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RESEARCH ARTICLE

# Economic Evaluation of Cobalt Ferrite (CoFe2O4) Through Coprecipitation Method Using Biodegradable Surfactant (Potato Starch)

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## ABSTRACT

The aim of this study was to analyse the feasibility of cobalt ferrite ($CoFe_2O_4$) nanoparticles production on an industrial scale using the coprecipitation synthesis method. The analysis was carried out based on an economic and technical perspective. The method used is by calculating several economic evaluation parameters such as gross profile margin (GPM), payback period (PBP), breakeven points (BEP), internal rate return (IRR), cumulative net present value (CNPV), return on investment (ROI), and profitability index (PI). The results show that the production of $CoFe_2O_4$ nanoparticles using the coprecipitation method is profitable with the recovery of investment funds which only takes three years after the project is made. Another advantage of production using this method is that it can use biodegradable surfactants (potato starch) and produce superior products with economical selling prices through practical product processing. This research is expected to provide a positive contribution to the industry for the manufacture of $CoFe_2O_4$ nanoparticles by coprecipitation method using biodegradable surfactants.

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***Kata Kunci: Economic Evaluation; Co-precipitation Synthesis Method; Cobalt Ferrite Nanoparticle; Potato Starch Surfactant.***

## ABSTRAK

Penelitian ini bertujuan untuk menganalisis kelayakan produksi nanopartikel kobalt ferit ($CoFe_2O_4$) skala industri dengan metode sintesis kopresipitasi. Analisis dilakukan berdasarkan perspektif ekonomi dan teknis. Metode yang digunakan adalah dengan menghitung beberapa parameter evaluasi ekonomi seperti *gross profile margin* (GPM), *payback period* (PBP), *breakeven point* (BEP), *internal rate return* (IRR), *cumulative net present value* (CNPV), *return on investment* (ROI), dan indeks profitabilitas (PI). Hasil penelitian menunjukkan bahwa produksi nanopartikel $CoFe_2O_4$ dengan metode kopresipitasi menguntungkan dengan pengembalian dana investasi yang hanya membutuhkan waktu tiga tahun setelah proyek dibuat. Keuntungan lain dari produksi menggunakan metode ini adalah dapat menggunakan surfaktan biodegradable (pati kentang) dan menghasilkan produk unggulan dengan harga jual yang ekonomis melalui pengolahan produk yang praktis. Penelitian ini diharapkan dapat memberikan kontribusi positif bagi industri untuk pembuatan nanopartikel $CoFe_2O_4$ dengan metode kopresipitasi menggunakan surfaktan *biodegradable*.

***Kata Kunci:*** *Evaluasi ekonomi; Metode sintesis Co-presipitasi: Nanopartikel CoFe; SUrfaktan pati kentang*

## 1. INTRODUCTION

Spinel ferrite nanoparticles have been a subject of interest due to their electronic, magnetic, and catalytic properties [1]. Cobalt ferrite ($CoFe_2O_4$) is a part of spinel ferrite that known with several properties such as high Curie temperature, large magneto crystalline anisotropy, high coercivity, moderate saturation magnetization, large magneto-strictive coefficient, excellent chemical stability and mechanical hardness [2]. Cobalt ferrite nanoparticle has a wide application in technological fields such as in magnetic hyperthermia, molecular imaging, electronics, spintronics, information storage, supercapacitors, drug delivery, magnetic resonance imaging, and catalysis [3]. Cobalt ferrite has an inverse spinel structure where the $Fe^{3+}$ ions filled the tetrahedral site and $Co^{2+}$ ions filled the octahedral site [4].

Several methods have been developed to synthesize cobalt ferrite such as thermal decomposition [1] [5-6], sol-gel auto combustion [7-9], reverse micelle [4] [10-11], Hydrothermal [12-14], microwave-assisted decomposition

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[15-16], and coprecipitation [17-19]. The most appropriate method for economic evaluation analysis is coprecipitation method using a biodegradable surfactant (potato starch). We chose this method because it is simple and economical. In addition, potato starch showed an effective action as a surfactant [17].

This study aims to determine the feasibility of the $CoFe_2O_4$ nanoparticle production on a large scale through the coprecipitation method using a biodegradable surfactant (potato starch) and then evaluate the technical and economic feasibility by comparing several parameters. In this study, we changed the number of materials and tools from a lab scale to an industrial scale. We perform several economic variations such as raw materials, sales, taxes, labor, and utilities.

## 2. METHOD

### 2.1 Theoretical Synthesis of Cobalt Ferrite Nanoparticle

The production of cobalt ferrite nanoparticles via co-precipitation synthesis method shown in Figure 1. The synthesis begins with dissolving 10 mmol of $CoCl_2{\cdot}6H_2O$, 20 mmol of $FeCl_3{\cdot}6H_2O$, and 0.5 g of potato starch as a surfactant in 150 ml of de-ionized water. The mixture was then stirred for 1 h at 500 rpm at room temperature. After that, 50ml of 3M NaOH was added as the precipitating agent until the pH of the mixture reached 11 and the precipitate from metal hydroxides appeared. The mixture subsequently heated to 90 °C. With this temperature of 90 °C, the mixture was refluxed with continuous magnetic stirring for 2 hours and was cooled down naturally to room temperature. Then, the de-emulsified mixture was centrifuged for 15 minutes at ~6000 rpm to separate the supernatant liquid. The obtained precipitate was then washed with de-ionized water and ethanol and dried at 90 °C for 12 h.

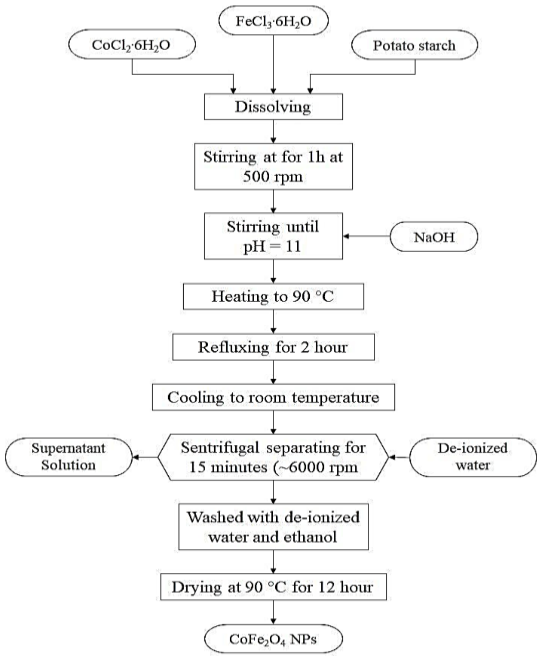


**Figure 1. Cobalt ferrite nanoparticle synthesis process with co-precipitation method**

### 2.2 Economic Evaluation

This study was carried out by analyzing the average price of products available on the online shopping web to guarantee the current prices of tools and materials. All data is calculated using Microsoft Excel. There are several parameters used in economic evaluation, as follows:

1. Break-Even Point (BEP) is the minimum value of production to gain profit or loss. BEP can be calculated by dividing fixed costs by profit [20].
2. Gross Profit Margin (GPM) is used to determine the level of profitability of a project. GPM is calculating by subtracting sales revenue from raw material prices [21].
3. Cumulative Net Present Value (CNPV) is obtained from the net present value (NPV) at a particular time level which states the income and expenses [20]. CNPV is obtained by adding up the initial NPV value until the end of the project [22].
4. Profitability Index (PI) is obtained by dividing the CNPV value by the total investment cost (TIC). The PI value can be used to determine the relationship between project impact and costs [23]. If the PI value is less than one, the project is considered unprofitable [22].
5. Payback Period (PBP) is a calculation to predict the length of time to return the total initial expenditure. PBP can be calculated when CNPV is at zero for the first time [22].
6. Internal Rate of Return (IRR) can be used to ensure the economic condition of a project [21].

Several assumptions are used to analyze and predict the possibilities that will occur in this project. The assumptions are:

1. 1 USD = IDR 15.000 ,00.
2. All item prices are based on online market prices.
3. The project runs for 300 days/year.
4. The synthesis of $CoFe_2O_4$ nanoparticles runs for one cycle/day.
5. The buyer bears shipping costs.
6. The 1st to 2nd year is a development process project.
7. $CoFe_2O_4$ nanoparticles sell for 150 USD/Kg.
8. Workers pay 150 USD/day for 30 workers.
9. The project lasted for nine years.

## 3. RESULTS AND DISCUSSION

The production process of $CoFe_2O_4$ nanoparticles shows in Figure 2 with the information of the symbols in Table 1. Based on the engineering perspective, the total cost of purchasing raw materials for one year was 291.010,00 USD. The cost of the equipment is 24.960,00 USD. Sales in 1 year are 3.105.000,00 USD. The profit earned is 2.502.647,07 USD. Based on the results of the complete accounting analysis, the project requires a considerable investment. The project went on for nine years. The CNPV/TIC value in the 9th year reached 65.9972 %, and the PBP was achieved in the 3rd year.

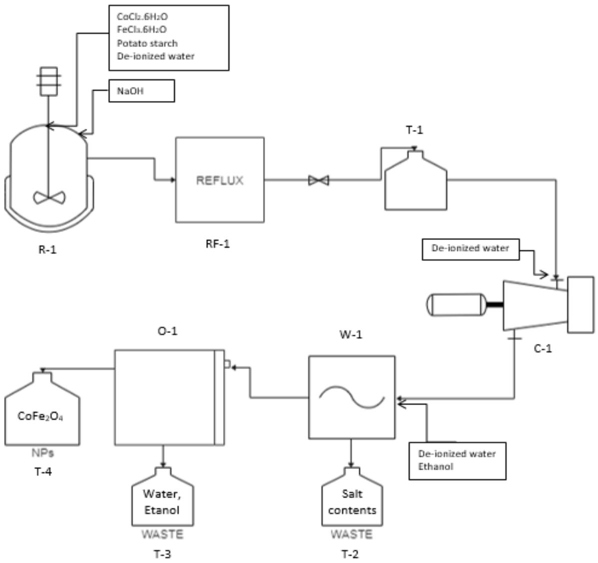


**Figure 2. $CoFe_2O_4$ nanoparticle manufacturing flow chart.**

**Table 1. Symbol and information flow chart for the manufacture of $CoFe_2O_4$ nanoparticles**

| No | Symbol | Information |
|---|---|---|
| 1 | R-1 | Reactor-1 |
| 2 | RF-1 | Reflux-1 |
| 3 | CF-1 | Centrifugation-1 |
| 4 | W-1 | Washer-1 |
| 5 | T-1 | Tank-1 |
| 6 | T-2 | Tank-2 |
| 7 | T-3 | Tank-3 |
| 8 | T-4 | Tank-4 |
| 9 | O-1 | Oven-1 |

## 3.2. Economic Evaluation

### 3.2.1. Ideal Condition

The graph of CNPV/TIC against time is shown in Figure 3 with lifetime (years) on the x-axis and the value of CNPV/TIC on the y-axis. In the first and second years, the curve decreases with the CNPV/TIC value below 0. This means that there is no profit in the first and second years. This is because the project is still in the development stage in the first 2 years. After the second year, the curve increases steadily. The first increase that occurs in the third year is called the Payback Period (PBP) [22]. In this period, profits have been able to cover the capital needed at the development stage in the first two years of the project.

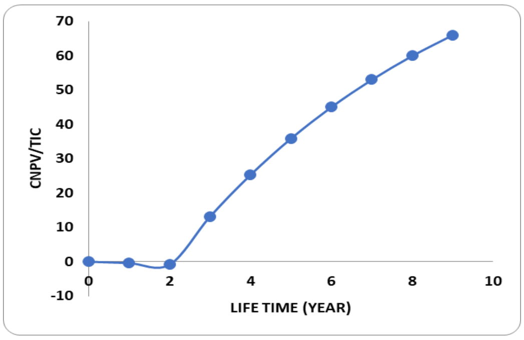


**Figure 3. Graph of CNPV/TIC against lifetime (year) under ideal conditions**

**Table 2. CNPV/TIC values under ideal conditions.**

| CNPV/TIC | Year |
|---|---|
| 0.0000 | 0 |
| -0.4093 | 1 |
| -0.8452 | 2 |
| 13.1254 | 3 |
| 25.2738 | 4 |
| 35.8377 | 5 |
| 45.0236 | 6 |
| 53.0114 | 7 |
| 59.9573 | 8 |
| 65.9972 | 9 |

Table 2 shows the value of CNPV/TIC every year under ideal conditions. In the first and second years, the value of CNPV/TIC was still negative with values of -0.41% and -0.86%, respectively. However, after the second year the CNPV/TIC value was positive and continued to increase until the ninth year. The largest CNPV/TIC value was obtained in the ninth year with a value of 65.99%. Based on the CNPV/TIC value obtained under ideal conditions, this project is considered profitable because it only takes a short time to recover investment costs.

### 3.2.2. Effect of External Condition

In this study, we calculated the CNPV/TIC value with several tax variations in the form of a percent (%) for nine years. Figure 4 shows a graph of CNPV/TIC with tax variations against the year, the y-axis is CNPV/TIC value, which is influenced by tax variations, and the x-axis is a lifetime (years). In this study, several taxes were carried out, namely 10, 25, 50, 75, and 90%.

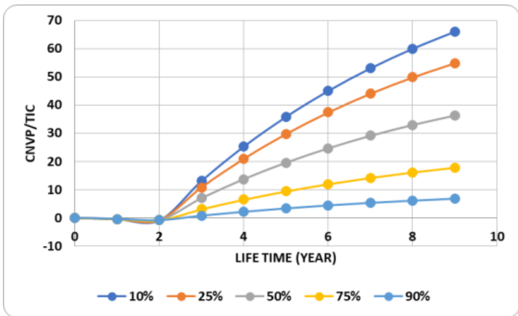


**Figure 4. Graph CNPV/TIC with tax variation against year**

Figure 2 shows that in the first to second years, there was a decrease in CNPV/TIC value in all variations because it was assumed the factory was in the construction stage. Based on CNVP/TIC value, it can be assumed that the profit decreased during the two first years. In all tax variations in this study, PBP is between the second and third years, PBP occurs when CNPV is at zero for the first time [22]. The increase occurred for the first time in the 3rd year to the 9th year. The value of CNPV/TIC in the 9th year for tax variations of 10, 25, 50, 75, and 90% is 65.99; 54.88; 36.35; 17.82; and 6.70 %. The increase of the percentage of taxes in this study caused a reduce in profit. Based on PBP, increasing the percentage of taxes will affect the length of time to return the total initial capital [22]. In this study, the factory can still

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run with the increase of the taxes to 90% marked by a curve that gives a positive value.

### 3.2.3. Change in Sales

Graph of connection between CNVP/TIC with variations in sales shown in Figure 5. Analysis of sales variations is done by increasing and decreasing the selling price by 10 and 20% from the ideal condition (100%). Then, the sales variations in this analysis are 80, 90, 100, 110 and 120%. In Figure 5, the curve shows a decrease from the first year and the second year, this is because the initial income was used for the initial cost of project development. Sales began to take effect in the third year. Based on Figure 5, the Payback Period (PBP) is obtained after the second year of the project. The sales variations effect the project profit. The lowest profit was obtained at the variation value of 70% with CPNV/TIC value of 42.82 % in the ninth year. And the highest profit obtained at variation of 120% with the CPNV/TIC value in the ninth year is up to 81.45 %.

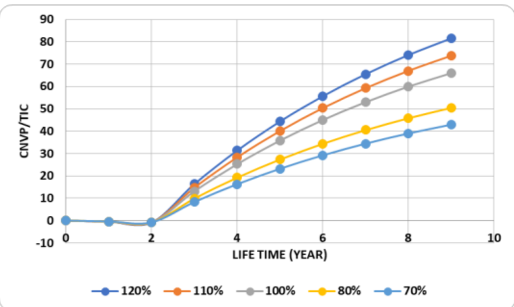


**Figure 5. Graph of CNPV/TIC with sales variation against year**

### 3.2.4. Changes in variable costs (raw materials, utilities, and labor)

A project can be affected by several variable costs, such as raw materials, utilities, and labor. Figure 6 shows a graph of CNPV/TIC with variations in raw material prices against years. The x-axis is a lifetime (years), and the y-axis is CNPV/TIC value, which is influenced by the cost of raw materials. The ideal raw material price is 100%. In this study, variations in the price of raw materials were carried out, namely 125, 110, 100, 90, and 75%.

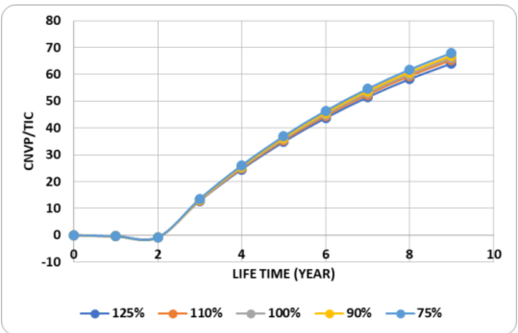


**Figure 6. Graph CNPV/TIC with variations in raw material prices against year**

In the first to second years, there was a decrease in CNPV/TIC in all variations because it was assumed the factory was in the construction stage. In all material price variations in this study, PBP is between the 2nd and 3rd years. There is an increase in the curve from the 3rd year to the 9th year. The value of CNPV/TIC in the 9th year for material price variations of 125, 110, 100, 90 and 75% is 64.05; 65.22; 65.99; 66.77; and 67.94%. The biggest profit was obtained by 67.94% from the variation of 75% raw material prices. The greater the price of raw materials on a project, the lower the profit on the project [21].

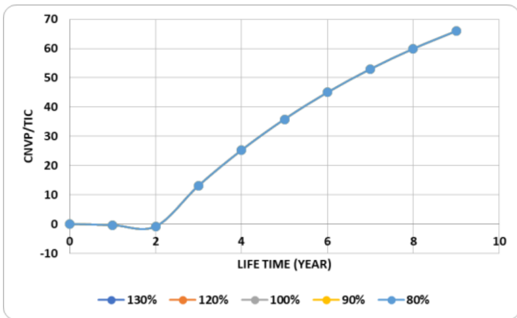


**Figure 7. Graph of CNPV/TIC with utility variation against year**

Figure 7 shows CNVP/TIC graph with utility variations. Analysis of utility variation is done by increasing and decreasing the selling price by 10, 20 dan 30% from the ideal condition (100%). The sales variation used in this analysis is 80, 90, 100, 120 and 130%. The CPVN/TIC value is negative in the project's first two years because the project is still in the development stage. Based on Figure 7 obtained after the second year. The graph shows that the variations of the utilities does not have a significant effect for CNVP/TIC value. The CPNV/TIC value obtained with the utility variations of 80, 90, 100, 120, 130 % are 65.9876; 65.9908; 65.9972; 66.0004; and 66.0036 %.

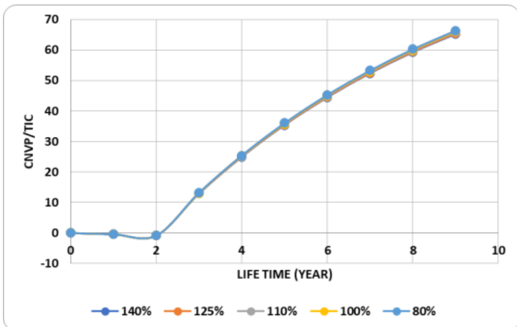


**Figure 8. Graph of CNPV/TIC with utility variation against year**

In addition to variations in the prices of raw materials and utilities, an analysis of the value of CNVP/TIC with variations in salary labor is also carried out. This analysis is carried out by increasing by 10, 25, 40% and reducing by 20% the salary labor. Figure 8 shows a graph of the value of CNVP/TIC with variations in salary labor over time. The variations used in this analysis are 80, 100, 110, 125, and 140%. The 100% is the normal salary labor. The curve looks like it's piling up, indicating that changes in salary labor have no significant effect on the CNVP/TIC value. The curve in the first two years of all variations decreases below 0 because the project is still in development. The curve increases after the second year to the ninth year. The CNVP/TIC values in the ninth year for variations of 80, 100, 110, 125, and 140% were 65.19; 65.49; 65.80; 66.00; and 66.40. After PBP is found in the third year, the project will still earn profit. Even with an increase in salary labor of up to 40%, the CNVP/TIC value is not negative, which means the project does not loss.

## 4. CONCLUSION

Based on economic analysis and engineering perspective, the production of cobalt ferrite nanoparticles can be carried out by coprecipitation method on a large scale. The analysed project can run for a period of nine years and based on the PBP analysis the investment can be recovered the third year. The project is considered as profitable because the initial capital can be covered in a short time, that is two years. The advantage of this method is that it can use biodegradable surfactant (potato starch) and produce superior products with economical selling prices through a simple process. Factors of utility prices and salary labour do not have significant influence on factory income. The increase in the selling price is directly proportional to the income, while the increase in the percentage of taxes and the price of raw materials can reduce profits. However, the project is still profitable in the third year and so on, even the profitability index in the ninth year reached 65.99%.

## 5. AUTHOR CONTRIBUTION

WRA, DYNS, SSD, SRP and ABDN all contributed on the experimentation and the writing. All authors have read the manuscript and agreed on the final version.

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