



Enhancement of Antibacterial Agent of Cobalt Ferrite/AC/DMSO with Ferrofluid

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Abstract

Global health is under serious threat due to antimicrobial resistance, especially in bacteria. Therefore, this study offers an alternative in the form of an antibacterial agent based on cobalt ferrite/AC/DMSO ferrofluid. This ferrofluid was successfully synthesized using the coprecipitation method, which was confirmed by XRD, SEM, FTIR characterization, and antibacterial tests. XRD results showed that cobalt ferrite nanoparticles formed an inverse cubic spinel crystal structure, and the AC material was amorphous. The particles were spherical in shape that were quite agglomerated with particle sizes of 28.5 ± 0.5 nm. Then, the formation of cobalt ferrite and AC was also confirmed by the appearance of M-O and C-O, C=O bonds. DMSO surfactant was shown with a typical bond, namely S=O. While coconut oil was detected by C-O, C=O, CH₂, and CH₃ bonds. Interestingly, the performance of cobalt ferrite/AC/DMSO ferrofluid is shown by the antibacterial test results which produce an inhibition zone diameter of *Escherichia coli* bacteria of 9.50 ± 1.01 mm.

Keywords: Antibacterial Agent, Ferrofluid, Cobalt Ferrite/AC/DMSO

1. Introduction

In recent years, antimicrobial resistance, particularly in bacteria, has become a serious threat to global human health. This condition can reduce the effectiveness of treatment and cause the spread of infections to become more widespread. The WHO reported in 2019 that the death toll due to resistance has increased to 5 million annually [1]. One of the bacteria that causes various serious infections is *Escherichia coli*. Based on data from the China Antimicrobial Resistance Surveillance System (CHINET), this bacteria is the pathogen that contributes to the highest number of deaths due to antimicrobial resistance [2]. This threat has highlighted the need for more effective and safe alternatives, one of which is through a nanotechnology approach in the form of cobalt ferrite nanoparticles as an antibacterial agent.

The use of cobalt ferrite nanoparticles is now attracting attention because it has unique properties such as large surface area, good biocompatibility, non-toxic, and has good interaction with bacterial cells so that it is easier to inhibit the growth of bacteria through the formation of reactive oxygen species (ROS) [3], [4]. However, this utilization has challenges such as easy agglomeration, so it is necessary to compost with other materials. Activated carbon (AC) with its porous structure can function as a support matrix that can help disperse cobalt ferrite nanoparticles by multiplying the active sites so that it can facilitate direct contact with bacteria and improve the oxidative mechanism in cell inhibition in bacteria [5].

Interestingly, cobalt ferrite/AC nanocomposites can be modified in the form of ferrofluids to enhance antibacterial activity. These ferrofluids have good stability and homogeneity to carry

nanocomposites towards bacterial targets [6]. The addition of dimethyl sulfoxide (DMSO) as a surfactant in ferrofluids can dissolve polar and non-polar compounds, prevent clumping, and increase bioactive fractions in favor of antibacterial activity [7]. Furthermore, the homogeneity of ferrofluids can be overcome by adding a dispersing medium in the form of coconut oil. Coconut oil contains compounds, especially lauric acid, oleic acid and linoleate which have antibacterial properties to increase its antibacterial performance [8]. Thus, cobalt ferrite/AC/DMSO ferrofluids can be a more effective alternative as an antibacterial agent.

2. Methods

The synthesis of cobalt ferrite/AC nanocomposites begins by reacting iron sand and HCl 12 M to obtain FeCl_2 and FeCl_3 solutions as in previous studies [9]. Next, the solution was added to CoCl_2 and composted with AC. After that, the sediment is washed to a neutral pH. After neutralization, the precipitate was dried using an oven at 100°C for 1 hour and then characterized by XRD and SEM. Next, the synthesis of cobalt ferrite/AC nanocomposite precipitate is carried out with DMSO surfactant and dispersed using coconut oil. The results of the synthesis formed a cobalt ferrite/AC/DMSO ferrofluid characterized by FTIR and antibacterial test.

3. Results and Discussion

The XRD results of the cobalt ferrite/AC nanocomposite are shown in Figure 1. The peak of diffraction of cobalt ferrite nanoparticles appears at $2\theta = 30.2^\circ$; 35.5° ; 43.4° ; 53.5° ; 57.2° ; and 62.9° with hkl planes (2 2 0), (3 1 1), (4 0 0), (4 2 2), (5 1 1), and (4 4 0) as in previous research by Ramadhani, et. to [10]. The crystal structure formed from these nanoparticles is an inverted cubic spinel that has a space group Fd-3m with $a = b = c = 8,376 \text{ \AA}$ [10]. Then, cobalt ferrite is composed of Co^{2+} ions that occupy the Fe atom at the tetrahedral site [11]. Moreover, in this diffraction peak, the AC material does not appear because it is amorphous and is covered by the cobalt ferrite composition [12].

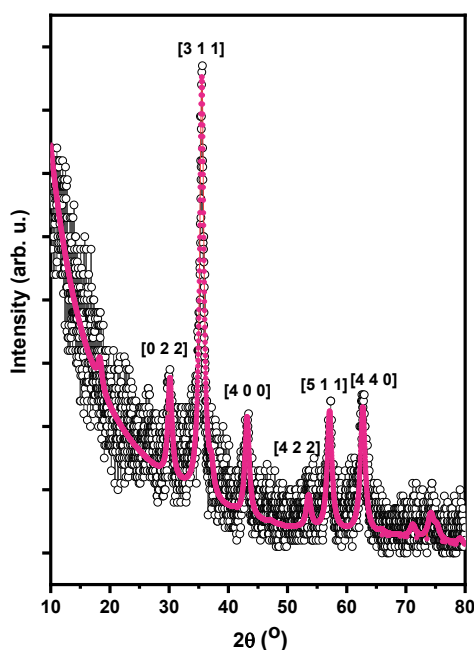


Figure 1. X-Ray Diffraction Pattern of Cobalt Ferrite/AC Nanocomposite.

Furthermore, the morphology and particle size of the SEM results are shown in Figure 2. The morphological shape of the cobalt ferrite/AC nanocomposite shows a spherical shape with particles that are sufficiently agglomerated on the surface of the AC. This agglomeration occurs due to the strong force between magnetic particles [13]. The nanocomposite produces a particle size of 28.5 ± 0.5 nm. The value in this study is smaller than previous studies that obtained CoFe_2O_4 particle sizes of 47.6, 51.6 and 50.1 nm [14]. This shown that the addition of AC is able to function as a supporting matrix that increases active sites and is quite helpful in the distribution of cobalt ferrite nanoparticles [5].

The formation of cobalt ferrite/AC/DMSO ferrofluid was confirmed by FTIR results at wave numbers of $4000 - 400 \text{ cm}^{-1}$ as in Figure 3. The material formed was indicated by the appearance of functional groups, where cobalt ferrite was confirmed by the appearance of M-O functional groups at wave numbers of 468 cm^{-1} and 589 cm^{-1} [11]. At wave numbers of 1315 cm^{-1} and 1743 cm^{-1} , C-O and C=O bonds appeared, indicating the presence of AC [15]. Then, the emergence of a typical bond of DMSO, namely S=O, which appeared at wave numbers of 952 cm^{-1} and 1027 cm^{-1} [7]. While coconut oil as a dispersing medium was indicated by C-O and C=O bonds at wave numbers of 1315 cm^{-1} and 1165 cm^{-1} [16]. In addition, these results have shown CH_2 and CH_3 bonds which indicate the presence of bioactive compounds from coconut oil at wave numbers 2851 cm^{-1} and 2953 cm^{-1} [17].

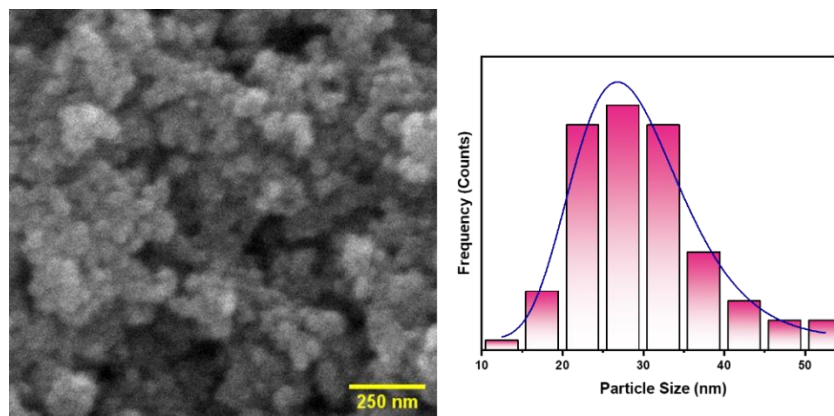


Figure 2. Morphology and Particle Size Distribution of Cobalt Ferrite/AC Nanocomposite.

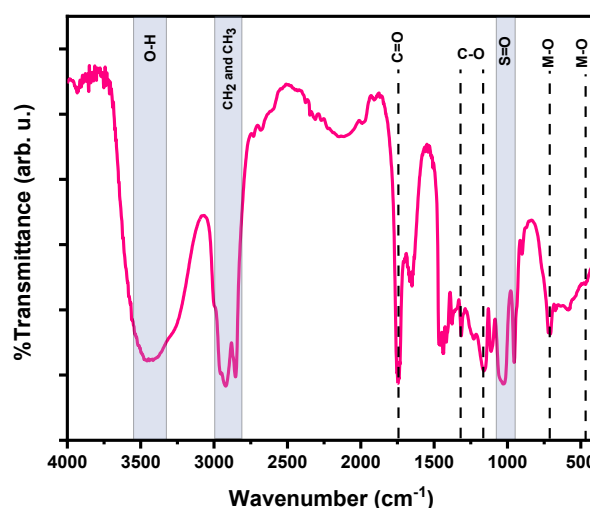


Figure 3. FTIR Spectrum of Ferrofluid Cobalt Ferrite/AC/DMSO.

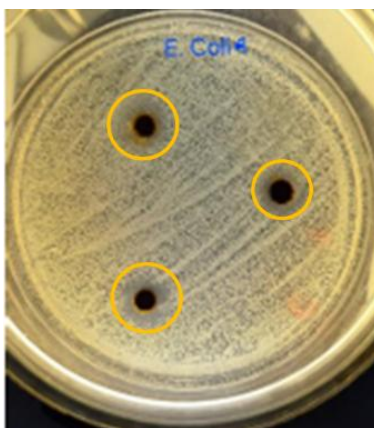


Figure 4. Diameter of the Inhibition Zone of *Escherichia coli* Bacteria.

Based on the results of the cobalt ferrite/AC/DMSO ferrofluid antibacterial test using the diffusion method shown in Figure 4. The results of this study show the diameter of the inhibition zone of *Escherichia coli* bacteria of 9.50 ± 1.01 mm. This antibacterial activity is caused by the interaction between the positively charged ferrofluid from Co^{2+} , Fe^{2+} , Fe^{3+} ions with negatively charged bacteria resulting in electrostatic forces. This interaction causes the ferrofluid to damage the cell wall and allows the ferrofluid to penetrate the bacterial cell wall. In bacteria, the ferrofluid produces reactive oxygen species (ROS) originating from the sample surface such as O^{2-} , OH , and H_2O_2 which can kill cells in bacteria [6]. Interestingly, in the ferrofluid there is a dispersing medium in the form of coconut oil which also plays a role in dissolving the cobalt ferrite/AC nanocomposite, making it easier to penetrate the bacterial cell wall and helping to damage bacterial cells with the presence of lauric acid compounds [16]. Thus, the cobalt ferrite/AC/DMSO ferrofluid is able to produce bacterial inhibition zone values as in Figure 4.

4. Conclusion

Cobalt ferrite/AC/DMSO ferrofluid as an antibacterial agent was successfully synthesized by coprecipitation method. XRD results have shown that cobalt ferrite nanoparticles form an inverse cubic spinel crystal structure and amorphous AC material. The formed particles tend to agglomerate with a spherical shape and produce a particle size of 28.5 ± 0.5 nm. Then, the formation of cobalt ferrite and AC was also confirmed by the appearance of M-O and C-O, C=O bonds. DMSO surfactant is shown by a typical bond, namely S=O. While coconut oil is detected by C-O, C=O, CH_2 , and CH_3 bonds. Furthermore, cobalt ferrite/AC/DMSO ferrofluid can be applied as antibacterial agent as it exhibits an inhibition zone diameter towards *Escherichia coli* bacteria of 9.50 ± 1.01 mm.

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