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Economic Evaluation of the Production of Titanium Dioxide (TiO_2) Nanoparticles using the Simple Aqueous Peroxo Route Method

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Abstract – *This study aims to analyze the economic evaluation on the production of TiO_2 nanoparticles using the simple aqueous peroxo route method. Economic evaluation is carried out using several economic parameters, such as Payback Period (PBP), Break Even Point (BEP), and Cumulative Net Present Value (CNPV). The economic evaluation method is carried out by calculating several factors to see the potential of TiO_2 nanoparticle production, such as an increase in tax prices, sales prices, and the effect of raw material prices. Based on tax evaluation, the greatest income achievement when taxed is 10%. Based on the sales evaluation, the minimum sales price so that the company does not lose is at the 90% point. Based on variations in raw material prices, an increase in raw material prices by up to 50% will not cause a loss. PBP analysis shows the investment in a short period of time, namely in the fourth year and until the 20th year the company's profits continue to increase. In conclusion, the results of the economic evaluation show good prospects. The impact of this research is the evaluation of large-scale economic data on TiO_2 nanoparticles, production prospects with estimated factors that may occur under ideal conditions.*

Keywords: *Economic evaluation, TiO_2, energy and mass balance, aqueous peroxo route method, PBP analysis.*

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I. Introduction

TiO_2 nanoparticles are an example of a nanometer-scale material which is currently the focus of research because TiO_2 is a good material for photocatalysis and the development of various biomaterials [1]. TiO_2 was chosen because it is relatively cheap, easy to reach, and non-toxic, its affinity for light, and its ability to degrade organic compounds and transfer energy [2]. TiO_2 is also an efficient catalyst, can remove various environmental pollutants, and has been shown to be able to clean wastewater and surface water [3], [4], [5]. In addition, TiO_2 nanoparticles are widely used in cosmetics as solar cells, paints, and foodstuffs because of their various properties, such as colloid stability, high reflection index, photo catalytic properties [6], and their size according to wavelength and ultraviolet absorbance. The biocompatibility properties of titania can also be used in bone tissue engineering for the regeneration and healing of damaged bones [7]. Various studies have demonstrated the synthesis method to produce TiO_2 nanoparticles. The synthesis method developed includes chemical methods, such as the simple aqueous peroxo route [8], the hydrolysis and peptisation method [9], the solvothermal method [10], the sol-gel method. [11], and hydrothermal methods [12]. In addition, biosynthetic methods using plants and microorganisms have also been developed, such as using Moringa oleifera leaf extract [13], Trigonella foenum-graecum leaf extract [14], Jatropha curcas L. leaf extract [15], cinnamon powder extract [16], Bixa Orellana seed extract [17], microorganism Staphylococcus aureus [7], Lactobacillus sp. and Saccharomyces [18]. The most effective method used in economic evaluation is the simple aqueous peroxo route method because the method is simple, low cost, environmentally friendly, and the results are pure (no impurities). The synthesis of TiO_2 nanoparticles using the simple aqueous peroxo route method has been proven by their research [8]. An economic evaluation analysis for the synthesis of TiO_2 nanoparticles has not been carried out on an industrial scale, so to provide that data, we will present economic evaluation data in this report. The results of these studies encourage further research on the synthesis of TiO_2 nanoparticles.

The purpose of this study was to analyze the economic evaluation data for the production of TiO_2 nanoparticles using the simple aqueous peroxo route method. An economic evaluation of the chemical industry is a form of a quantitative assessment of what is expected and desired by the community to carry out the process of investing in a project. This evaluation analysis uses several parameters, such as calculating the Payback Period (PBP) to predict the length of time it will take for an investment to be able to return the total initial outlay; Cumulative Net Present Value (CNPV) is calculated to predict project condition as a function of year of production or CNPV can be obtained as the sum of cumulative financial flows each year; calculate the Break-Even Point (BEP) which states the minimum capacity at which the project does not benefit. This BEP is an important factor to avoid project losses [19]. In this study, we performed a variation of several factors to see its effect on the economic evaluation, such as increases in tax prices, decreases and increases in product prices, and the effect of raw material prices. All calculations are carried out under ideal conditions for 20 years of production. The evaluation results obtained affect the CNPV/TIC curve (%) against Life Time (years) when the variation is carried out. The impact of this research is to find out the economic evaluation of TiO_2 nanoparticle production on a large scale, production prospects by predicting the worst possible factors for ideal conditions.

II. Method

II.1. Theoretical Synthesis of TiO_2 Nanoparticles

TiO_2 nanoparticles can be synthesized by simple aqueous peroxo route method. Synthesis using $TiOSO_4.5H_2O$ was dissolved in water at room temperature and then 30% H_2O_2 was added to the solution. The resulting yellow solution shows the formation of a peroxo complex from the Titanium solution. This peroxo-titanium solution produces a yellow titanium oxy-hydroxide gel after keeping at room temperature for several hours. Then the gel is separated by centrifugation at a rotation speed of 10,000 rpm, washed with double distilled water, and dried overnight in the oven. The dried titanium-peroxo complex was annealed at a temperature of 200 to 550^oC for 1 hour. All processes of forming TiO_2 nanoparticles are shown by the flowchart in Figure 1.

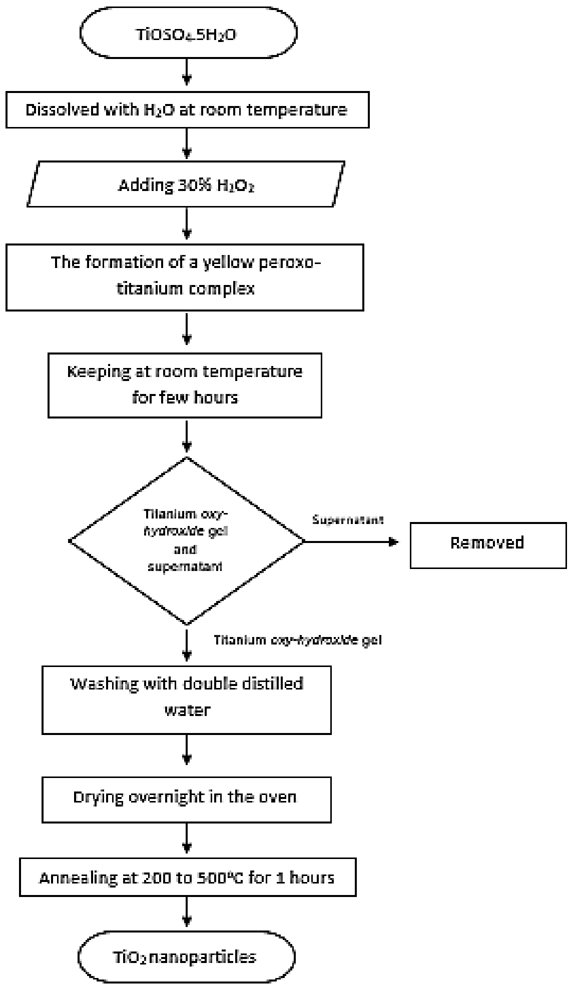

Figure 1. Flowchart diagram of TiO_2 synthesis nanoparticles

II.2. Energy and Mass Balance

Figure 2 shows the synthesis process of TiO_2 using $TiOSO_4.5H_2O$ and 30% H_2O_2. To produce 190 kg of TiO_2 nanoparticles, 400 kg of $TiOSO_4.5H_2O$ and 85 kg 30% H_2O_2 are required for the reaction. The formation of TiO_2 is in accordance with the chemical reaction equation below:

$$TiOSO_4 + H_2O_2 + 2H_2O \rightarrow H_4TiO_5 + H_2SO_4 \quad (1)$$
$$H_4TiO_5 + H_2SO_4 \rightarrow TiO(OH)_2 + H_2O_2 + H_2SO_4 \quad (2)$$
$$TiO(OH)_2 \rightarrow TiO_2 + H_2O \quad (3)$$

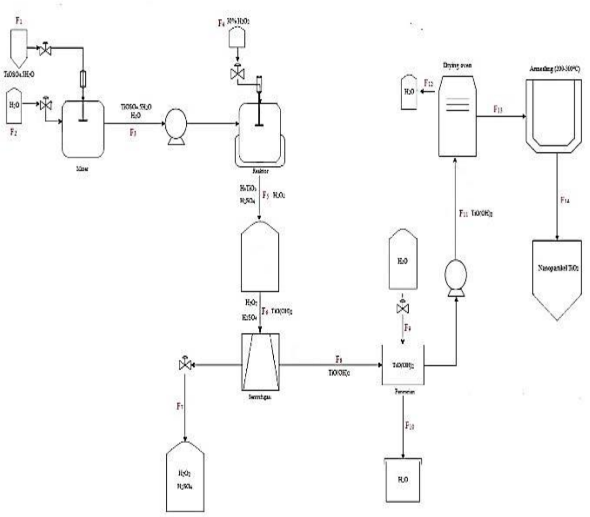

Figure 2. Process flow diagram of the synthesis of TiO_2 nanoparticles

II.3. Economic Evaluation

Economic evaluation that could compare the costs and consequences of alternatives and ensure an efficient choice that could maximize benefit while using minimal cost [20], equipment specifications including prices can be obtained from online shopping sites. Then, all data is calculated based on literature with simple mathematical calculations to obtain various economic evaluation parameters such as GPM, PBP, BEP and CNPV from various variable costs [21]. To get the results of the calculation of this study using several formulas such as:

1) GPM is calculated by selling substitutes and the cost of raw materials
2) PBP is the length of time required to return investment costs. The easiest way to get PBP is obtained from the CNPV curve. The PBP value is determined when the CNPV value first reaches zero.
3) CNPV is the value obtained from the net present value (NPV) at a certain time. NPV is calculated by adding a discount factor to the cash flow multiplication calculation.
4) BEP is a value that describes the minimum value of production to gain profit or loss. Calculated by dividing fixed costs and profits. After that, the project feasibility study was tested under ideal conditions, the effect of raw materials, and various variable costs.

Some of the assumptions in this study include:

- All chemical compositions in the reaction, such as titanium oxisulfate pentahydrate, hydrogen peroxide, and water are used for the production of TiO_2 nanoparticles.
- Titanium oxisulfate pentahydrate has been dissolved in water and the sodium hydroxide is reacted. Both are assumed to have finished reacting to give titanium oxide of 95% purity.
- The conversion rate for forming titanium oxide is 100%.
- Loses every 5% of the transfer process.
- The total investment cost (TIC) is calculated based on the *Lang Factor*.
- Land purchased. Thus, land costs are added at the beginning of the factory construction year and recovered at the end of the project.
- One cycle of the TiO_2 nanoparticle manufacturing process takes 12 hours.
- Shipping costs are borne by the buyer.
- TiO_2 nanoparticles are sold for IDR 120,000.00/ pack of 500 grams (8.4 USD).
- The one year project lasts 300 days.
- To simplify utility, utility units can be described and converted into electrical units, such as kWh. The unit of electricity is converted into cost by multiplying the cost of electricity. Assuming the utility cost is IDR 1,380/kWh.
- Total salary per worker is assumed to have a fixed value of IDR 2,850,000.00/ month.
- The discount rate is 15% per year.
- Income tax of 10% annually.
- The duration of project operation is 20 years.

III. Result and Discussion

III.1. CNPV in Ideal Conditions

Figure 3 shows the relationship between the x and y-axis where the x-axis is the year of production and the y-axis is CNPV/TIC. In the first and second years, there was a decrease in the graph, because at the beginning of production there were costs incurred for project needs such as purchasing tools, materials, and other production support facilities. The payback period (PBP) occurs in the fourth year and has increased. The payback period (PBP) is a period of time used to assess the capital in a business or to see how long it takes for a new business to return investment [22]. The profit earned every year increases until the 20th year. This shows that the production of TiO_2 nanoparticles can be said to be a profitable project.

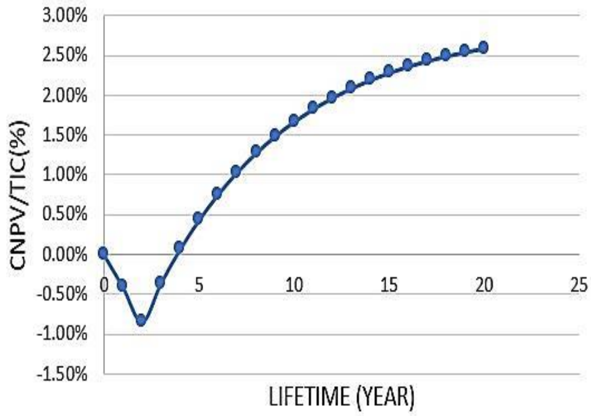

Figure 3. CNPV in ideal conditions

III.2. Variations in Tax Increases

Figure 4 shows the effect of a tax increase on CNPV/TIC. The x-axis is the year of production while the y-axis is the CNPV/TIC value which is affected by changes in the tax prices. Variations of tax prices are starting from 10%, 15%, 20%, 25%, 30%, 35%, and 40%.

The PBP (Payback Period) value for each variation of tax increases is different. The greater the value of tax, the year of return is longer. With a production time of 20 years, the company with a 10% tax obligation has the largest profit. This shows that the greater the tax value that must be paid. The company received more/less profit [23].

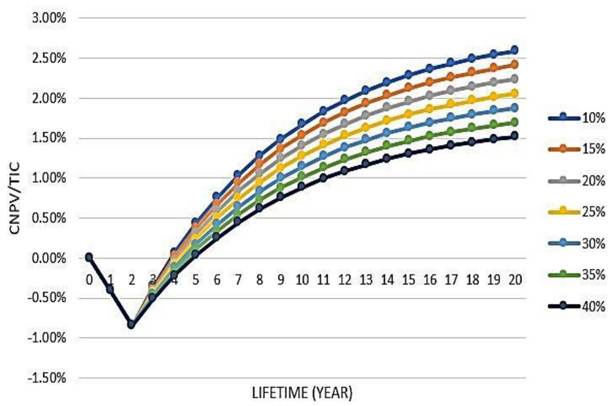

Figure 4. Variation of the tax increase to the value of CNPV/TIC

III.3. Variations in Selling Prices

Figure 5 shows the CNPV chart with variations of selling prices. The x-axis is the life time (year) and the y-axis is CNPV/TIC. The variations in the selling price are the range if they are increased or decreased, namely 130%, 120%, 110%, 100%, 90%, 80%, and 70%.

The results of the Payback Period (PBP) are shown in Figure 5. The initial conditions (from 0 to 2 years of the project) of CNPV at variations of selling price are the same because the project is still under construction. The effect of selling price on CNPV can be obtained after 2 years.

Profits continue to increase after reaching the PBP point until the 20th year. The profits obtained each year increases with the increase in selling price from ideal conditions. However, the profits obtained each year decreases with the decrease in selling price and losses when the selling price is decreased by 20 and 30% from ideal conditions. Thus, the minimum selling price for obtaining BEP (the point at which both the profit and loss in the project) is 90%. Changes in selling prices less than 90% lead to project failure [24].

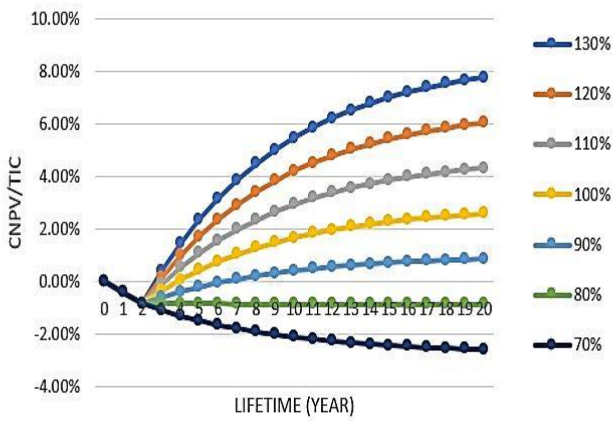

Figure 5. Variation in selling prices against CNPV/TIC value

III.4. Variations of Increase in Raw Material Prices

Instability in raw material prices can affect a project. An analysis is needed to prevent failure if the price of raw materials increases.

The analysis was carried out on variations in the increase in raw material prices by 10%. The variations are 0% (no increase), 10%, 20%, 30%, 40%, and 50%. This variation is carried out with the assumption that the production capacity in each variation is the same as the production capacity in ideal conditions, but with different raw material prices. This evaluation is carried out to analyze the effect of changes in raw material prices on the profitability of TiO_2 nanoparticles production. If there is an increase in raw material prices, the CNPV/TIC chart changes as shown in Figure 6. From this graph, it can be concluded that the greater the price of the raw materials used, the slower the rate of increase in CNPV/TIC. This means that by increasing the price of raw materials, the rate of income and profit decreases. This occurs because raw materials are closely related to overall production costs. With the same number of sales, an increase in production costs will reduce profits. With the remaining production and sales capacity, an increase in production costs will reduce profits. The increase in raw material prices has a negative impact on this project [25]. The results of the PBP analysis show that capital will return to variations in the increase in raw material prices by 10%, 20%, 30%, 40%, and 50% respectively in years 5, 5, 6, 7 and 9. Profits will continue to increase after PBP reaches its 20th year. The CNPV/TIC variations in the 20th year were 2.59%, 2.17%, 1.75%, 1.32%, 0.90%, and 0.48%. So, even if there is a condition, the price of materials will still increase by up to 50%, the project can run.

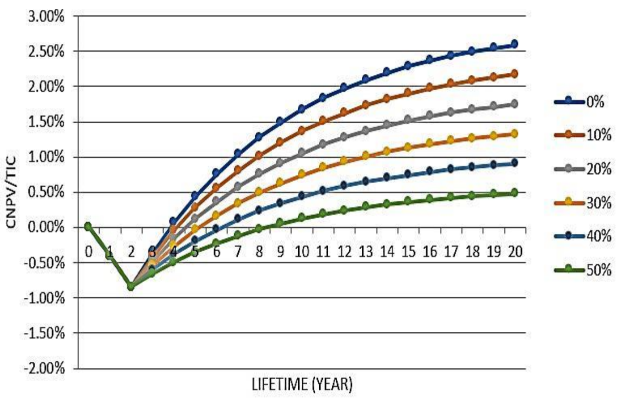

Figure 6. Variations in raw material prices for CNPV/TIC

IV. Conclusion

We conducted an economic evaluation of the synthesis of TiO_2 nanoparticles by the simple aqueous peroxo route method. The results of the economic evaluation show good prospects. Based on the tax increase evaluation, the company gets the biggest profit when the tax liability is 10%. From the sales evaluation, the minimum sales price so that the company does not lose is at the 90% point. Based on variations in raw material prices, an increase in raw material prices of up to 50% will not cause losses. PBP analysis shows that investment returns in a short time, namely in the fourth year and until the 20th year the company's profits continue to increase. The ups and downs of company profits are influenced by several factors including tax increases, increases in raw material prices and sales prices. The results of our research are expected to provide an economic evaluation for the development of TiO_2 nanoparticle synthesis using a simple aqueous peroxo route method, a production prospect by estimating the worst possible factors under ideal conditions.

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