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Uncaria gambir Roxb Leaf Extract Mediated Hydrothermal Synthesis of Magnetite Nanoparticles

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Abstract: This study aims to investigate the effect of UGR plant extract in the synthesis process of magnetite nanoparticles (MNPs). *Uncaria gambir* Roxb (UGR) leaves contain bioactive compounds that can interact with magnetite precursors. Magnetite nanoparticles were synthesized through hydrothermal method between $FeCl_3$ and UGR extract. The results showed that the use of UGR extract in the synthesis of magnetite nanoparticles produced a significant effect on the crystal structure. There is a change in the crystal lattice parameters of the nanoparticles synthesized with UGR extract compared to the nanoparticles synthesized without the use of the extract. In addition, the particle size of magnetite nanoparticles also decreased significantly, with a more homogeneous particle size distribution in magnetite nanoparticles involving UGR extract. Furthermore, this study also proved that UGR extract has an influence on the magnetic properties of the nanoparticles produced. MNPs with UGR extract showed stronger magnetic properties compared to nanoparticles synthesized without UGR extract. This indicates that UGR extract can act as a reducing agent in the synthesis process of magnetite nanoparticles. This research provides new insights into the use of UGR plant extract in the synthesis of magnetite nanoparticles and broadens our understanding of the interaction between natural compounds and magnetic materials. It is hoped that the results of this study can serve as a foundation for the development of new applications of magnetite nanoparticles synthesized using UGR extract.

Keywords: Magnetite; Uncaria gambir Roxb; hydrothermal method, magnetic properties.

Introduction

Nanotechnology is a branch of science that has experienced rapid development in recent decades. The story of nanoscale materials offers a wide range of potential applications, such as catalysis, electronics, and biomedicine. In this research, magnetite nanoparticles, a nanomaterial form of iron oxide (Fe_3O_4), have attracted significant attention due to their unique magnetic properties and potential for applications in current technologies (Salih and Mahmood, 2023). The synthesis of magnetite nanoparticles involves organic solvents such as sodium borohydride, hydrazine, and carbon monoxide as reducing agents. These solvents have very high reactivity and potentially harm the environment. Synthesis of nanomaterials by green chemistry method has begun started develop.(Katata-Seru *et al.*, 2018; Vasantharaj *et al.*, 2019)

Magnetic nanoparticles can be applied as biosensors, catalysts, magnetic resonance imaging, and drug delivery (Nikitin *et al.*, 2017; Mabrouk *et al.*, 2020; Tracey *et al.*, 2020; Rahmayeni *et al.*, 2021). To overcome these problems, we have started to develop and improve research on nanomaterials based on the green chemistry method. A previous study reported that the synthesis of magnetite nanoparticles was successfully carried out by utilizing plant extracts such as *Chlorella vulgaris* (Saad AlGarni, Ali and Al-Mohaimeed, 2023), *Thymbra spicata flower* (Tang, Li and Sun, 2022), and *Mentha longifolia flower* (Wang *et al.*, 2022). This study reports the synthesis of magnetite

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nanoparticles using *Uncaria gambir* Roxb extract media.

Based on this, we want to conduct similar research with different samples. Ferrite nanoparticles were synthesized using *Uncaria gambir* Roxb extract—the principle in this study, green synthesis of magnetite nanoparticles by hydrothermal method. The reducing agent used is an active compound contained in the section and has functional groups that are easily oxidized. Apart from being a reducing agent, the active compounds contained in the plant extract are expected to act as capping agents/stabilizers.

Materials and Methods

The *Uncaria gambir* Roxb leaf samples were taken from the Agricultural Experimental Garden of Andalas University. More than ten gambir plants grow in the garden area. Leaves are taken randomly on the stem from the base to the tip. Leaf color varies from light green to dark green; some leaves are reddish green. Gambir leaves that have been obtained are washed first using water. Cleaning with water aims to remove dust particles attached to the leaves. After washing, the leaves are cut into pieces and dried in the air for up to ± three days. On the third day, the color of the leaves had turned brown. The physical condition of the leaves is fragile and easily crushed by hand. The dried leaves are mashed through a grinding process using a grinding tool. This grinding process aims to change the physical condition of the gambier leaves into finer and more homogeneous particles in powder form.

$FeCl_3.6H_2O$ 10 mmol was reacted with 50 ml of *Uncaria gambir* Roxb extract while stirring at room temperature for 1 hour and adding 3M NaOH dropwise to pH 10-12. The synthesis process by hydrothermal method. The mixture was put into the autoclave at a temperature of 180 ^{0}C for 24h. Then, the mixture is cooled before centrifugation. The centrifuged mixture is separated between the solid phase (residue) and the liquid phase (supernatant). The residue obtained was washed using ethanol and water. The residue was then dried in an oven at 85°C to evaporate the remaining solvent after washing. The residue obtained is ferrite nanoparticles, and further characterization is carried out. The definition of magnetite nanoparticles was employed by FTIR spectroscopy (Perkin-Elmer), XRD (Shimadzu 7000), TEM (JEM 1400), and vibrating-sample magnetometer (VSM Oxford 1.2 type).

Results and Discussion

The catechin compounds in *Uncaria gambir* Roxb act as reducing agents in the magnetic synthesis process, as seen in the reaction below. Figure 1 shows the reaction mechanism at the green synthesis of magnetite nanoparticles using *Uncaria gambir* Roxb leaf extract. The response shows the process of reducing Fe^{3+} to Fe^{2+} and the oxidation of the hydroxyl groups in catechins to become ketones (Arief *et al.*, 2020) For the reaction of forming magnetite precipitates with sodium hydroxide precipitating rock, as shown in Figure 1b.

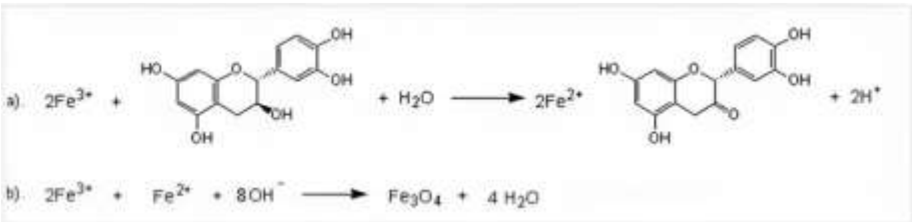

Figure 1. Magnetite formation reaction of (a) Fe^{3+} reduction process and (b) magnetic formation with NaOH precipitators.

Based on Figure 2a, it can be seen that the FTIR spectrum of catechins from *Uncaria gambir* Roxb extract shows characteristic absorption regions for OH groups at peaks of 3309 cm^{-1}, C=C groups around 1608 cm-1. Spectrum b and spectrum c show the different of the spectrum, which changed as indicated by the appearance of the Fe-O stretching vibrations in the 480 cm-1 wavenumber regions.

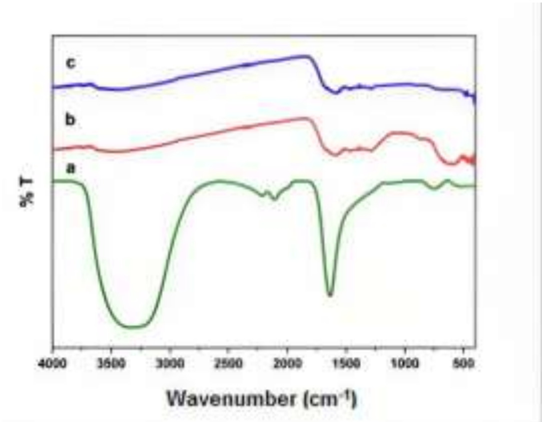

Figure 2. FTIR spectrum of gambir extract (a), Magnetite with *Uncaria gambir* Roxb (b), and Magnetite without *Uncaria gambir* Roxb ©

To determine the crystallographic and phase structure of the greenly produced magnetite nanoparticles, as shown in Figure 3. They indicate the cubic degree of magnetite corresponding to the JCPDS No. 85-1436. Magnetite nanoparticles often exhibit several peaks at 2θ = 30.22, 35.72, 44.64, 53.57, 57.0, and 63.64°, respectively, corresponding to (220), (311), (400), (422), (511), and (440) as shown in figure 3.

TEM characterization was employed to determine the morphology and particle size of magnetite nanoparticles. Fig. 4. (a-b) shows the TEM image of magnetite nanoparticles with a magnification of 200.000×. It can be seen that TEM has a cubic shape with a particle size of approximately 20 nm for magnetite using *Uncaria gambir* Roxb, as shown in Figure 4a. Furthermore, magnetitenanoparticles without *Uncaria gambir* Roxb have a particle size were 80 nm, as shown in Figure 4b.

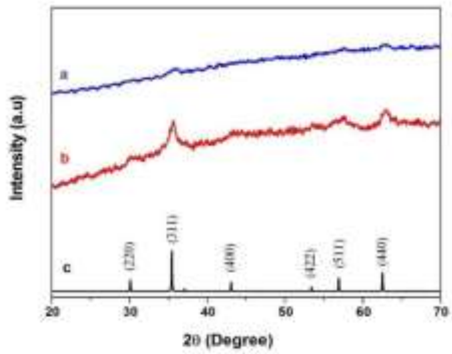

Figure 3. XRD Pattern of magnetite nanoparticles

Since the material has an iron core, studying the magnetic characteristics of magnetite by VSM is essential. It generates a typical magnetic hysteresis curve when a magnetic field of 20 kOe to 20 kOe is applied, demonstrating that the material is naturally paramagnetic (Fig. 4c). 23.6 emu/g was discovered to be the saturation magnetization (Ms) value. Due to the loading of magnetite without *Uncaria gambir* Roxb extract, the lower magnetic value than magnetite with *Uncaria gambir* Roxb extract.

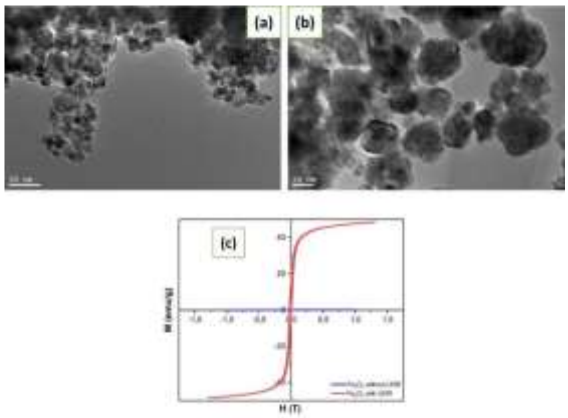

Figure 4. TEM images of (a) magnetite nanoparticles with gambir extract, (b) magnetite nanoparticles without gambir extract, and VSM spectrum of magnetite nanoparticles.

Conclusions

In conclusion, using *Uncaria gambir* Roxb extract in hydrothermal synthesis can affect crystal growth, reduce particle size, and improve the magnetic properties of the resulting magnetite nanoparticles. The functional groups in the active compounds of *Uncaria gambir* Roxb leaves interact with Fe^{3+} ions in the reduction process to Fe^{2+} ions. *Uncaria gambir* Roxb leaf extract can also act as a capping agent that produces magnetite particles of a smaller size. The result is magnetite nanoparticles with higher crystallinity, smaller particle size, and more robust magnetic properties, thus having broad application potential in various fields.

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Conflict of Interest: The authors declare that there are no conflicts of interest concerning the publication of this article.

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