THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Green Synthesis and Characterization of Ripe Banana Peels Stabilized Iron Nanoparticles

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Abstract:
In this work, we demonstrate for the first time bio-inspired iron nanoparticles prepared from ripe banana peels extract (RBPE) through green synthesis procedure and characterized by various physicochemical techniques like UV-visible spectroscopy, scanning electron microscopy (SEM), tunneling electron microscopy (TEM) and energy dispersive X-ray spectrometry (EDS) and X-ray diffraction. The results obtained confirmed the synthesis of polydisperse and stable iron nanoparticles (FeNPs) by the ripe banana peels extract. Moreover, FTIR spectroscopy indicated the involvement of phenols, nitriles and carboxylic groups in the synthesis process.

Keywords: *Bio-inspired iron nanoparticles, ripe banana peels, green synthesis*

1. Introduction

Nanotechnology is a rapidly growing field of research in the world today [1]. The research explosion in this area is because nanoparticles have been found to have exceedingly better characteristics compared to their macroscale counterparts [2-5]. To this end, nanoparticles have found great use in the worlds of technology, medicine, computers and sensors and biosensors [6-9].

Iron nanoparticles (FeNPs) innovation represents perhaps one of the first-generation nanoscale advances. In the course of the most recent couple of years, different engineered strategies have been created to deliver iron nanoparticles, adjust the nanoparticle surface properties and improve the productivity for field conveyance and responses. While several types of iron nanoparticles (FeNPs) are available in the market, information on the nanoparticles synthesis and properties is still limited in journals. Chemical [10] and physical methods [11] have been applied to synthesize metallic nanoparticles of specific sizes and morphologies. These methods employ harmful chemicals such as sodium borohydride, sodium citrate dehydrate which are possibly hazardous and very costly to the natural settings and organic functions [12]. There is a need therefore to develop environment friendly procedures for synthesizing FeNPs devoid of toxic by-products, high pressure and high energy requirements.

Banana (Musa *paradaisica*) belongs to the family *Musaceae* and is a standout amongst the most vital tropical fruits in the world market. Banana peels extracts have shown prospects in FeNPs synthesis which is a 'green chemistry' synthetic approach. Banana peels contains diverse high levels of phenolic compounds that can act as both reducing and capping agents hence afford a green synthetic approach [12]. Banana peels forms18-33% [13] of the whole fruit and at present, they are not being utilized for any other purposes if not dumped as solid waste at large expense to the environment. It is consequently critical and even crucial to discover applications for these peels as they can add to genuine ecological issues.

Results presented in this paper demonstrate the green synthesis of iron nanoparticles using ripe banana peels extracts. Also, their spectroscopic and microscopic characteristics are presented.

2. Experimental

2.1. Chemicals and Reagents

Iron (III) chloride was purchased from Merck and was used without further purification. The ultra-purified and distilled de-ionized water (DDW) were obtained from the Biochemistry laboratory at the University of Nairobi. Ripe banana peels (*figure 1C*) were collected locally from the dumping sites in Nairobi Kenya.

Figure 1: (A) Banana plants (B) Ripe banana fruits and (C) Ripe banana peels

2.2. Preparation of aqueous Banana Peels Extract (BPE)

About 100g of fresh taxonomically authenticated peels of ripe banana were collected, washed thoroughly with double distilled water and cut into fine pieces and allowed to air-dry for some days. The dry ripe banana peels powder (8.3g) was extracted with 125 ml of DDW at 25, 50, and 80°C while being stirred for 30 min. The extract was allowed to cool to room temperature before being filtered through Whattman filter paper (No.42). After extraction, the samples were centrifuged at 8000 rpm for 30 min. The supernatant was collected, filtered and stored at -20°C before use.

2.3. Biosynthesis of Iron Nanoparticles (FeNPs) using BPE

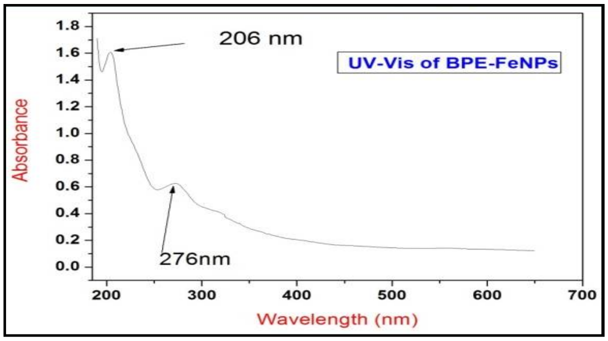
The iron nanoparticles were prepared by adding 0.1M $FeCl_3$ solution to the aqueous ripe banana peels extracts (supernatant at ambient temperature) in a 2:1 volume ratio. The mixture was then hand shaken for 1 minute and allowed to stand at room temperature for 1hour. After 10 minutes, the change in colour of the solution from brown to black indicating the formation of iron oxides nanoparticles was noted and recorded. The mixture was centrifuged at 8000 rpm for 30 min and the supernatant poured out. The black paste obtained was re-dispersed in ethanol followed by ultra-purified water to remove excess biological molecules. The process of centrifugation and re-dispersion in ethanol and ultra-purified water was repeated 3 times to completely purify the nanoparticles. The light black paste collected was then oven dried at 60^{o}C overnight, packed and stored for characterization. All the experiments were carried out in triplicates and the formation of the nanoparticles were monitored for different time intervals and the resulting nanoparticles characterized further.

2.4. Characterization of the biosynthesised iron Nanoparticles (FeNPs)

UV-Vis spectra analyses of the synthesized FeNPs were performed using a Nicolet Evolution 100 (Thermo Electron Cooperation, UK) UV-Vis spectrometer. The wavelength was scanned from 200 to 700 nm at a resolution of 1 nm. A potassium bromide (KBr) disc method was used for all the FTIR measurements and samples were pelletized before analysis using a Nicolet Magna-IR system 560 FTIR spectrometer. The TEM images were obtained using a Philips CM20T-LaB6 TEM microscope operating at acceleration voltage of 120 keV. Before viewing, samples were dispersed in DDW water and then placed onto carbon-coated copper grids. The morphologies of the ripe banana peels extract iron (BPE-Fe) nanoparticles were examined using a Hitachi X-650 SEM analyzer with acceleration voltage of 25kV and a resolution of 20µm. Elemental analyses of samples were performed using energy dispersive spectroscopy (EDS). The EDS spectra were obtained for10µL of Fe nanoparticles placed on a carbon-coated copper grid and measured using an accelerating voltage of 10 kV. The x-ray diffraction (XRD) characterization was carried out in order to determine the crystal structure of the synthesized iron solids. Measurements were done using a PANanalyticalXpert Pro θ-2θ diffractometer using Cu K_α radiation at 45 kV and a current of 40 mA. Prior to measurements, the FeNPs samples were oven dried.

3. Results and Discussions

Iron nanoparticles formation was monitored visually and by UV–Visible spectroscopy. When iron chloride ($FeCl_3$) solution were added to ripe banana peels aqueous extract solution, the colour of the mixture gradually changed from transparent yellow to black in 4 minutes at 90 °C. The UV-vis spectroscopy had a characteristic peak around 276 nm shown in *figure 2*. Similar observations had been reported for eucalyptus leaf extract synthesized Iron nanoparticles [14].



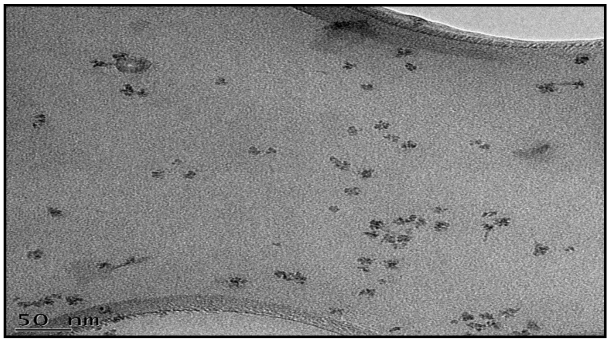


Figure 2: UV-Vis spectrum of ripe banana peels (RBPE) synthesized iron nanoparticles
Figure 3: Tunneling Electron Microscope (TEM) image of the biosynthesized iron nanoparticles

TEM images of biologically synthesized iron nanoparticles (*figure 3*) are granular in nature. The particles are nanosized, with size ranging between 20 nm and 50 nm. Similar results of iron nanoparticles synthesized from other plant extracts have been reported [15-18].

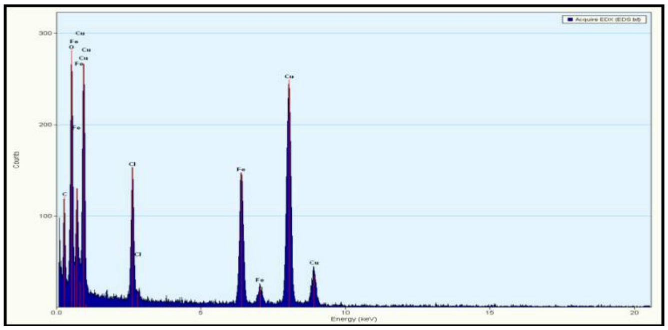


Figure 4: Energy dispersive spectroscopy (EDS) spectra of the biosynthesized iron nanoparticles

Energy dispersive spectroscopy (EDS) values are helpful in reflecting the atomic content on the surface regions of the nanoparticles. The EDS profile showed intense peak signals (*figure 4*) of iron at 182, 215, 424 and 458 energies. Other signals observed include that of chlorine, oxygen, carbon and copper. The oxygen and chlorine signals must be originating from $FeCl_3$ and ripe banana peels extract precursors used in the synthesis of RBPE-FeNPs. The Carbon signals are attributed mainly to the polyphenol groups and other carbon containing molecules in the banana peels extracts. Copper signals were due to the copper grid onto which the sample was placed during the analysis. These spectra are indicative of iron metal and are consistent with earlier reports [17, 19].

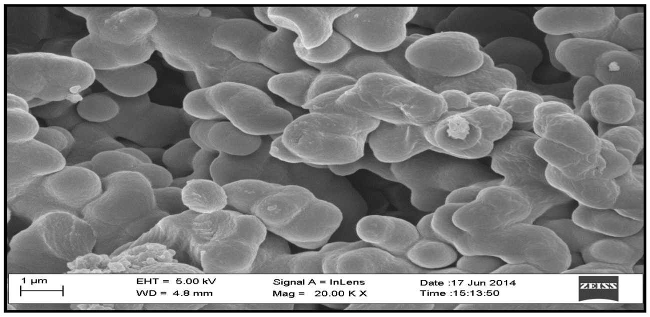


Figure 5: Scanning electron microscope (SEM) images of the biosynthesized iron nanoparticles

The morphological studies and the structure of the synthesized iron nanoparticles were analyzed by scanning electron microscopy (SEM). The SEM images of the iron nanoparticles synthesized shown in *figure 5* depicted that the shapes of the iron nanoparticles were nearly round with smooth surfaces. All the nanoparticles were well separated with slight aggregation which agrees with TEM analyses. These SEM results were consistent with reported results of synthesized FeNPs using aqueous sorghum bran extracts as the reducing agent [20].

The XRD analysis shown in *figure 6* indicates that the synthesized iron nanoparticles were amorphous with weak characteristic peak of iron, implying the non-crystalline nature of the nanoparticles. The intense peaks observed at Bragg reflection $2\theta=18.1466°$, $24.6345°$ and $35.7775°$ were due to crystal planes of (110), (200) and (112) planes respectively. These miller indices can be perfectly indexed to crystalline iron not only in their peak positions but also in their relative intensities. This too confirmed the presence of iron nanoparticles.

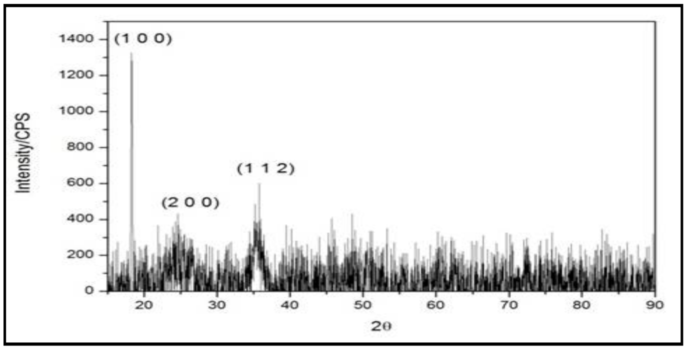


Figure 6: The X-ray diffraction (XRD) spectra of biosynthesized iron nanoparticles

The crystallite sizes were estimated using Scherrer's formula (*equation1*):

$$D = \frac{K\lambda}{\beta cos\theta} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where the D is the crystallite size, K is a constant taken to be 0.94, λ is the wavelength of X-ray, β is the half width of the most intense peak and θ is the Bragg angle of the most intense peak. Using this equation, the crystallite size was calculated to be 2.4383nm.

The unassigned peaks on the XRD pattern spectra may indicate the crystallization of bio-organic phase present in the extract. This is indicative of some ripe banana peels extracts adsorbed on to the formed iron nanoparticles due to the fact that the extracts act as capping and stabilizing agents evidently protecting iron from oxidization. Overly, these results agree closely with the XRD results obtained from other green synthetic approaches [20, 21] which were also amorphous in nature.

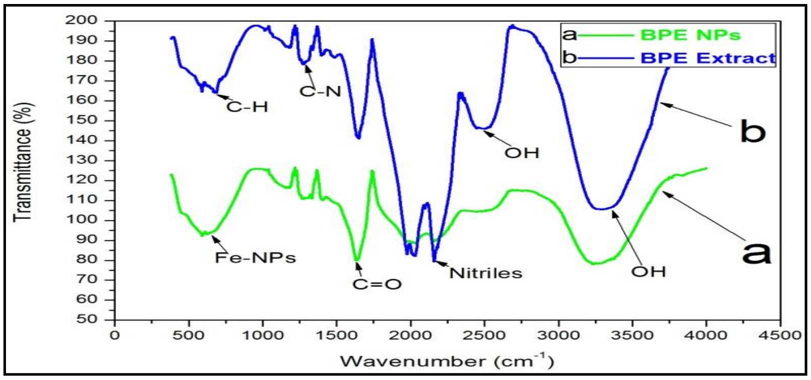


Figure 7: Fourier Transform-Infrared (FTIR) spectra of
(a) Ripe banana extract nanoparticles (BPE NPs) and (b) Ripe banana peels extract (BPE).

FTIR spectroscopy was used to determine different functional groups on ripe banana peels extracts (RBPE) and predict their role in iron nanoparticle synthesis (*Figure 7*). From the FTIR spectra, the O-H stretch at 3316 cm^{-1} was attributed to OH stretch in phenols present in the BPE. The peak located at around 2506cm^{-1}in the BPE was attributed to the O–H stretching in carboxylic acids. The reduction in the peak intensity in the iron nanoparticle spectra implicated that these groups maybe involved in the process of nanoparticle synthesis. The peak located at 1635 cm^{-1}could be assigned to the C=O stretch in carbonyls. The nitriles stretch at 2133cm^{-1} in the BPE reduced in intensity and their shift indicated the possible involvement of nitrile groups of the BPE powder in iron nanoparticles capping. The presence of C-H stretches of aromatics at 687cm^{-1}in the BPE spectrum and absence of the same peak in the nanoparticle spectrum indicated its involvement in the synthesis of the nanoparticles. A comparison of these results with earlier reports [22] indicated that hydroxyl, carboxyl and amide groups in RBPE might be participating in the process of nanoparticles synthesis. The strong peak at 640cm^{-1} was attributed to iron nanoparticles vibrations and this further confirmed the synthesis of the iron nanoparticles.

4. Conclusion

Iron nanoparticles were successfully synthesized using eco-friendly, rapid, simple and low-cost approach through reduction of ferric chloride solution in a green method using ripe banana peels extract as the reducing agent. The characteristics of the synthesized iron nanoparticles were studied using UV-vis, EDS, XRD, FTIR, TEM and SEM techniques which confirmed the formation of the iron nanoparticles.

5. Acknowledgement

Special thanks to Southern and Eastern Africa Network of Analytical Chemists (SEANAC), Sensor Lab at the University of Western Cape and University of Nairobi for the financial assistance.

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