Biosynthesis and characterization of zinc ferrite (ZnFe$_2$O$_4$) via Antidesma bunius L. fruit extract

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Abstract. Biosynthesis of ZnFe$_2$O$_4$ via Antidesma bunius L fruit extract has been carried out. In this synthesis, Zn(NO$_3$)$_2$·6H$_2$O and Fe(NO$_3$)$_3$·9H$_2$O were used which act as precursors of Zn$^{2+}$ and Fe$^{3+}$ ions with a coefficient ratio of 1:2 using the coprecipitation method with variations in calcination temperatures of 500 °C, 600 °C and 700 °C. The precursor used is NaOH. XRD data showed that there are diffraction peaks of ZnFe$_2$O$_4$ in all samples but at a calcination temperature of 700 °C the diffraction peaks of ZnFe$_2$O$_4$ with high intensity are more visible at 2θ = 31.78°, 34.42°, 35.2°, 36.22°, 56.61° this peak corresponds to the peak ZnFe$_2$O$_4$ diffraction (JCPDS 22-1012) in addition there is also a peak of ZnO at 2θ = 31.7°, 34.4°, 36.2°, 47.5°, 62.8°, 66.5° and 69.2° (JCPDS 36-1451). FTIR analysis showed that the Zn-O stretching group was at wave numbers 837 cm$^{-1}$, 870 cm$^{-1}$, 1058 cm$^{-1}$, 1065 cm$^{-1}$, and 1350 cm$^{-1}$. The Zn-O-Zn strain is found at wave numbers 1350 cm$^{-1}$, 1633 cm$^{-1}$, and 1634 cm$^{-1}$, respectively. The appearance of these bonding groups proves that the synthesis of ZnFe$_2$O$_4$ has been formed.

1. Introduction
Ferrite oxide nanoparticles (MFe$_2$O$_4$; M = Zn, Mn, Co, etc.) are ferromagnetic materials that can be applied as photocatalytic materials in visible light, one of the materials that can be used as photocatalysts because it has good photochemical stability, like zinc ferrite (ZnFe$_2$O$_4$) [1]. In addition, ZnFe$_2$O$_4$ can also be applied as a catalyst [2], gas sensor [3] and adsorbent [4]. Various methods to synthesize ZnFe$_2$O$_4$ have been carried out like hydrothermal, precipitation, sonochemical [5], sol gel [6], microemulsion [7], combustion [8] and electrospinning methods [9], but all the above methods require complex synthesis equipment, involve toxic chemical and are large energy intensive. Many biological synthesis procedures have been carried out employing organisms such as bacteria [10], plant extract [11], and food waste [12], it might also be a sustainable, eco-friendly alternative to chemical and physical nanoparticle production techniques. These biosynthetic methods can easily be scaled up for large-scale manufacturing. Both reducing and capping agents, these plant extracts are used. Multifunctional ZnFe$_2$O$_4$ nanoparticles were synthesized using Aloe vera extract [13]. Moringa oleifera extract [14] and leaf extract of Tristaniopsis merguensis [11].

Buni fruit is one of the plants found on the Bangka Islands (Antidesma bunius L). Buni fruit contains a lot of total phenolics and has a lot of antioxidant activity. [15]. In the synthesis of zinc
ferrite (ZnFe$_2$O$_4$), the phenolic content could be utilized as a bioreductor. In this study, the biosynthesis and characterization of ZnFe$_2$O$_4$ was carried out using *Antidesma bunius* L fruit extract.

2. Methods

2.1 Materials

Zn(NO$_3$)$_2$.6H$_2$O and Fe(NO$_3$)$_3$.9H$_2$O were produced by Sigma Aldrich and Merck. The *Antidesma bunius* L 'buni' fruit came from Bangka (Indonesia).

2.2 Instrument

The crystalline structure was determined by XRD pattern Rigaku Miniflex600 D with Cu K-alpha=1.5406 radiation. FTIR absorption spectrometer (Bruker Alpha) was used to detect chemical bonding in the 500-4000 cm$^{-1}$ range.

2.3 Antidesma bunius L fruit extract

30 g of Antidesma bunius L fruit were placed in 300 ml of deionized water and stirred for 2 hours with a vigorous stirring (50 °C). After chilling to room temperature, the mixture was centrifuged and refrigerated for future research.

2.4 Biosynthesis of Zinc Ferrite (ZnFe$_2$O$_4$)

50 ml of Antidesma bunius L fruit extract was used to dissolve 5 g of Zn(NO$_3$)$_2$.6H$_2$O and Fe(NO$_3$)$_3$.9H$_2$O over 1 hour of vigorous stirrer. The mixture was covered with foil and maintained at room temperature for 18 hours after cooling to ambient temperature. After 18 hours of drying in a normal oven at 100°C, the mixture was washed multiple times with distilled water and annealed for 2 hours at 500°C, 600°C, and 700°C.

3. Result and Discussion

3.1 Biosynthesis of ZnFe$_2$O$_4$

Biosynthesis of ZnFe$_2$O$_4$ using coprecipitation method which is an acid-base reaction method that will produce water and crystalline solids. In addition, the coprecipitation method has a fairly low energy or <100 °C and can control the size of the resulting particle [16]. The stages of the synthesis of ZnFe$_2$O$_4$ are by mixing solid Zn(NO$_3$)$_2$.6H$_2$O as a provider of Zn$^{2+}$ ions and solid Fe(NO$_3$)$_3$.9H$_2$O as a provider of Fe$^{3+}$ ions [11]. After the two solids are mixed, add the buni fruit extract dropwise until the mixture dissolves. The phenolic compounds in the buni fruit extract have a hydroxyl group that functions to donate electrons and have reducing properties so that they can be used as bioreductants in the synthesis of ZnFe$_2$O$_4$. After that, NaOH solution is added drop by drop, where NaOH is one of the strong bases that acts as a precursor for the formation of precipitates [14,17], the final stages are drying and calcination. Biosynthesis mechanism for producing metal nanoparticles [18] and product of the synthesis can be seen in Figure 1.

![Figure 1](image-url)
3.2 XRD analysis

The purity phase of ZnFe$_2$O$_4$ was analyzed using XRD analysis (Figure 2). The ZnFe$_2$O$_4$ sample was calcined at temperatures of 500°C, 600°C, and 700°C in this investigation.

![XRD diffractogram](image)

**Figure 2.** XRD diffractogram of sample calcination temperature of (a) 500°C, (b) 600°C and (c) 700°C.

Based on the XRD diffractogram in Figure 2, there are diffraction peaks of ZnFe$_2$O$_4$ in all samples but at a calcination temperature of 700 °C the diffraction peaks of ZnFe$_2$O$_4$ with high intensity are more visible at 2θ = 31.78°, 34.42°, 35.2°, 36.22°, 56.61° this peak corresponds to the peak. ZnFe$_2$O$_4$ diffraction (JCPDS 22-1012) in addition there is also a peak of ZnO at 2θ = 31.7°, 34.4°, 36.2°, 47.5°, 62.8°, 66.5° and 69.2° (JCPDS 36-1451) which indicates that the formation of ZnFe$_2$O$_4$ is not optimal because it is suspected that the presence of organic compounds that have not been decomposed binds to the Fe$_2$O$_3$ phase, causing the formation of ZnO phase in all samples. A calcination temperature of 700 °C is regarded the optimum calcination temperature for the production of zinc ferrite (ZnFe$_2$O$_4$) using plant extracts.[14].

3.3 FTIR analysis

The ZnFe$_2$O$_4$ sample was then examined using FTIR spectroscopy to identify the functional group of ZnFe$_2$O$_4$, with calcination temperatures varying between 500 °C, 600 °C, and 700 °C. ZnFe$_2$O$_4$ FTIR spectra can be seen in Figure 3.

![FTIR spectrum](image)

**Figure 3.** FTIR spectrum of ZnFe$_2$O$_4$ at temperatures: (a) 500 °C, (b) 600 °C and (c) 700 °C
Based on Figure 3, it can be seen that the wave numbers 3726 cm$^{-1}$ and 3740 cm$^{-1}$ indicate the presence of an octahedral O-H group, where the group comes from phenolic compounds found in buni fruit extracts. While the wave numbers are 2173 cm$^{-1}$, 2186 cm$^{-1}$, and 2194 cm$^{-1}$, respectively, showing the stretching vibration of C=C. At wave numbers 2881 cm$^{-1}$, 2885 cm$^{-1}$, and 2895 cm$^{-1}$, respectively, the aldehyde C-H stretching vibration group (alkane group) [19]. This shows that there are still chemical compounds derived from buni fruit [15].

Then for the Zn-O stretching group, the wave numbers are 833 cm$^{-1}$, 868 cm$^{-1}$, 878 cm$^{-1}$, 1054 cm$^{-1}$, and 1063 cm$^{-1}$. The Zn-O-Zn strain is found at wave numbers of 1421 cm$^{-1}$, 1635 cm$^{-1}$, and 1523 cm$^{-1}$, respectively. Metal-oxide (Fe-O) bonds appear at wave numbers 616 cm$^{-1}$ and 626 cm$^{-1}$ [20]. The main absorption band of ZnFe$_2$O$_4$ has a high intensity and a rapid shift to the wavenumber 500-900 cm$^{-1}$, which corresponds to the metal oxygen bond’s stretching vibrations (Zn-O-Fe) [21,22]. Based on the FTIR spectrum, it is possible to conclude that all calcination temperatures generate typical zinc ferrite absorptions. The appearance of these bonding groups proves that the synthesis of ZnFe$_2$O$_4$ has been formed. The mechanism proposed for the formation of ZnFe$_2$O$_4$ is shown in Figure 4.

![Figure 4](image_url)

**Figure 4.** The proposed mechanism for the synthesis of ZnFe$_2$O$_4$ nanoparticles in the presence of plant extracts as a capping agent is illustrated schematically [23]

### 4. Conclusion

The biosynthesis of Zinc Ferrite (ZnFe$_2$O$_4$) was successfully carried out in this work using *Antidesma bunius* L fruit extract. The ZnFe$_2$O$_4$ and ZnO phases dominate all samples, according to XRD data, although the ZnFe$_2$O$_4$ phase appears more strongly at a calcination temperature of 700 oC. The Zn-O stretching group and the Zn-O-Zn strain were found to be Zn-O stretching groups and Zn-O-Zn stretches, according to FTIR analysis. The suggested mechanism for zinc ferrite synthesis is based on an FTIR analysis of the interaction of Zn$^{2+}$ and Fe$^{3+}$ ions through active compounds of the *Antidesma bunius* L extract.

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