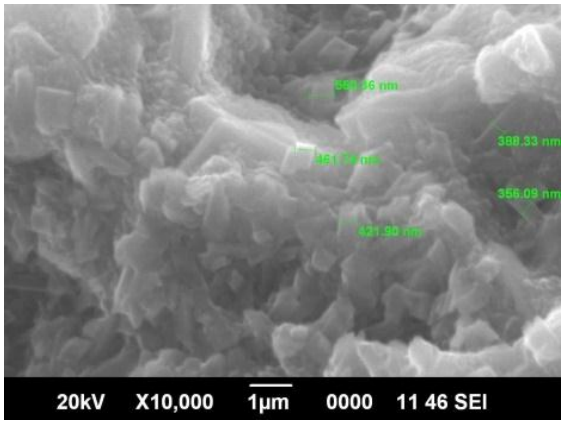
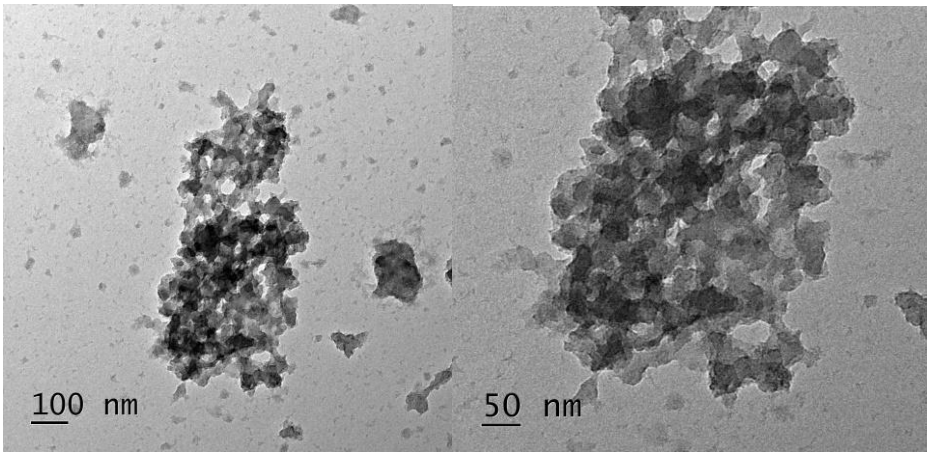


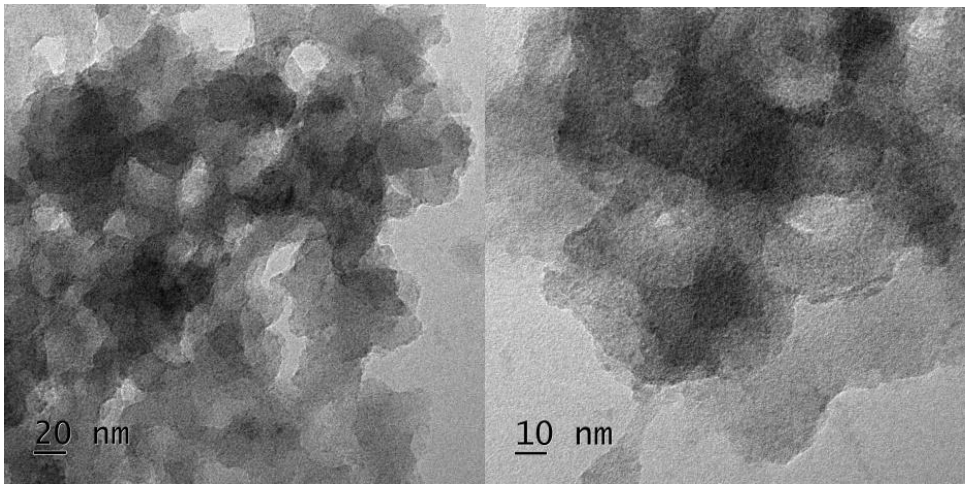
Fig. 5

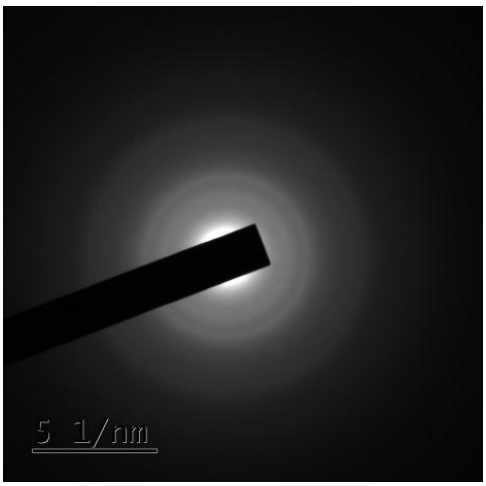
Upon high magnification we can see that the particles are uniformly distributed particles and we can found out that the iron nano particles are cubical in shape. This may be due to the presence of capping agents present in the plant extract. SEM images give clear morphology of iron nanoparticles. Upon low magnification of SEM image of iron nanoparticles it can be seen that the particles are agglomerated. The images also give a clear idea the size of the iron nanoparticles formed and it varies between 560.36 nm and 461.74 nm.

Transmission Electron Microscopy (TEM) Analysis

The samples were analyzed by TEM to determine the size and morphology of the particles. The TEM images support the crystalline structure of iron nano particles. The lighter regions are mainly on the surface of the particle and the dark regions are concentrated in the center of the particle. TEM instruments are designed so that the elements with higher atomic number seem to be darker than the ones with lower atomic number. The TEM images are:-







TEM images show the size distribution and shape of nanoparticles based on the phenomenon of transmittance of electron beam through an ultra-thin specimen. It is clear from the TEM images that the size of iron nanoparticles is almost uniform and all particles are cubic in shape. As shown in the figure the mean diameter size of this nanoparticle was found to be 51 nm. For iron nanoparticles the TEM images are seen in between the particle size 0 to 100 nm. The nanoparticles can be distinguished from each other and is in agreement with SEM results.

In vitro cytotoxicity analysis

The iron nanoparticles prepared from *Artocarpus heterophyllus* leaf extract were studied for short term in vitro cytotoxicity using Dalton's lymphoma ascites cells. It is applied to a tumor bearing mice and the percentage cytotoxicity was calculated. It is conducted in various nanoparticle concentrations. Upon 200 µg drug concentration the percentage cytotoxicity was found to be 28. Using 100 µg it is found to be 16%. On 50 µg drug concentration the percentage cytotoxicity was found to be 8.

Table 1: In vitro cytotoxicity analysis of the iron nanoparticles synthesized using *Artocarpus heterophyllus* tender leaf extract.

Drug concentration (µg/ml)	Percentage of cell death
200	28%
100	16%
50	8%
20	0%

From cytotoxicity analysis it is found that the iron nanoparticles formed have the ability to destroy tumorous cells. The percentage cytotoxicity was observed to be greater upon high drug concentration and the percentage cytotoxicity decreases upon lower drug concentration. It was found that the iron nanoparticles can induce cytotoxic effects on DLA cells, inhibiting tumor progression and thereby effectively controlling disease progression without toxicity to normal cells.

CONCLUSIONS

Green synthesis give advances over chemical and physical method as it is cost operative, atmosphere friendly and easily scrabbled up for large scale synthesis and in this method there is no need to use high energy, temperature and toxic chemicals. Green synthesis offer better influence, control over crystal growth and their steadiness. Green synthesized nano particles are cheap and economical and have many applications in science.

There is a critical need in the field of nanotechnology for the development of reliable and ecofriendly process in the synthesis of metal nanoparticles. Green synthesis and characterization of iron nanoparticles using *Artocarpus heterophyllus* tender leaf extract was conducted. Plant extract of tender leaves of *Artocarpus heterophyllus* was prepared and iron nanoparticles were successfully synthesized. These iron nanoparticles have been characterized by FTIR spectroscopy, Scanning Electron Microscope (SEM), Transmission Electron Microscopy (TEM), and UV-Visible spectroscopy and *in vitro* cytotoxicity analysis was conducted.

Results obtained from the above analysis revealed that the efficient capping and stabilization properties of these nanoparticles by the functional groups present in the plant extract. Capping agents would prevent the growth of nanoparticles while stabilizing agent could be used to prevent the agglomeration of nanoparticles. But any kind of capping or stabilizing agents are not used in this green synthesis of iron nanoparticles using *Artocarpus*

heterophyllus. Thus it was concluded that the synthesized of iron nanoparticles is quite stable without using any chemicals as capping and stabilizing agents.

Formation and stability of iron nanoparticles in aqueous solution was confirmed by using UV-Visible spectral analysis. The optical absorbance was done at a range of 200 to 800 nm and observed the absorption peak at approximately 238 nm due to vibrations in iron nanoparticles which are identical to the characteristic UV-Visible spectrum of metallic iron. From the optical absorbance measurements optical band gap energy was calculated and it was found to be approximately of 2.3 eV which further confirms the formation of iron nanoparticles.

From the FTIR spectroscopic analysis the different functional groups present in the *Artocarpus heterophyllus* leaves was identified. It showed the ability of this plant to act as reducing agents and stabilizers of iron nanoparticles. The FTIR spectra shows the presence of O-H, C=O, C-H and Fe-O bonds.

Scanning Electron Microscope (SEM) was employed to analyze the morphology of iron nanoparticles. It was demonstrated that SEM is capable to provide a reliable characterization of morphology of nanoparticles both as a screening method for accompanying characterization close to the nanoparticles and as a meteorological tool for evaluation of shape and size distribution. From the SEM images it was observed that the iron nanoparticles are in the form of nanocubes which exist in contact with each other and form chains.

TEM images revealed that the iron nanoparticles have an average core diameter of 51 nm and the nanoparticles obtained and are seen in a clustered form. This method offered the scale invariant feature applied to image with different magnifications, yielding comparable average size. Also, this image processing method successfully characterized agglomerated nanoparticles in TEM images.

From the *invitro* cytotoxicity analysis it is observed that the iron nanoparticles formed has the ability to destroy tumor cells. It showed that the formed nanoparticles have the capability to act against cancer. The iron nanoparticle was able to reduce cell toxicity of DLA cells in a dose-dependent manner. The cytotoxicity results demonstrated that the iron nanoparticles mediate a concentration dependent increase in cytotoxicity. It was also concluded that iron

nanoparticles serve as anti-tumor agents by decreasing progressive development of tumor cells.

Green synthesis of iron nanoparticles has been evolved as a method that would impart more stabilization of iron nanoparticles against aggregation and help to overcome the other synthesis method so far. This approach is highly promising for green, sustainable production of iron nanoparticles. Success of such a rapid time scale for the synthesis of iron nanoparticles is an alternative to chemical synthesis protocols for synthesizing iron nanoparticles. This green method of synthesizing iron nanoparticles could be extended to fabricate other, industrially important metals.

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