Biosynthesis of iron oxide nanoparticles using Psidium guajava fruit extract

K.M. Ponvel[1], F. Mercy [2]

[1] Assistant Professor

[1,2] Department of Chemistry, V.O. Chidambaram College, Thoothukudi - 628008, Tamil Nadu, India.

Abstract- **Iron oxide nanoparticles (Fe3O4) were prepared by using biosynthetic route. Psidium guajava fruit extract was used as a reducing as well as capping agent. The reaction process was very simple, bio orientated, and convenient to handle. The iron oxide nanoparticles were characterized by x-ray diffraction, transmission electron microscopy, energy dispersive spectroscopy, Fourier transform infrared spectroscopy and vibrating sample magneto meter techniques. The size of the iron oxide nanoparticles was found to be 10-25 nm. Saturation magnetization of the nanoparticles was found to be 17.2 emu/g.**

Key words: Fe_3O_4; Biosynthesis; Psidium guajava; Magnetic properties.

1. INTRODUCTION

Iron oxide nanoparticles with properties of super para magnetism in addition to their low toxicity and biocompatibility have been intensively studied due to their unique magnetic properties and potential applications in the frontier fields of biomolecular separation, magnetic resonance imaging, drug delivery, enzyme immobilization and immunoassays [1-5]. Numerous methods were reported in the literature for the synthesis of iron oxide nanoparticles such as coprecipitation methods, hydrothermal processes, sonochemical methods, sol-gel techniques, electrochemical reactions and polyol methods [6-9]. The biosynthesis of nanoparticles was intended as a cost effective environmental friendly and an alternative to chemical method. Plant extracts are particularly promising for the synthesis of magnetic nanoparticles since they are freely available, cheap, and offer simplicity of use and scalability [10-17]. Plant extracts contain a potent array of organic substances such as polyphenols, carbohydrate, nitrogenous bases, and amino acids, which serve to improve particle stability.

Psidium guajava was used as a medicine by people worldwide. Guava fruit is a good source of vitamins and minerals, pectin, carbohydrates and phenolic compounds [18]. It was reported that white and pink seedling varieties of guava are containing glucose, fructose and sucrose components. These sugar components can serve both as effective reducing agents and as capping agents in the synthesis of iron oxide nanoparticles. Therefore, in the present study, naturally abundant guava fruits were used for the synthesis of iron oxide nanoparticles by the bio route.

EXPERIMENTAL METHODS

Materials

Ferric chloride hexahydrate, sodium acetate and aqueous ammonia (28 W%) were all purchase from Sigma-Aldrich. Doubly distilled deionized water was used throughout the experiments. White seedling Psidium guajava fruits used in this work were collected from the local area (Thoothukudi,Tamilnadu,India).

Preparation of guava fruit extract

Fruits of guava were thoroughly washed with double distilled water to remove dust particle and dried at room temperature. Dried fruits were cut into small pieces. An amount of 10 g of fruits of Psidium guajava were boiled in 100 mL of distilled water at 80 °C for 30 min. The extract was cooled to room temperature and passed through Whatman No. 41 filter paper and was stored at -4 °C in order to be used for further experiments.

Synthesis iron oxide magnetic nanoparticles

Iron oxide magnetic nanoparticles were prepared through a simple method [19]. For nanoparticle synthesis, 5 mmol of ferric salt and 5 mmol of sodium acetate were mixed with 40 ml of water. Fruit extract (40 ml) was added to the above solution and then the mixture was stirred vigorously for 2 h at 80°C. The resulting solution became black in color indicating the formation iron oxide magnetic nanoparticles. The obtained black product was isolated by applying an external magnetic field and washed several times with water and dried in a vacuum over at 80 °C for 24 h.

Results and Discussion

Iron oxide nanoparticles were synthesized by allowing Psidium guajava fruit extract to react with ferric ion solution. Reduction of ferric ions to magnetic nanoparticles could be noted by the color changing of ferric ions from yellow to brown color. Fe3+ was hydrolyzed to give ferric hydroxide and released H+ ions in presence of sodium acetate. Then ferric hydroxide was partially reduced by the fruit extract containing carbohydrate to produce iron oxide nanoparticles and carbonic acid. The reaction equations are;

$$Fe^{3+} + 3H_2O \xrightarrow[\Delta]{CH_3COONa} Fe(OH)_3 + 3H^+$$

$$Fe(OH)_3 + \text{Carbohydrate} \xrightarrow{\Delta} Fe_3O_4$$

The crystalline structure of the nanoparticles was characterized by X-ray powder diffraction. The X-ray diffraction patterns obtained for the iron oxide nanoparticles synthesized using guava fruit extract was shown in Figure 1. It was found that there exist strong diffraction peaks with 2θ values of 30.2°, 35.3°, 43.8°, 55.5° and 60.8°, corresponding to the crystal planes of (220), (311), (400), (511) and (440) of crystalline iron oxide naoparticles, respectively. The results were in agreement with the XRD standard for the magnetite nanoparticles [20-22].

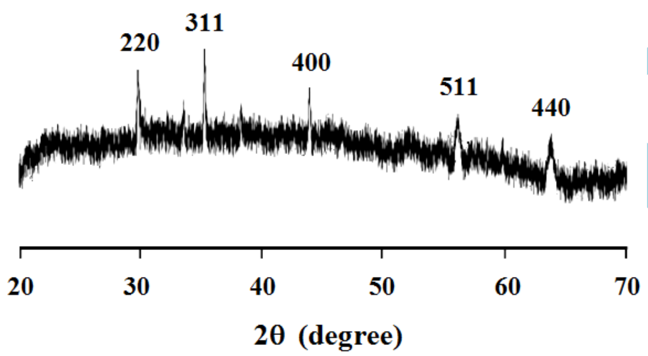

Figure 1. X-ray diffraction patterns of iron oxide nanoparticles.

TEM images shown in Figure (2a), reveal that iron oxide nanoparticles formed were irregular in shape and non uniform in size ranging from 10-25 nm. Iron oxide nanoparticles were surrounded by a faint thin layer of other materials, which may be the capping organic materials from Psidium guajava fruit extract.

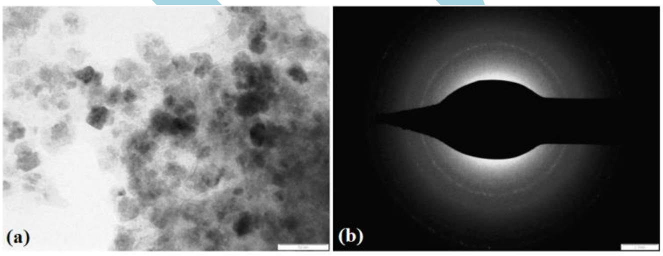

Figure 2. (a) TEM and (b) SAED images of iron oxide nanoparticles.

The ring-like diffraction pattern and the approximately circular nature of the selected area electron diffraction (SAED) spots indicated in Figure 2b reflected that the particles were semi crystalline in nature.

With Energy Dispersive X-ray Spectroscope (EDX) analysis, Figure 3 indicates the peaks of Fe and O elements present in the nanoparticles. Iron and oxygen elements confirmed the formation or iron oxide nanoparticles.

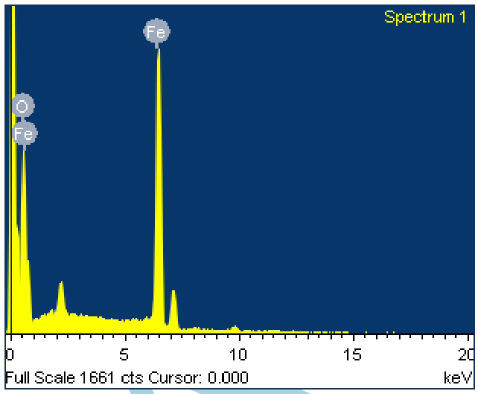

Figure 3. EDX image of iron oxide nanoparticles.

FT-IR spectroscopy was used to identify the functional groups of the active components presented in the fruit extract. Figure 4 showed FT-IR spectra of Psidium guajava fruit extract and capped Fe3O4-NPs. IR spectrum of dried plant extract was shown in Figure 4a. Presence of several absorption bands in the region of 3410, 2926, 1610, 1384 and 1070 cm□1 indicated the presence of active functional groups in the extract. Bands at 3410 cm−1 (OH stretching), 2,926 cm−1 (CH stretching), 1610 (C=O stretching), 1384 cm−1 (aromatic C-H stretching) and 1104 cm−1 (C-N stretching) were observed as characteristic functional groups. Figure 4b showed the phyto constituents stabilized Fe3O4 NPs. The absorption bands appeared in the IR spectrum of fruit extract could also be seen in the IR spectra of phyto capped Fe3O4 NPs. The formation of Fe3O4 was characterized by two absorption bands at 582.06 and 435.53 cm−1 which correspond to the Fe–O bond in magnetite [22].

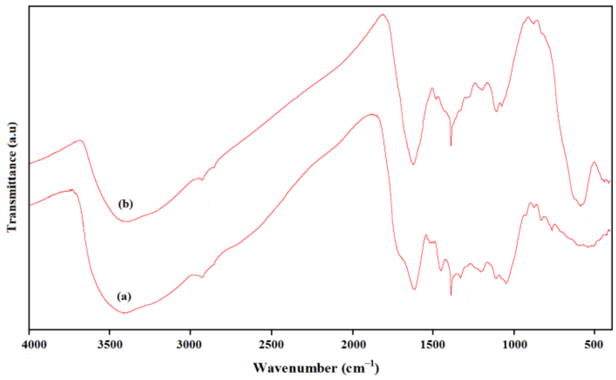

Figure 4. FT-IR spectra of (a) dried plant extract and (b) iron oxide nanoparticles.

From the FTIR results, the soluble elements present in guava fruit extract could have acted as capping agents preventing the aggregation of nanoparticles in solution, and thus playing a relevant role in their extracellular synthesis.

In order to study the magnetic behaviour and the superparamagnetic property of iron oxide nanoparticles magnetization measurement recorded with VSM was performed. As can be observed in Figure 5, the specific saturation magnetization value was measured to be 17.2 emu/g.

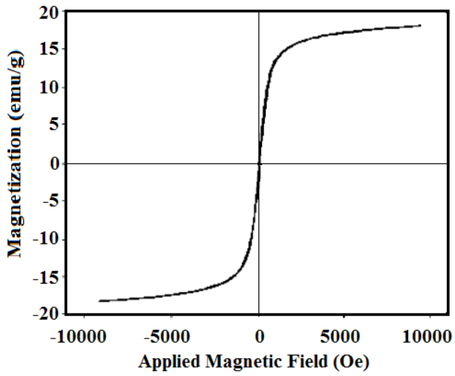

Figure 5. Magnetization curve of iron oxide nanoparticles.

The magnetization curve showed zero remanence and coercivirty, which indicated that these nanoparticles had superparamagnetic properties. This could be due to the formed magnetic nanoparticles within the guava fruit extract should be smaller than 25 nm, and they might be considered to have a single magnetic domain. The superparamagnetism enables the nanoparticles to respond to an applied magnetic field without any permanent magnetization and re-disperse rapidly when the magnetic field is removed. So this magnetic property can permit the magnetic nanoparticles to be utilized in biomedical applications.

CONCLUSION

Biosynthesis of iron oxide nanoparticles using Psidium guajava fruit extract was reported and it explained assure for bio route synthetic technology. This process appeared to be cost efficient alternative to conventional physical and chemical methods of iron oxide nanoparticles and would be apt for large scale production. The TEM showed that the size iron oxide nanoparticles were in 10-25 nm. The magnetization of resulting iron oxide nanoparticles offers easy separation and may have potential applications in future nano strategy.

REFERENCES

[1] Y.-w. Jun, J.-s. Choi, J. Cheon, Heterostructured magnetic nanoparticles: their versatility and high performance capabilities, Chem. Commun. (2007) 1203-1214.

[2] S. Laurent, D. Forge, M. Port, A. Rach, C. Robic, L.V. Elst, R.N. Muller, Magnetic iron oxide nanoparticles: synthesis, stabilization, vectorization, physicochemical characterization, and biological application, Chem. Rev. 108 (2008) 2064-2110.

[3] E.-J. Woo, K.M. Ponvel, I.-S. Ahn, C.-H. Lee, Synthesis of magnetic/silica nanoparticles with a core of magnetic clusters and their application for the immobilization of His-tagged enzymes, J. Mater. Chem. 20 (2010) 1511-1515.

[4] D.-G. Lee, K.M. Ponvel, M. Kim, S. Hwang, I.-S. Ahn, C.-H. Lee, Immobilization of lipase on hydrophobic nano-sized magnetite particles. J. Mol. Catal. B. Enzymatic 57 (2009) 62-66.

[5] K.M. Ponvel, D.-G. Lee, E.J. Woo, I.-S. Ahn, C.-H. Lee, Immoblization of lipase on surface modified magnetite nanoparticles using alkyl benzenesulfonate. Korean J. Chem. Eng. 26 (2009) 127-130.

[6] Hua J, HeQing Y. Sci. China Ser. E Tech. Sci. 51 (2008) 1911–1920.

[7] Nazrul Islam M.D, Van Phong L, Jeong J.R, Kim C.G. Thin Solid Films 510 (2011) 8277–8279.

[8] Deng Y, Wang L, Yang W, Fu S, Elaissari A. J Magn Magn Mater 257 (2003) 69–78.

[9] Franger S, Berthet P, Berthon J. J Solid State Electrochem 8 (2004) 218–223.

[10] Ponvel, K.M.; Narayanaraja, T.; Prabakaran, J. Biosynthesis of Silver nanoparticles using root extract of the medicinal plant Justicia adhatoda: Characterization, electrochemical behavior and applications. Int. J. Nano Dimens. 6 (2015) 339-349.

[11] Jayalakshmi, Yogamoorthi, A. Green synthesis of copper oxide nanoparticles using aqueous extract of flowers of Cassis alata and particles characterization. Int. J. Nanomat. Biostruc. 4 (2014) 66-71.

[12] Subhankari, I.; Nayak, P.L. Synthesis of copper nanoparticles using Syzygium aromaticum (Cloves) aqueous extract by using green chemistry. World J. Nano. Sci. Technol. 2 (2013) 14-17.

[13] Xia, B.; He, F.; Li, L. Preparation of bimetallic nanoparticles using a facile green synthesis method and their application. Langmuir 29 (2013) 4901-4907.

[14] S. Venkateswarly, Y. SubbaRao, T. Balaji, B. Prathima, N.V.V. Jyothi, Biosynthesis of Fe3O4 magnetic nanoparticles using plaintain peel extract. Mater. Lett. 100 (2013), 241-244.

[15] W. Lu, Y. Shen, A. Xie, W. Zhang, Green synthesisandcharacterizationofsuperparamagnetic Fe3O4 nanoparticles. J. Magn. Magn. Mater. 322 (2010) 1828-1833.

[16] M. Senthil, C. Ramesh, Biogenic synthesis of Fe3O4 nanoparticles using Tridax Procumbens leaf extract and its antibacterial activity on Pseudomonas aeruginosa. Dig. J. Nanomater. Bios. 7 (2012) 1655-1660.

[17] Makarov, V.V.; Makarova, S.S.; Love, A.J.; Sinitsyna, O.V.; Dudnik, A.O.; Yaminsky, I.V.; Taliansky, M.E.; Kalinina, N.O. Biosynthesis of Stable Iron Oxide Nanoparticles in Aqueous Extracts of Hordeum vulgare and Rumex acetosa Plants Langmuir, 30 (2014) 5982-5988.

[18] Hassimotto, N. M.; Genovese, M. I.; Lajolo, F. M. (2005). Antioxidant activity of dietary fruits, vegetables, and commercial frozen fruit pulps. Journal of Agricultural and Food Chemistry, 53(8) (2005) 2928-2935.

[19] Venkateswarly, S.; Rao, Y.S.; Balaji, T.; Prathima, B.; Jyothi, N.V.V. Biogenic synthesis of Fe3O4 magnetic nanoparticles using plantain peel extract. Mater. Lett. 100 (2013) 241-244.

[20] E.Woo, K.M. Ponvel, I.S. Ahn, C.H. Lee, J. Mater. Chem. 2010, 20, 1511-1515.

[21] K.M. Ponvel, D.G. Lee, E. Woo, I.S. Ahn, C.H. Lee, Kor. J. Chem. Engin. 2009, 26, 127-130.

[22] D.G. Lee, K.M. Ponvel, M. Kim. S. Hwang, I.S. Ahn, C.H. Lee, J. Mol. Catal. B: Enzym. 2009, 57, 62-66.