Sensitivity analysis of nitrocellulose production from palm oil empty fruit bunches

Jabosar Ronggur Hamonangan Panjaitan¹* and Misri Gozan²

¹ Energy System Engineering Program, Institut Teknologi Sumatera, Lampung 35365, Indonesia
² Chemical Engineering Department, Universitas Indonesia, Depok 16424, Indonesia.
* Email: jabosar.panjaitan@tse.itera.ac.id

Abstract. Nitrocellulose as a propellant can be obtained using a nitration reaction of Palm Oil Empty Fruit Bunches (POEFBs). In this study, we examined the sensitivity analysis of nitrocellulose production from POEFBs based on POEFBs price, electricity price, nitrocellulose price, and production capacity. The results showed that economic evaluations without sensitivity analysis deviations produced NPV, IRR, PBP and ROI in the values of US$ 1,437,097, 18.36%, 4.51 years and 16.31%. The most influential variable in the sensitivity analysis of nitrocellulose production was nitrocellulose price and production capacity. On the other side, POEFBs price and electricity price did not significantly affect the sensitivity analysis of nitrocellulose production.

1. Introduction
One of cellulose derivative product is nitrocellulose which can be produced from a reaction between cellulose and nitric acid [1]. The application of nitrocellulose for industrial purposes was very broad, especially for single base propellant. Folded Fin Aerial Rocket (FFAR) is a double base rocket used by the Indonesian armed forces with its main composition being nitrocellulose and nitroglycerin [2]. In addition, Grand View Research (2018) predicted the need of nitrocellulose for the application in printer inks, paints, wood coatings, leather finishes and nail varnishes that increase every year by 6.1% from 2018 to 2024 [3].

Cellulose fraction from POEFBs is one of the potential ingredients to produce nitrocellulose because Indonesia has palm oil plantations area which reached 11.6 million hectares in 2016 [4]. However, lignin and hemicellulose fraction in POEFBs were still a challenge to produce nitrocellulose. Therefore, pretreatment methods using alkali and acid should be done before producing nitrocellulose.

Sensitivity analysis is an analysis to show how much the changing of economic parameters would effect the project. In this study, sensitivity analysis parameters was chosen such as plant capacity, OPEFBs price, levulinic acid price and electricity price. These sensitivity analysis parameters were assume to have a large effect on the value of project profitability.

In this study, sensitivity analysis of nitrocellulose production from POEFBs with sensitivity analysis parameters such as POEFBs price, electricity price, nitrocellulose price, and plant capacity will be investigated. The economic analysis process was carried out using SuperPro Designer 9.0 Academic License software. Techno-economic evaluation was conducted to determine the effect of sensitivity analysis parameters on project profitability.
2. Methods

2.1. Process Simulation
Nitrocellulose production consist of three main steps such as POEFBs pretreatment, nitrification, and nitrocellulose separation. Ammonium hydroxide and sulfuric acid pretreatment were used as POEFBs pretreatment. On the other side, nitric acid and sulfuric acid were used as acid solutions to produce nitrocellulose. Operating condition of nitrocellulose production was based on Setiadi et al. [5] which carried out at 5°C for 90 minutes with a ratio of POEFBs and acid solutions was 1:20. Pretreatment and nitrification of nitrocellulose production can be seen in Table 1.

Table 1. Operating condition of nitrocellulose production.

| Operation                  | Temperature (°C) | Solid to Liquid Ratio | Reaction Time (hour) | Reference |
|---------------------------|------------------|-----------------------|----------------------|-----------|
| Ammonium hydroxide pretreatment | 27               | 1:6                   | 14                   | [3]       |
| Sulfuric acid pretreatment | 120              | 1:12                  | 1                    | [8]       |
| Nitrification             | 5                | 1:20                  | 1.5                  | [10]      |

Ammonium hydroxide pretreatment was carried out by a simple immersion method at room temperature. After that, biomass solid fraction from ammonium hydroxide pretreatment mixed with sulfuric acid solution for acid pretreatment. Then, cellulose residue from sulfuric acid pretreatment was used as raw material for nitrification reaction. After the nitrification reaction, solid product or nitrocellulose can be washed with water to clean the spent acid solution. The flow chart of nitrocellulose production can be seen in Figure 1.

Figure 1. Nitrocellulose Production Process

2.2. Economic Evaluation Method
The economic simulation of nitrocellulose production was carried out using SuperPro Designer 9.0. The economic parameters of such as return of investment (ROI), payback period (PBP), net present value (NPV), and internal rate of return (IRR) were evaluated. The following assumptions and constants were used in calculating economic evaluation:

- The year for cost analysis was 2019.
- United Stated Dollars used as currency.
- Two years for plant construction and 20 years for plant operation.
- The total investment cost was obtained from loan with 10% compound interest per year.
- The plant capacity was 250 tons of POEFBs/year with POEFBs price was US$ 10/ton.
- Electrical for utility was US$ 0.1/kW-h.
- MACRS method was used as depreciation method with 15 years period.
- Minimum Acceptable Rate of Return was 11%.
- 25% tax was used.
- The price of nitrocellulose was US$ 3000/ton.

2.3. Sensitivity analysis calculation
Sensitivity analysis used a range of deviations of -10%, -5%, + 5%, and + 10%. Sensitivity analysis parameters such as production capacity, POEFB price, levulinic acid price and electricity price will be deviated and used to obtain economic profitability values such as NPV, IRR, PBP and ROI.
3. Results and Discussion

3.1. Economic Evaluation Result
The economic evaluation of nitrocellulose production from POEFBs at 250 tons/year capacity, US$ 10/ton POEFBs price, US$ 3,300/ton nitrocellulose price, and US$ 0.1/kW-h electricity price can be seen in Table 2. Based on Table 2, it was found that the NPV, IRR, PBP and ROI without any sensitivity deviation (0% deviation) were US $ 1,437,097, 18.36%, 4.51 years and ROI 16.31%.

| Parameters                  | Route – 1 |
|-----------------------------|-----------|
| Total Capital Investment (US$) | 2,580,180 |
| Total Revenue (US$/year)    | 1,065,077 |
| Total Operating Cost (US$/year) | 72,000   |
| ROI (%)                     | 16.31     |
| PBP (years)                 | 4.51      |
| NPV (US$)                   | 1,437,097 |
| IRR (%)                     | 18.36     |

3.2. Sensitivity Analysis
Changes in NPV, IRR, PBP and ROI values on sensitivity analysis can be seen in Figure 2 to 5 below.

![Figure 2. Sensitivity Analysis of NPV.](image1)

![Figure 3. Sensitivity Analysis of IRR.](image2)
Based on Figures 2 to 5 it can be seen that changes in nitrocellulose price greatly affect NPV, IRR, PBP and ROI. Based on the calculation, if there was a slight decrease in the nitrocellulose price, the plant was less feasible to build. This was happened because nitrocellulose was the main income in this plant (US$ 3000/ton). At the highest selling price of nitrocellulose, which was US$ 3,300 with a deviation of 10%, the NPV, IRR, PBP and ROI values were US$ 1,836,059, 20.34, 4.13 and 18.25.

The change in nitrocellulose production capacity had sufficient effect on NPV, IRR, PBP and ROI. Significant change in plant capacity with 10% deviation resulted in a significant change in NPV value to US$ 1,934,438. Changes in production capacity resulted in a reduction and increase in equipment volume to produce the desired product. If the production capacity was enlarged, product will be increased and the total income will be increased, but if the production capacity was reduced, product will be decrease and the total income will be decrease. Therefore, changes in production capacity affect the NPV, IRR, PBP and ROI.

The effect of changes in OPEFB prices and electricity prices did not significantly affect the NPV, IRR, PBP and ROI according to Figures 2 to 5. This was due to changes in OPEFB prices and electricity prices to 10% deviation causes small changes in OPEFB and electricity prices which were US$ 11 and US$ 0.11. Therefore, if there was a change in OPEFB price and electricity price will not significantly affect the project profitability.
4. Conclusion
In this study, we investigated the sensitivity analysis of nitrocellulose production from POEFBs based on POEFBs price, electricity price, nitrocellulose price, and plant capacity. From the economic evaluation results showed that NPV, IRR, PBP and ROI without any sensitivity deviation (250 tons/year capacity, US$ 10/ton POEFBs price, US$ 3,300/ton nitrocellulose price, and US$ 0.1/kW-h electricity price) were US $ 1,437,097, 18.36%, 4.51 years and 16.31%. Changes in nitrocellulose price and production capacity were the most influential variables in nitrocellulose sensitivity analysis production, but POEFBs and electricity price did not significantly affect the sensitivity analysis of nitrocellulose production.

Acknowledgement
Authors would like to thank to Institut Teknologi Sumatera for providing the research grant (No:B/328/IT9.C1/PT.01.03/2019) through “Hibah Penelitian ITERA SMART 2019”.

References
[1] Seta F T, Sugesty S, and Kardiansyah T 2014 Jurnal Selulosa 4 97–106. [in Bahasa]
[2] Miranda, Padil, and Yelmida 2013 Universitas Riau, Pekanbaru, Indonesia. [in Bahasa]
[3] Grand View Research 2018 www.grandviewresearch.com.
[4] Kementerian Pertanian. 2016. [in Bahasa]
[5] Setiadi, Mulyadi Y, and Kusmartono B 2017 Prosiding Seminar Nasional XII Rekayasa Teknologi Industri dan Informasi 2017 Sekolah Tinggi Teknologi Nasional Yogyakarta. [in Bahasa]