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Techno-Economic Evaluation of Gold Nanoparticles Using Banana Peel (*Musa Paradisiaca*)

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ABSTRACTS

Biosynthesis of gold nanoparticles using banana peels is considered more economical and has been proven to produce gold nanoparticles that have various applications in the medical field. Therefore, the production of gold nanoparticles needs to be developed on an industrial scale. This paper aims to determine the feasibility of a gold nanoparticle biosynthesis project using banana peels on an industrial scale. The economic evaluation method uses an analysis of several economic evaluation parameters such as GPM (Gross Profit Margin), BEP (Break-Even Point), CNPV (Cumulative Net Present Value), PBP (Payback Period), and PI (Profitability Index). The results show that on an industrial scale, it is assumed that the amount of AuNP production in one year is 120 L. The total price required for production in one year is 3,125,204.84 USD with annual sales of 3,240,000 USD so that the total price is 114,795.16 USD per year. Under ideal conditions, the PBP analysis shows that the project will have a profit in the 3rd year, and the PI analysis shows that the initial capital costs can be covered since the 4th year. The results of the analysis in some non-ideal conditions indicate that project losses will occur. Based on the economic evaluation, it can be concluded that the production of industrial-scale gold nanoparticles by biosynthetic methods using banana peels can be carried out with anticipation of losses that will occur due to changes in some ideal conditions.

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1. INTRODUCTION

Gold nanoparticles are synthesized gold materials with dimensions at the nanometer scale (1-100 nm) (Dreaden *et al.*, 2012). Gold nanoparticles have different properties from materials in their bulk form, including physical, chemical, electronic, electrical, mechanical, magnetic, thermal, dielectric, optical, and biological properties (Deokar & Ingale, 2016). Even gold nanoparticles have excellent biomedical properties such as low toxicity and excellent biocompatibility with human systems (Suganya *et al.*, 2016). Therefore, gold nanoparticles have various medical applications (Zhang, 2015) such as cancer treatment (Vijayakumar *et al.*, 2011), photothermal therapy (Silva *et al.*, 2016), drug delivery (Daraee *et al.*, 2016), cholesterol reduction (Raj *et al.*, 2011), anti-tumor function (de Araújo Júnior *et al.*, 2017), etc. Based on Sungaya *et al.*, (2016), Nanoparticles with anti-tumor functions have been successfully synthesized by biosynthetic methods using various types of proteins and polysaccharides derived from plant parts, one of which is banana peel (Suganya *et al.*, 2016). The number of banana peels is abundant in Indonesia as a residue from the banana-based food industry, so that banana peels can be obtained easily and cheaply (Kusrini *et al.*, 2018). Therefore, the biosynthesis of gold nanoparticles using banana peels is often considered more economical.

The use of banana peels in the biosynthesis of gold nanoparticles has advantages, that is: 1) Banana peel extract has several functions as a reducing agent, capping agent, and stabilizer (Deokar & Ingale, 2016). 2) The synthesis process runs faster than the biosynthetic process using other plants (Deokar & Ingale, 2016). 3) The result of the synthesis is gold nanoparticles which are stable for months (Suganya *et al.*, 2016). Biosynthesis of gold nanoparticles using banana peels has been carried out on a laboratory scale by Ashok *et al.*, (2010) with the general synthesis process shown in **Figure 1**. However, the synthesis results of gold nanoparticles on a laboratory scale are much less than the quantity required for large-scale production because most of them are only about 1 g per batch (Tsuzuki, 2009). Therefore, this biosynthesis method needs to be developed on an industrial scale that is economically feasible.

The purpose of this study was to determine the feasibility of producing gold nanoparticles using banana peels, based on economic aspects. This scientific article was created because there are no articles that discuss the economic evaluation of biosynthetic methods using banana peels on an industrial scale. The research uses methods in the form of determining economic parameters under ideal conditions as well as on variations in sales prices, raw material prices, utility prices, employee salaries, and taxes.

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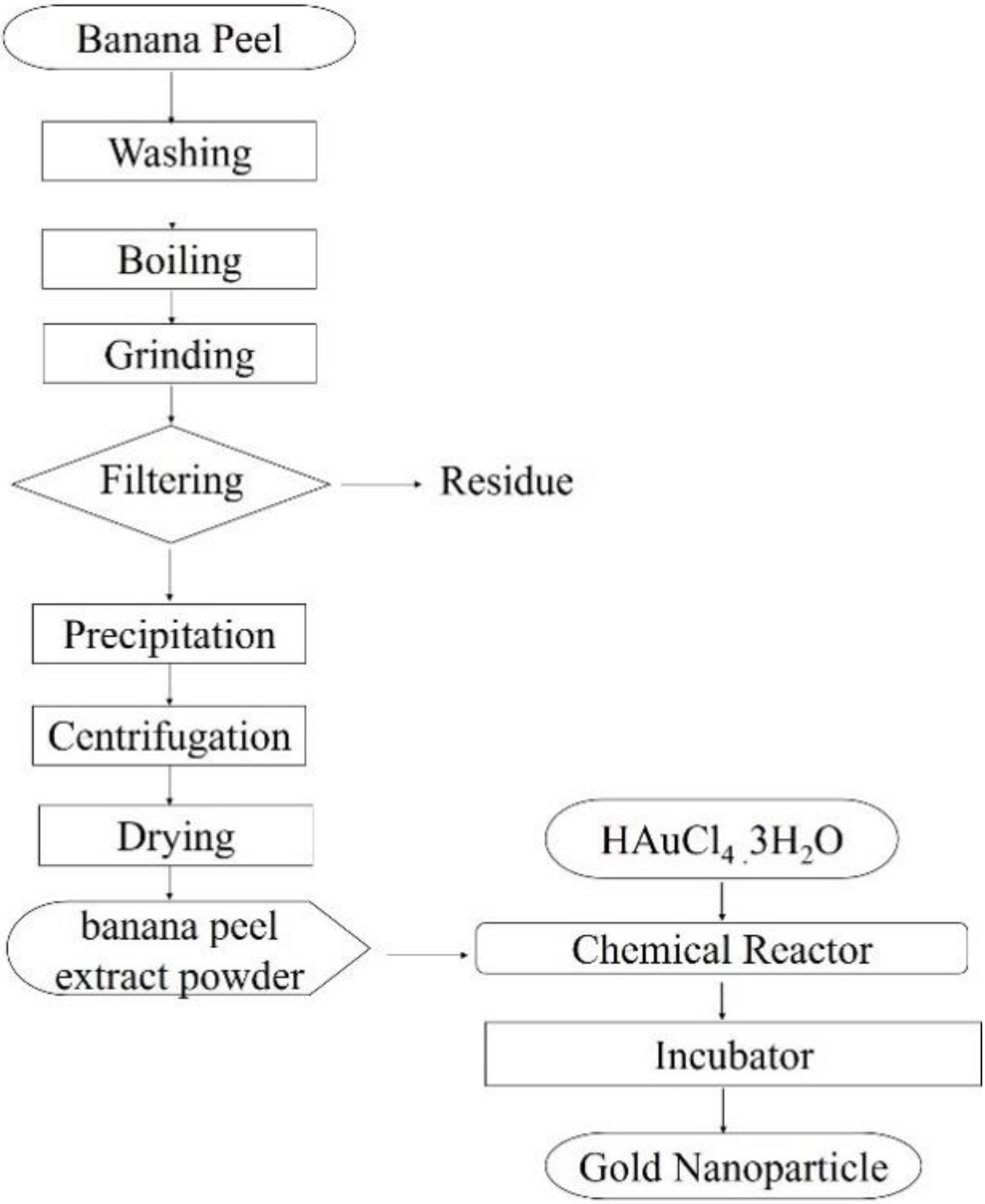

Figure 1. Biosynthesis process of gold nanoparticles using banana peels.

2. METHOD

This research uses a method based on an analysis of the prices of materials, supplies, and special equipment available in online stores. All price data is calculated using Microsoft Excel software to determine the value of several economic evaluation parameters. The economic evaluation parameters used are based on the literature (Maulana & Nandiyanto, 2019; Zahra *et al*., 2020) including: (1) GPM (Gross Profit Margin) is a parameter to predict the level of profitability of a project. GPM is calculated by subtracting the cost of selling the product from the cost of raw materials. (2) BEP (Break-Even Point) is a parameter to determine the minimum number of products that must be sold at a certain price to cover the total cost of production. BEP is calculated by dividing fixed costs against the difference in selling prices with variable costs. (3) CNPV (Cumulative Net Present Value) is a parameter to predict project conditions as a function of the year of production. CNPV is calculated by adding the NPV from the start of the project establishment. NPV is a value that expresses the expenses and income of a business. (4) PBP (Payback Period) is a parameter for estimating possible profit years. PBP is calculated when CNPV is at zero for the first time, it can be seen in the graph between CNPV/TIC (y-axis) and year (x-axis). PBP is indicated by a point parallel to the x-axis. (5) PI (Profitability Index) is a parameter to identify the impact of project costs. PI is obtained by dividing the CNPV by the total investment cost (TIC). If the PI is less than one, then the project can be classified as an unprofitable project and if the PI is more than one, the project can be classified as a profitable project (Zahra *et al*., 2020).

To calculate the values of these parameters, assumptions are needed to calculate the economic evaluation. In this study, several assumptions were used, including: (1) 1 USD is equivalent to 15,000 IDR, (2) the price of 1 gram of $HAuCl_4.3H_2O$ with a purity of 99.9% is 1,000,000 IDR, (3) the salary for 20 workers is 30,000 USD annually, (4) the utility fee to be paid annually is 655.78 USD, (5) 10% income tax, (6) 15% discount on average, (7) AuNP selling price is 70 USD in 1 mL, (7) the synthesis is carried out 20x a day, (8) the project operates for 20 years.

3. RESULTS AND DISCUSSION

3.1. Engineering Perspective

The basic principle of gold nanoparticle biosynthesis is to utilize natural bioactive molecules that act as reducing agents, stabilizers, and capping agents in the gold nanoparticle synthesis process (Qiao & Qi, 2021). Raw materials used for the synthesis of gold nanoparticles are chloroauric acid trihydrate ($HAuCl_4.3H_2O$) and banana peels. Chloroauric acid trihydrate is a precursor of Au particles in the form of Au^{3+} which are reduced to Au^0 by natural bioactive molecules in banana peels. Banana peel contains pectin which is soluble in hot water, cellulose, hemicellulose, lignin, protein, and gum (Emaga *et al*., 2007; Chanakya *et al*., 2009). Banana peel components that play a role in the reduction process are proteins, proteins reduce metal ions by oxidizing aldehydes to carboxylic acids (Deokar & Ingale, 2016). The banana peel component that acts as a stabilizer is pectin because it has the function of a stabilizer (Emaga *et al*., 2008). The banana peel component that acts as a capping agent is another type of carbohydrate (Kumar *et al*., 2011).

Figure 2 shows the process of synthesizing gold nanoparticles on an industrial scale. The synthesis process was adopted from Ashok *et al*., (2010). Based on the numbers in the figure, there are 9 steps of synthesis. First, the banana peels (Musa paradisiaca) were collected in the tank and washed thoroughly (step 1). Furthermore, banana peel was cleaned and boiled in distilled water at 90 ^oC for 30 minutes (step 2). 1 Kg of boiled banana peel was crushed by a grinding machine in 1 L of distilled water (step 3). The resulting extract was filtered in a sieve machine (step 4). So the filtrate was precipitated using 1 L cold acetone (Step 5). The resulting precipitate was collected by centrifugation at 1000 rpm for 5 minutes (step 6), centrifugation was carried out because it could collect particles in centrifuge only for several minutes (Nadiyanto & Ragadhita, 2019). Furthermore, the centrifuged material was dried in an oven (step 7) to produce banana peel extract in powder form. A total of 100 mg of banana peel extract powder was reacted with 200 ml of chloroauric acid trihydrate solution (100 mM) in the reactor (step 8). The time required for the formation of Au^0 is 38 minutes (Deokar & Ingale, 2016). The mixture was incubated in a water bath at 80 ^oC for 3 minutes (step 9).

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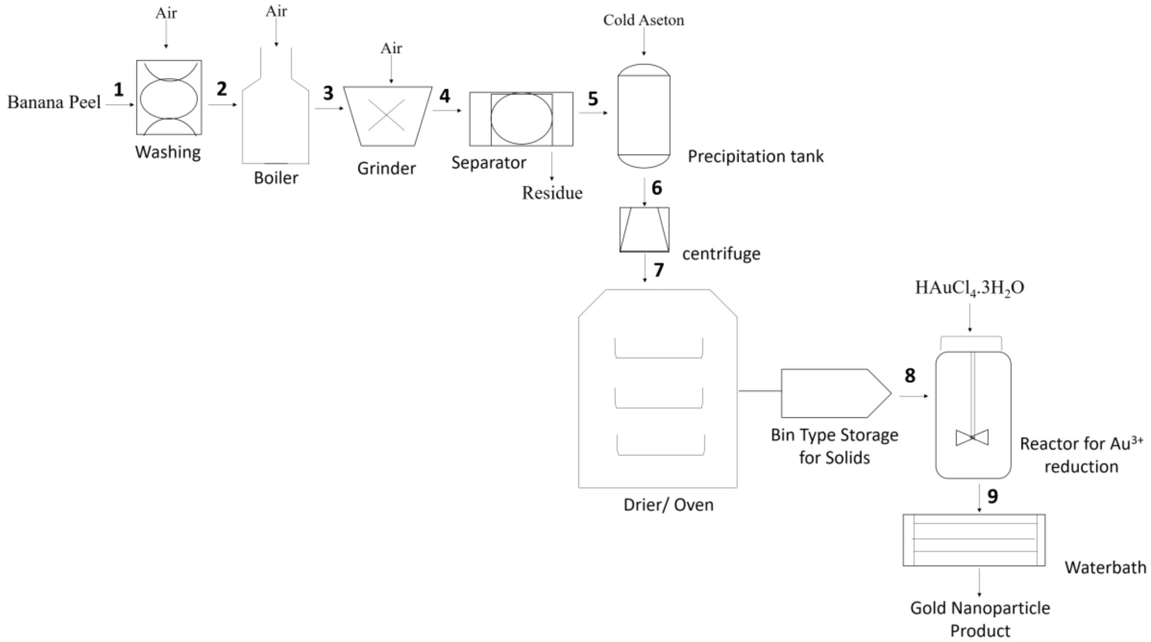

Figure 2. Process Flow Diagram of AuNP Biosynthesis.

One laboratory-scale cycle produces 20 mL AuNP from 0.7 grams of $HAuCl_4.3H_2O$ and 10 mg powder banana peel extract. This number has been multiplied to reach an industrial scale. Thus, on an industrial scale, it is assumed to be the amount of production in one year as much as 120 L. Production requires $HAuCl_4.3H_2O$ as much as 42 tons and powder banana peel extract as much as 30 grams. The total cost required in one year for production is 3,125,204.84 USD with annual sales of 3,240,000.00 USD, resulting in a total of 114,795.16 USD each year. These advantages will be further reviewed in the economic evaluation and the value of the project will be demonstrated over a 20 years timeframe.

3.2. Economic Evaluation

3.2.1. Ideal condition

Figure 3 shows a graph of the relationship between lifetime (year) on the x-axis and the value of CNPV/TIC on the y-axis. The CNPV/TIC value shows the Profitability Index (PI). If the PI value of a project is less than 1, then the project can be classified as unprofitable and the project can be classified as profitable if the PI value is more than 1 (Zahra *et al*., 2020). In the figure, it can be seen that the CNPV/TIC (%) is less than 1 until the 4th year. This is due to the initial cost of purchasing nanoparticle production equipment.

The lowest CNVP/TIC value occurred in the 2nd year of -0.845204551%. However, from the 4th year to the 9th year, this project can be said to be profitable because the CNPV/TIC value has increased to more than 1. In the 3rd year, there is an increase in income, which is the Payback Period (PBP). Based on **Table 1**, CNVP/TIC is negative from the 1st year to the 2nd year. Then the CNVP value increased to positive in the 3rd year with a value of 0.049162924% and continued to increase until the 9th year with a value of 3.433881157%. Therefore, the production of gold nanoparticles (AuNP) using biosynthetic methods can be said to be profitable because it takes 4 years to restore the initial capital costs.

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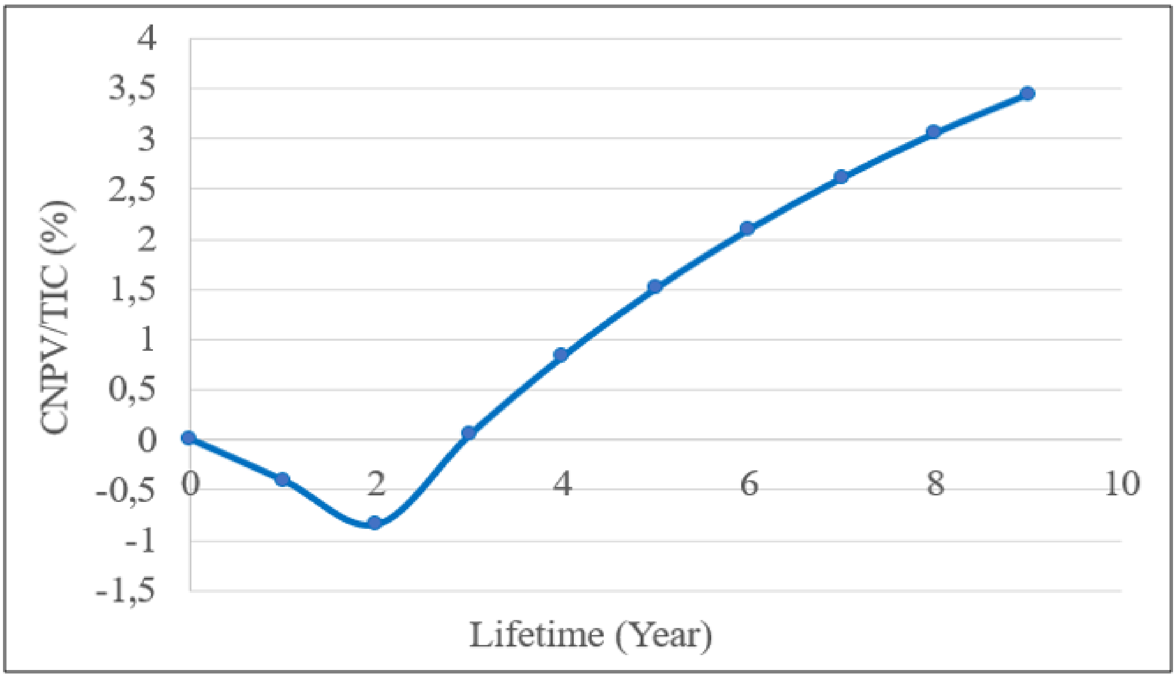

Figure 3. CNPV/TIC graph for lifetime year under ideal conditions.

Table 1. Annual CNPV values in ideal conditions.

CNPV/TIC (%)	Year
0	0
-0.409351928	1
-0.845204551	2
0.049162924	3
0.826873773	4
1.503144076	5
2.091205208	6
2.602562715	7
3.047221417	8
3.433881157	9

3.2.2. The effect of external conditions

One of the external factors that affect the success of a project is the income tax provided by the country to finance various public expenditures. **Figure 4** shows a graph of the relationship between the value of CNPV/TIC for 9 years with tax variations, where the y-axis is CNPV/TIC (%) and the x-axis is a lifetime (year). An increased tax every year will affect the CNPV value and if the tax increases, it will result in a low profit. This is related to PBP because the higher the income tax, the PBP will be much greater than in ideal conditions.

When the income tax is 10%, the income successfully returns the initial capital in the 3rd year; 25% tax in 3,1 year; 50% tax in 3,5 years; 75% tax on 3,8 year and 100% tax on 4th year. The profit of the project will continue to increase when it reaches the PBP point until the 9th year. The CNPV/TIC values in year 9 for 10, 25, 50, 75 and 100% were 3.43; 3.29; 3.05; 2.80 and 2.56% respectively.

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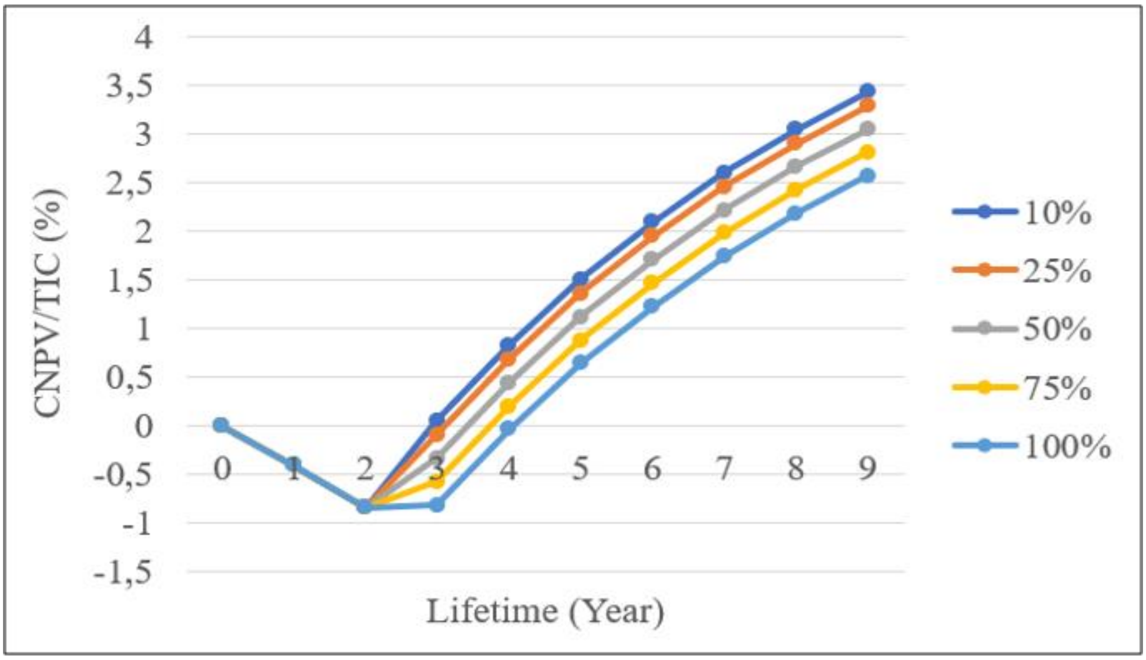

Figure 4. Graph of CNPV/TIC for tax variations.

3.2.3. Change in sales

Figure 5 shows a graph of the relationship between CNPV/TIC with variations in sales. The y-axis is CNPV/TIC (%) and the x-axis is a lifetime (year). The analysis was carried out by increasing and decreasing the sales by 10% and 20%, which is the ideal sales is 100%. When the sales are decreasing by 10% and 20%, the percentage of sales is 90% and 80%, respectively. When the sales are increasing by 10% and 20%, the percentage of sales becomes 110% and 120%, respectively. The CNPV/TIC value in the 1st and 2nd years with variations in sales is the same because the project is still developed. The effect of the sales can be seen after the project has been running for 2 years. The higher sales, the more profit you will get. However, if there are conditions that cause the sales of the product to decrease, the project's profit will decrease.

Based on the PBP analysis, the return on investment will occur when the sales variation is 120, 110, and 100% in the 2nd to 3rd year, while the sales price variation of 90 and 80% will not reach PBP. PBP on sales variations of 90 and 80% will not be achieved until 9 year. However, the difference in profit generated each year will decrease along with a decrease in sales and the company will experience a loss when sales are less than 10% of ideal conditions. On the other hand, the profit generated every year will increase as sales increase from ideal conditions. The value of CNPV/TIC in the 9th year for each variation of 120, 110, 100, 90 and 80% is 26.48; 14.95; 3.43; -8.08 and -19.61%.

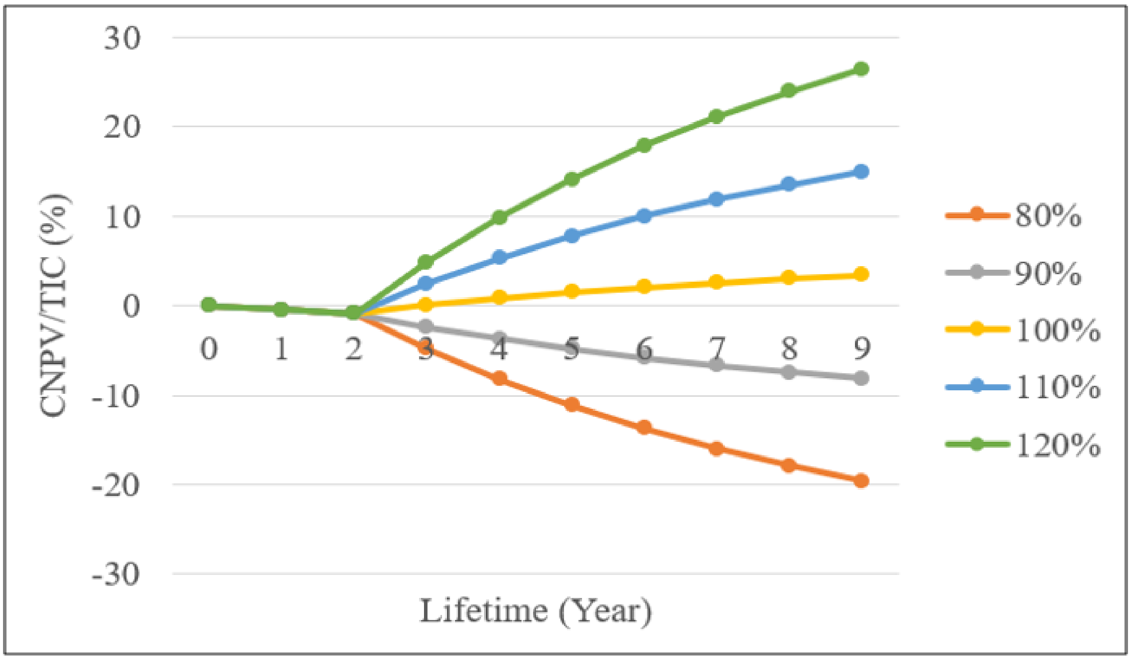

Figure 5. Graph of CNPV for sales variations.

3.2.4. Change in variable cost (raw material, utility, labor salary)

Factors such as raw materials, utilities, and worker wages can affect the success of a project. **Figure 6** shows a graph of the relationship between CNPV/TIC with variations in raw material prices. The y-axis is CNPV/TIC (%) and the x-axis is a lifetime (year). The ideal raw material price is 100%. Analysis of variation in raw materials is carried out by increasing and decreasing the percentage of prices of these raw materials by 10% and 20% from ideal conditions. The variations of the raw materials used in this paper are 80, 90, 100, 110, and 120%. The value of CNPV/TIC is constant in the initial conditions of the project (0-2 years) because the project is still developed. Variations in raw materials begin to affect the value of CNPV/TIC after the 2nd year of the project. A decrease in raw materials will increase profits and an increase in raw material prices will reduce company profits.

The value of CNPV/TIC in the 9th year for variations of 80, 90, 100, 110 and 120% raw materials are 25.08; 14.25; 3.43; -7.39 and -18.21%. PBP values obtained from each variation of raw materials 80, 90, and 100% are 2.2; 2.3; and 3 years. The payback period (2.2) with the largest profit (CNPV/TIC = 25.08%) can be obtained from the variation of 80% raw material prices.

Figure 7 shows a graph of the relationship between CNPV/TIC and utility price variations. The y-axis is CNPV/TIC (%) and the x-axis is a lifetime (year). The analysis is done by increasing and decreasing the percentage of utility prices by 10 and 20% from the ideal price. The ideal value of utility is 100%. The utility price variations used are 80, 90, 100, 110, and 120%.

The CNPV/TIC value from year 0 to year 2 is constant because the project is still developed. The effect of utility on the value of CNPV/TIC can be seen after 2 years. The results show that there is no significant effect on the variation of utility prices. The project can still go on and make a profit. The value of CNPV/TIC from year 9 for utility variations of 80, 90, 100, 110 and 120% is 3.44; 3.43; 3.43; 3.43 and 3.42%. PBP results from utility variations of 80, 90, 100, 110 and 120% can be obtained in the 3rd year. The payback period (3rd year) with the largest profit (CNPV/TIC = 3.43%) can be obtained from the 80% utility price variation.

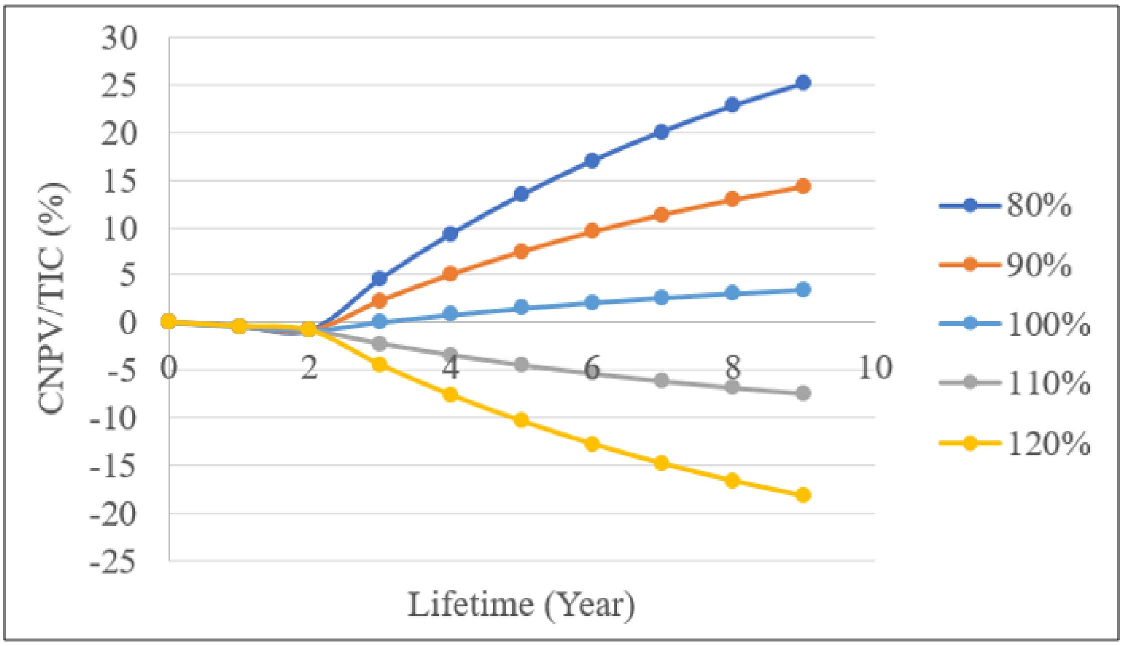

Figure 6. Graph of CNPV/TIC for raw material variations.

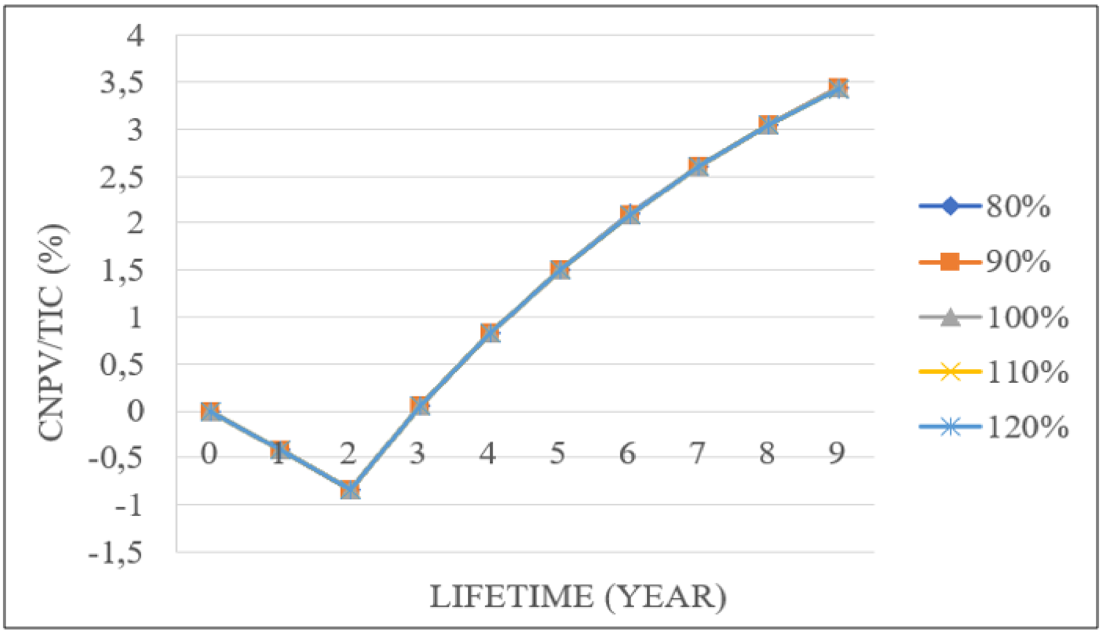

Figure 7. Graph of CNPV/TIC for utility variations.

Figure 8 shows a graph of the relationship between CNPV/TIC and variations in labor salary. The y-axis is CNPV/TIC (%) and the x-axis is a lifetime (year). The analysis is carried out by increasing and decreasing the percentage of labor salary by 10% and 20% from ideal conditions. The ideal labor salary on the chart is 100%. Variations in the labor salary used are 80, 90, 100, 110, and 120%. From year 0 to year 2, the value of CNVP/TIC is constant because the project is still being developed. The effect of variations on labor salary will be seen after the 2nd year. With the greater salary of labor, the profit will decrease and vice versa. The value of CNPV/TIC in the 9th year for worker salary variations of 80, 90, 100, 110, 120% is 3.81; 3.62; 3.43; 3.24 and 3.05%. The value of PBP for each labor salary variation of 80, 90, 100, 110, and 120% is achieved in the 3rd year. The payback period (3rd year) with the largest profit (CNPV/TIC = 3.81%) can be obtained from the 80% variation in worker wages.

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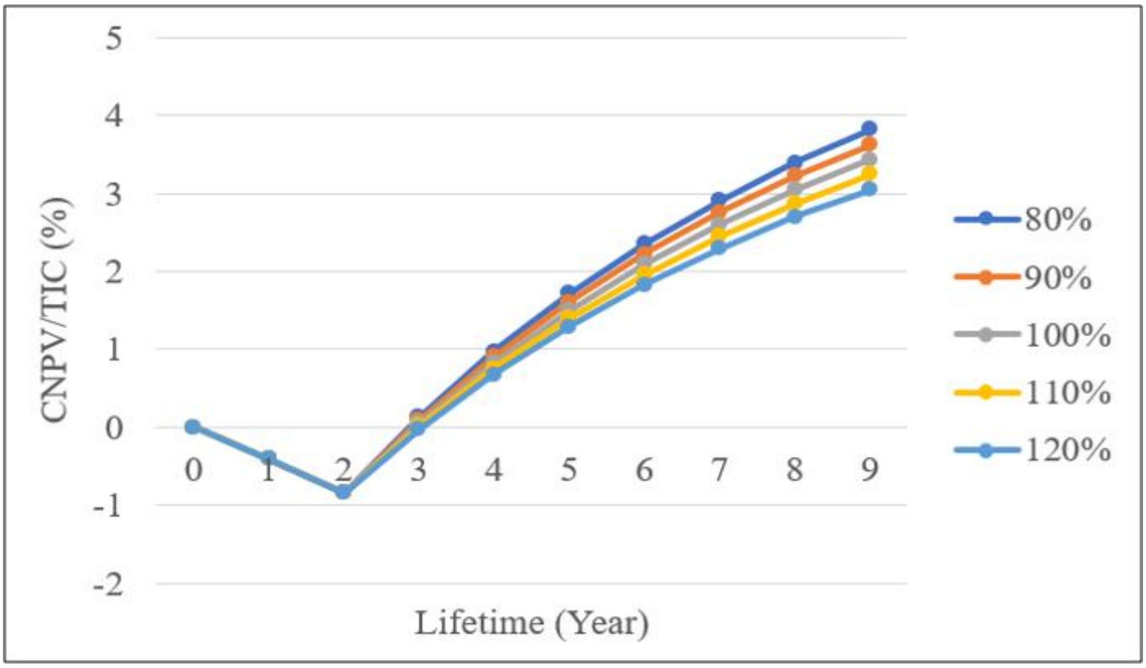

Figure 8. Graph of CNPV/TIC for labor salary variations.

4. CONCLUSION

Based on the above analysis, the production of gold nanoparticles by biosynthetic methods using banana peels is promising. This project can compete with PBP capital market standards due to the short investment return. The biosynthetic method using banana peels was chosen because banana peels are easy to obtain and inexpensive, the process is simple, and produces stable nanoparticles. According to the results of the economic evaluation analysis, it can be concluded that this project is can be carried out with anticipation of losses that will occur due to changes in selling prices and raw material prices.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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