EFFICIENCY ENHANCEMENT AND CHARACTERIZATION OF IRON NANOPARTICLES SYNTHESIZED VIA ULTRASOUND-ASSISTED LEAF EXTRACT OF SOLANUM

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ABSTRACT

Iron nanoparticles, have drawn a lot of attention because of their distinct physicochemical characteristics and wide range of uses in biomedicine, environmental remediation, and catalysis. The efficiency improvement and characterisation of Iron nanoparticles produced with an ultrasound-assisted green synthesis method and leaf extract from Solanum trilobatum as a stabilizing and reducing agent are the main objectives of this work. Ultrasound irradiation produces a consistent particle size distribution, increases nanoparticle yield, and improves reaction kinetics. To verify the structural, morphological, and chemical characteristics of the synthesized Iron nanoparticles, a variety of analytical methods were used. X-ray diffraction determines the grain size of the nanomaterial. Impurity peaks are absent, indicating that the iron nanoparticles are highly crystalline. The Debye-Scherrer formula suggests that the particle's average crystalline size is 47 nm and also it is discovered that their HCP structure is crystalline and the Anti bacterial activity gives the moderate antibacterial activity against Staphylococcus aureus and Pseudomonas aeruginosa., but no activity against Escherichia coli towards Iron nanoparticles. The results indicate that the ultrasound-assisted approach creates extremely stable, monodispersed Iron nanoparticles with higher surface activity and better catalytic efficiency. Additionally, the study assesses these Iron nanoparticles effectiveness in pollutant removal, dye degradation, and antibacterial activity, highlighting their potential for long-term industrial and environmental uses.

KEYWORDS: catalysis, grain size, green synthesis ,XRD, antibacterial activity.

INTRODUCTION

Nanoparticles are extremely small particles, usually ranging in size from 1 to 100 nanometers (nm). Because of their distinct size, nanoparticles can display distinct physical and chemical characteristics from bigger particles. Because of their high surface area-to-volume ratio, nanoparticles interact and react more readily with their surroundings. Quantum mechanics is important at the nanoscale, where it produces special optical, electrical, and magnetic characteristics. By using acoustic energy to cause the solvent to cavitate, ultrasound-assisted extraction is a non-thermal method that speeds up the release and diffusion of target materials. Although conventional techniques have been used for many years to produce nanoparticles, research has shown that green ways are more successful because they are easier to describe, less costly, and less likely to fail. *Solanum Trilobatum*, Southern India has greater access to *linn* (Solanaceae), one of the important medicinal herbs. *Solanum trilobatum* is used extensively in Indian traditional medicine to treat a variety of human ailments. The objectives of the present research is, To prepare Ultrasound assisted extract of Solanum Trilobatum leaves. To synthesis Iron nanoparticles by using the extract of Solanum Trilobatum leaves and To study the structural, antibacterial and magnetic properties.

MATERIALS AND METHODS

Water molecules are included in the structure of ferric sulphate hydrate, which is a hydrated version of ferric sulphate ($Fe_2(SO_4)_3$). It is an inorganic substance that is frequently used as a coagulant, to clean water, and to make pigment. A hydrated salt of ferric sulphate ($Fe_2(SO_4)_3$), ferric sulfate hydrate has water molecules in its crystal structure. Iron(III) cations (Fe^{3+}) and sulphate anions (SO_4^{2-}) combine to form this ionic compound.

Leaves of Solanum trilobatum are gathered from nearby area and cleaned with purified water. Use Wattman filter paper to filter the leaves after grinding them. Ultrasonification is applied to the final extract. The extract is kept in sonicator about half an hour. 100 ml of leaf extract from Solanum trilobatum was mixed with 1 M of ferric sulphate hydrate. For approximately three hours, the mixture is agitated at 600 RPM using a magnetic stirrer. The residue undergoes many washings with ethanol and double-distilled water. It is dried for three hours at 100 degrees Celsius in a hot air oven. For five hours, the dried sample is heated to 600 degrees Celsius in a muffle furnace. The resulting precipitate has a fine power. The dried iron nanoparticles are characterized by XRD and Antibacterial activity.

RESULTS AND DISCUSSIONS

X- RAY DIFFRACTION (XRD)

The structural characterization of the iron nanoparticles is carried out by the XRD method. The X-ray diffraction experiments are carried out with the XPERTPRO diffraction system using the CuKa radiation of wavelength 1.5406A°. The type of the scan used is continuous and range from 10 to 80.

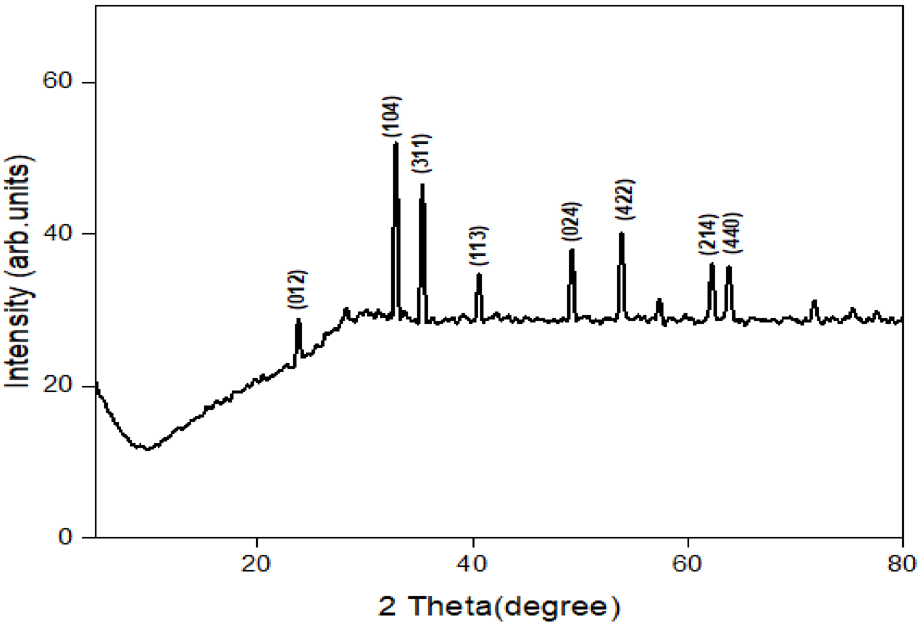

Fig 1 XRD pattern for Iron nanoparticles

The average grain size is calculated using Debye Scherrer formula,

$$D=K\lambda/\beta\cos\theta$$

λ - X-ray wavelength

β- line broadening at half the maximum intensity (FWHM)

θ- Bragg angle

The XRD results for the Iron nanoparticles exhibit strong peaks around 2θ =32.856 and 2θ =35.338 belongs to Iron Oxides. These peak values are in good agreement with the JCPDS cards. From the observation it is clearly indicates that the iron nanoparticles exhibit HCP structure as confirmed from the JCPDS file. The JCPDS card number for Fe2O3 is 96-900-0140.The absence of impurity peaks denotes the high crystalline nature of the Iron nanoparticles are shown in figure (1). The average crystalline size of the particle is **47 nm** which is calculated using Debye Scherrer formula are shown in table (1)

The dislocation density has been calculated using crystallite size, by the equation,

$$\textit{Dislocation} = 1/D^2$$

The microstrain has been calculated by the given formula,

$$\textit{Microstrain} = \beta \cos\theta /4$$

h k l	**Peak Positions 2θ (deg)**	**D(nm)**	**Dislocation density**	**Microstrain (10^{-2})**
0 1 2	23.835	74.38728	0.000599	-3.92838
1 0 4	32.856	44.36163	0.000602	4.682303
3 1 1	35.338	44.88747	0.000596	-1.81697
1 1 3	40.573	37.48341	0.000882	0.682932
0 2 4	49.183	40.91941	0.000787	-10.2274
4 2 2	53.812	39.42622	0.000881	-1.38078
2 1 4	62.201	30.95915	0.001551	-23.7535
4 4 0	63.775	39.40366	0.000973	15.63281

Table 1 Calculation of size of iron nanoparticles from XRD pattern

ANTI BACTERIAL ACTIVITY

Microbial strains used

Utilized microbial strains, for antibacterial action, three bacterial strains *Escherichia coli, Staphylococcus aureus and Pseudomonas aeruginosa* were employed.

Bacterial inoculum preparation

The Nutrient broth was made and autoclaved for 15 minutes at 15 pounds of pressure to sterilize it. The sterilized marine broth was used to individually inoculate each of the three bacterial strains, which were then incubated for 24 hours at 37°C.

A sterile cotton swab was used to inoculate the petri plates with the 24-hour-old bacterial broth cultures of *Escherichia coli, Staphylococcus aureus and Pseudomonas aeruginosa*.

a) ***Pseudomonas aeruginosa*** **b)** ***Staphylococcus aureus*** **c)*****Escherichia coli***

Fig 2 Antibacterial activity of acetic acid on Iron nanoparticles

Bacterial strains (mm)	**200**	**300**	**400**	**PC**	**NC**
Staphylococcus aureus	0	0	4	6	0
Pseudomonas aeruginosa	3	3.5	4	5	0
Escherichia Coli	0	0	0	7	0

Table 2 Bacterial strain for Iron nanoparticles

The Solanum trilobatum extract shows moderate antibacterial activity against Staphylococcus aureus and Pseudomonas aeruginosa but no activity against Escherichia coli. The antibacterial effect is dose-dependent, with higher concentrations (400 µg/ml) showing more inhibition.

The positive control (PC) consistently has stronger antibacterial effects, indicating that the extract is not as effective as the standard antibiotic used in the control. The negative control (NC) shows no inhibition, confirming that the observed antibacterial effects are due to the extract itself. The table presents the antibacterial activity of an acetic acid extract of Solanum trilobatum against three bacterial strains: Staphylococcus aureus, Pseudomonas aeruginosa., and Escherichia coli. The results are given in millimeters (mm) as the zone of inhibition, indicating the effectiveness of the extract at different concentrations (200, 300, and 400 µg/ml).

Outcomes of table (2) Acetic acid extracts of different *Lagocephalus spadiceus* tissues have antibacterial action against bacterial strains, In *Staphylococcus aureus* the skin extract created zones of inhibition of 0 mm, 0 mm, and 4 mm at 200ul, 300 µl, and 400 µl, respectively. The zones of inhibition for *E. coli* were 0 mm, 0 mm, and 0 mm at doses of 200 µl, 300 ul, and 400 µl. In *Pseudomonas* the zone of inhibition reached 3 mm, 3.5mm, 4mm at a concentration of 200µl, 300 µl and 400 µl.

CONCLUSION

Nowadays, nanotechnology is a significant factor in every area of research and technology. The green method enables the most stable metal-based nanoparticles at a reasonable cost and without harming the environment. Therefore, the present work incorporates the findings of a study that involved the synthesis and characterisation of iron nanoparticles employing *Solanum trilobatum* extract as stabilizing agents.

XRD examination indicates that the particle size is about 47 nm. The absence of impurity peaks denotes the high crystalline nature of the Iron nanoparticles. It is discovered that their Hexagonal closed packed structure is crystalline. The Iron nanoparticles has moderate antibacterial activity against Staphylococcus aureus and Pseudomonas aeruginosa., but no activity against Escherichia coli.

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