

Techno-economic analysis of lipase enzyme production from agro-industry waste with solid state fermentation method

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Abstract. Needs for this kind of catalyst derived from biological raw materials (biocatalysts) has increased along with development of products based on eco-friendly. To achieve the needs of biocatalyst (enzyme), large production is necessary. This study aimed to get the best conditions and design equipment to produce lipase enzyme based on solid state fermentation using SuperPro Designer v9.0. Several equipment such as *Tray Bioreactor*, *Mixing Tank 1*, *Filter Press*, centrifuge, *Mixing Tank 2*, and a dryer have been improved during the simulation. Economic analysis in the form of NPV, IRR, Payback Period, and the Benefit Cost Ratio was evaluated respectively. The result showed that production of 10 kg enzyme with NPV Rp112.796.147.423,00; IRR 54.20%; Payback Period 1.95 years; and Benefit Cost Ratio of 3.36 was more advantageous.

1. Introduction

The usage of enzymes for various industrial needs has increasing every year. In 2015, national needs of enzyme reached 2,500 tons while enzyme consumption growing up to 4-6% each year which is still import up to 99% usage [1]. Data showed that the enzyme market value is quite promising. However, it is necessary to build a system of enzyme production that are capable to produce independently because its market share is high (minimum competitor) and its development still limited only for laboratory scale. The process of making the enzyme, in terms of biomass cultivation medium used, was divided into 2 types fermentation: fermentation with solid medium (solid state fermentation) and fermentation with liquid medium (submerged fermentation). The advantages of solid state fermentation compare to the submerged fermentation include the minimization of contamination due to the lack of the water, the needs of a few fermentation media, the high yield of products, and the requirement of simple equipment [2].

2. Methods

2.1. Determination of mass balance, simulation, and equipment sizing

Determination of mass balance conducted by using secondary data from related researches about production of enzyme that has been done before [3,4,5]. The material needed including agro-industry waste; *Aspergillus sp.*; nutrients; olive oil as inducer; and skim milk powder as additives that needs to be added so that the enzyme would not denatured by heat drying. After calculating the mass balance of



each processes, then sizing the main equipment [6,7] such as Tray Bioreactor, Mixing Tank 1, Filter Press, Mixing Tank 2, and Dryer. Simulation of lipase enzyme production then will be performed using SuperPro Designer v9.0. The results will be used as reference to analyse its economical related to the profitability of enzyme production.

2.2. Determination of profitability analysis (NPV, IRR, PBP, B/C)

To determine the profitability analysis of lipase production, studies carried out related to the parameters that will affect the profitability of production [8,9,10]. The Total Purchase Equipment (TPE) is calculated based on the main equipment. The calculation is based on literature and vendor equipment purchased estimation with scale (six-tenths-factor-rules). Then the Total Capital Investment (TCI) will be calculated using delivered equipment cost percentage method [11]. After the calculation of TCI completed, the calculation of operating costs is followed by the assumption that the plant life is around 20 years. The operating costs including raw material costs, labor costs, maintenance costs, insurance costs, electricity and water utilities costs, as well as the costs of distribution for raw material and finish product. After determining the operating costs, the calculation of capital investment was done using the loan assumption from the bank as much as 40% with BI (Bank Indonesia) rate is about 7.5% and the remaining amount is 60% from capital investment. MARR value was calculated to determine the annual capital repayment that has to be paid. Afterall, the determination of product's prices was carried out based on production batch number and annual production capacity. In the end, the prices will be used to determine the value of NPV, IRR, payback period, and Benefit Cost Ratio.

2.3. Variation of substrate price, product price, exchange rate of rupiah, and production capacity toward profitability analysis

The variation of sensitivity level is done by using independent variables such as the price of agro-industry waste, in this study is rice bran. The rice bran deviation of variation started from -30 until +30 with the range of variation is about ± 10 . The price of lipase enzyme deviation of variation started from -10 to +10 with range of variation is about ± 2 . The exchange rate of rupiah against dollar with the deviation of variation started from -20 to +20 with range of variation is about ± 5 .

3. Results and discussion

3.1. Mass balance 1 kg and 10 kg basis

The calculation of mass balance 1 kg and 10 kg basis is used to determine the amount of raw material that needed to produce lipase enzyme with 1 kg and 10 kg production capacity. The following table below are the detail of raw material composition.

Table 1. Raw material composition in enzyme lipase production 1 kg and 10 kg basis

Raw Material	Usage Amount			
	1 Kg Basis [Kg/h]	10 Kg Basis [Kg/h]	1 Kg Basis [Kg/Batch/day]	10 Kg Basis [Kg/Batch/day]
Agro-industry waste	1.70	16.96	8.48	84.80
Olive oil	0.03	0.34	0.17	1.70
<i>Aspergillus sp.</i>	0.17	1.70	0.85	8.50
MgSO ₄ ·7H ₂ O	0.00076	0.00763	0.0038	0.0382
Sodium phosphate	0.031	0.305	0.15	1.53
Ammonium sulphate	0.013	0.127	0.064	0.636
Calcium chloride	0.00064	0.00636	0.003	0.032
Distilled water	18.06	180.62	90.31	903.12
Glucose	0.025	0.254	0.13	1.27

Raw Material	Usage Amount			
	1 Kg Basis [Kg/h]	10 Kg Basis [Kg/h]	1 Kg Basis [Kg/Batch/day]	10 Kg Basis [Kg/Batch/day]
Potassium phosphate	0.005	0.051	0.03	0.25
Skim milk powder	2.143	21.430	10.71	107.15
Urea	0.0058	0.0577	0.03	0.29
Total	22.19	221.86	110.93	1109.31

3.2. Process simulation of enzyme lipase production 1 kg and 10 kg basis

The process simulation of lipase enzyme production is using SuperPro Designer v9.0 software. From the simulation, it was obtained that the production is feasible for lipase enzyme product 1 kg/batch (with 1 kg basis) and 9.92 kg/batch (with 10 kg basis).

3.3. Profitability analysis of enzyme production

Profitability analysis is determined by following a few methods that are accepted as parameters of the economic feasibility of production. The methods including Net Present Value, Internal Rate of Return, Payback Period, and Benefit Cost Ratio. Profitability analysis is related to the level of sensitivity for some items which is define as the variation of research.

Table 2. Economical parameters of lipase enzyme production 1 kg and 10 kg basis

Parameters	Unit	Amount	
		1 kg basis	10 kg basis
Capital expenditure (CAPEX)	Rp	2,974,435,697	25,219,549,876
Operational expenditure (OPEX)	Rp/years	1,668,331,785	8,594,329,744
Maintenance	Rp/years	14,880,000	126,100,000
MARR/WACC	%	10	10
Enzyme production capacity	kg/years	288	2880
Enzyme's price	Rp/kg	9,947,300	9,947,300
Tax rate	%	25	25
Loan period	years	6	6
Internal rate of return (IRR)	%	22.32	54.20
Net present value (NPV)	Rp	5,264,974,339	112,796,132,099
Payback period	years	7.50	1.95
Benefit cost ratio (B/C)	-	1.16	3.34

After specify the economical parameters that needed to measure the sensitivity, the sensitivity graph will be obtained as shown below.

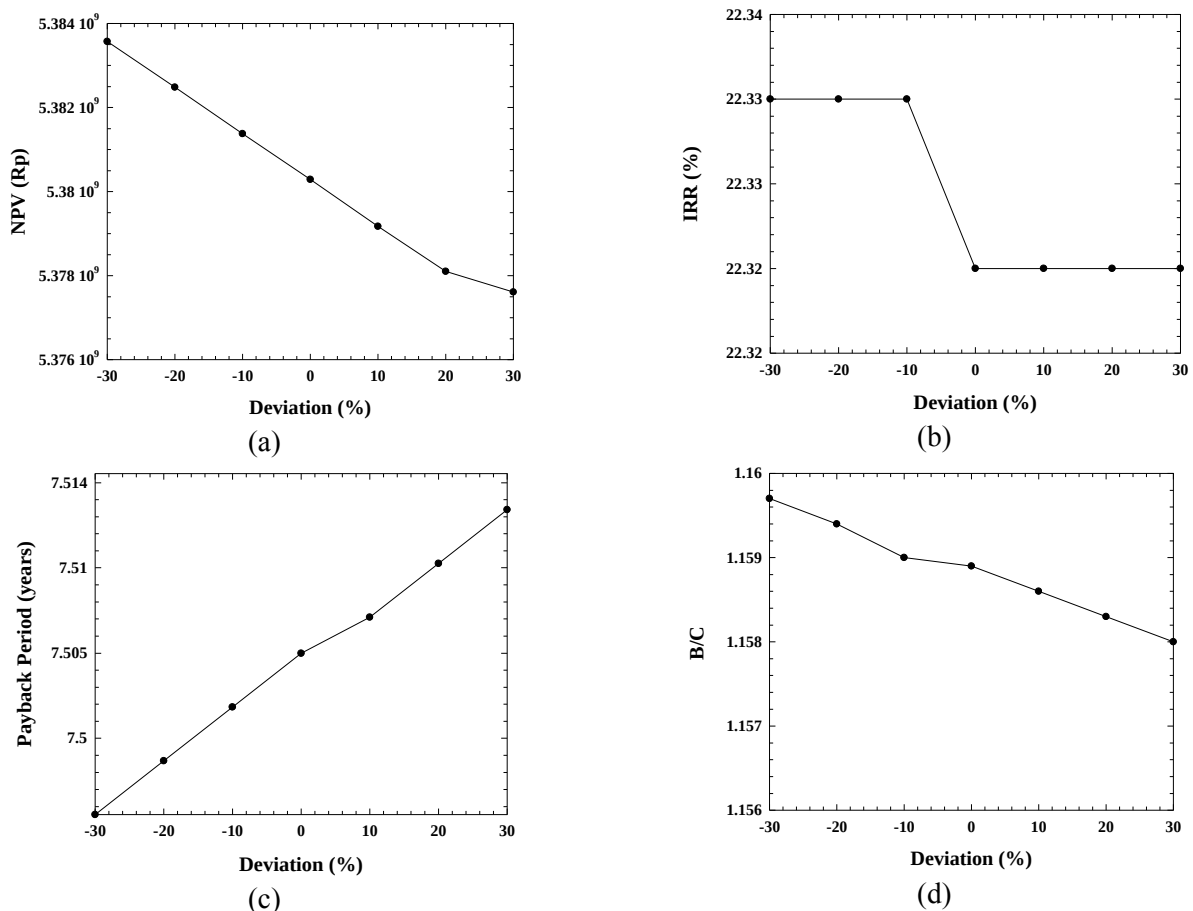
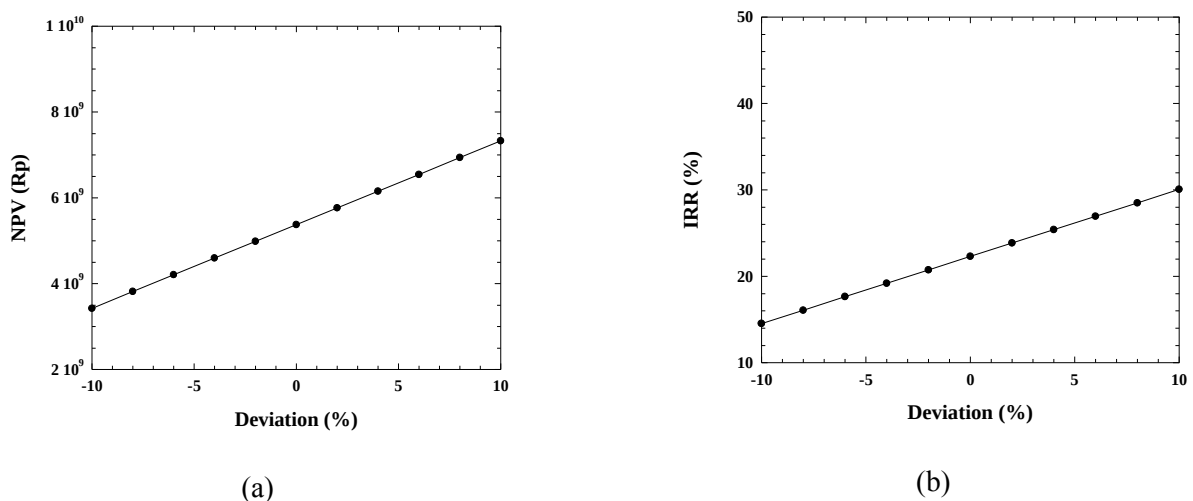


Figure 1. Sensitivity analysis of 1 kg basis substrate prices deviation (a) toward NPV (b) toward IRR (c) toward Payback Period (d) toward B/C

The results showed that the price of substrate which has been varied by the deviation, rises against payback period and declines toward NPV, IRR, and also B/C. On the other hand, IRR and B/C graphs are less sensitive than the NPV and Payback Period graphs. The highest result of NPV, IRR, and B/C with lowest Payback Period in the amount of substrate price is Rp 139.00/kg, and Rp 5,383,574,903 of NPV; 22.33% of IRR; 7.5 years of Payback Period; and 1.1597 of B/C.



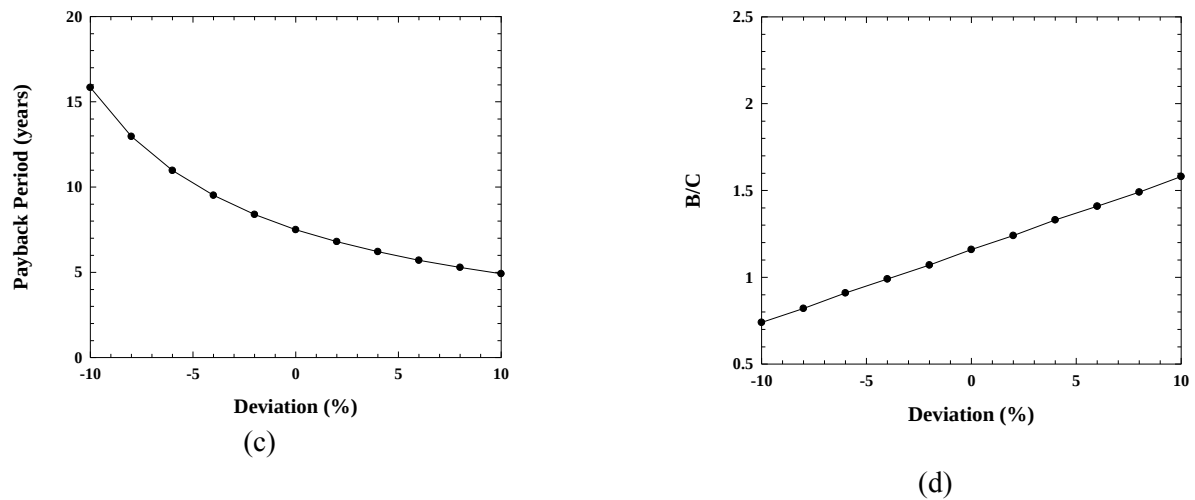
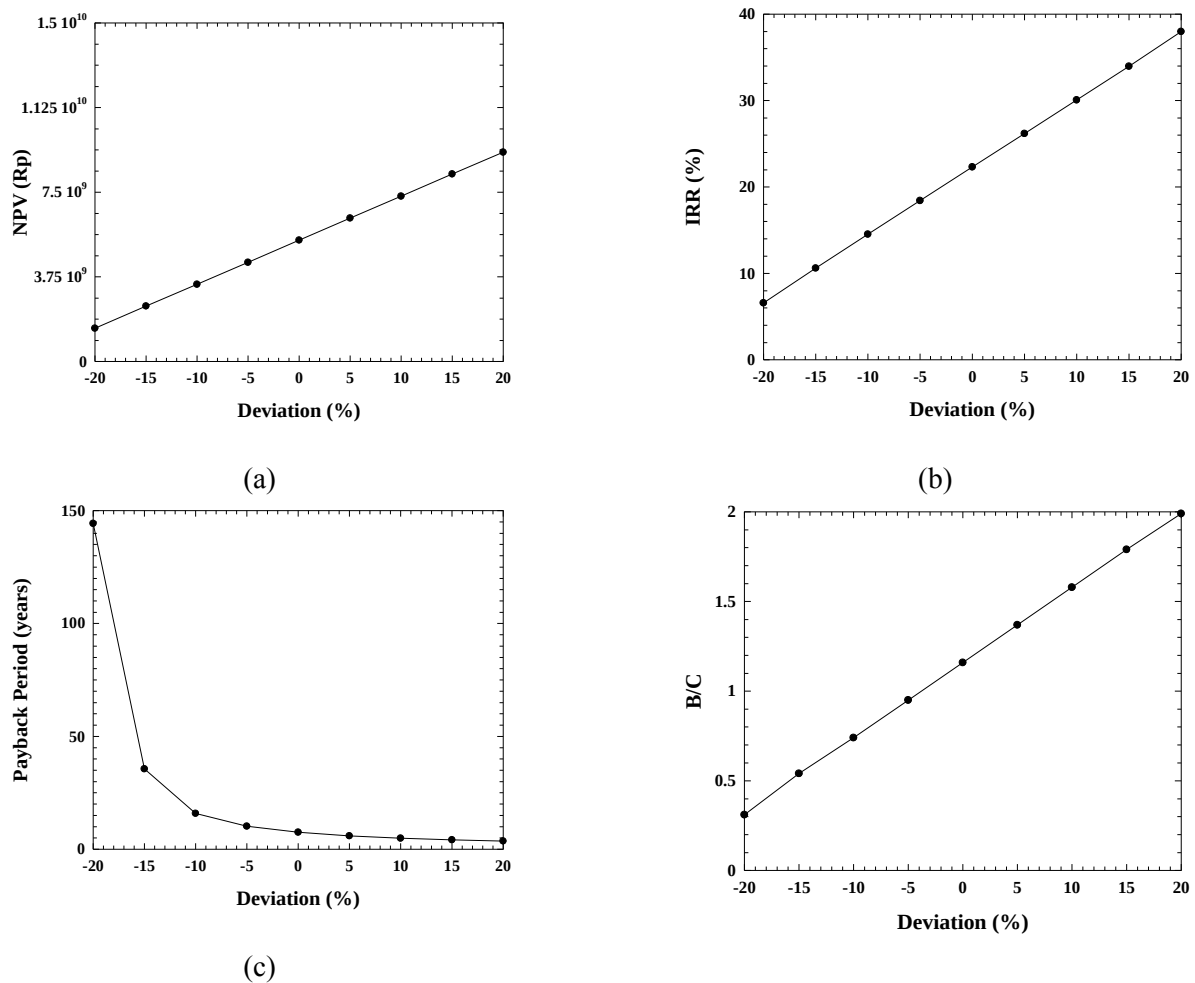


Figure 2. Sensitivity analysis of 1 kg basis enzyme prices deviation (a) toward NPV (b) toward IRR (c) toward Payback Period (d) toward B/C

Based on the graphic above, the best variation was obtained at 10th deviation with enzyme prices is about Rp 10,924,035.00 and Rp 7,327,689,990.00 of NPV; 30.07% of IRR; 4.92 years of Payback Period; and 1.58 of B/C.



(d)
Figure 3. Figure 3 Sensitivity analysis of 1 kg basis rupiah's value deviation (a) toward NPV (b) toward IRR (c) toward Payback Period (d) toward B/C
 Based on the graphic above, the best variation was obtained at 20th deviation with the exchange rate of rupiah upon dollar is Rp 15,923.00 and Rp 9,278,365,765.00 of NPV; 37.98% of IRR; 3.66 years of Payback Period; and 1.99 of B/C.

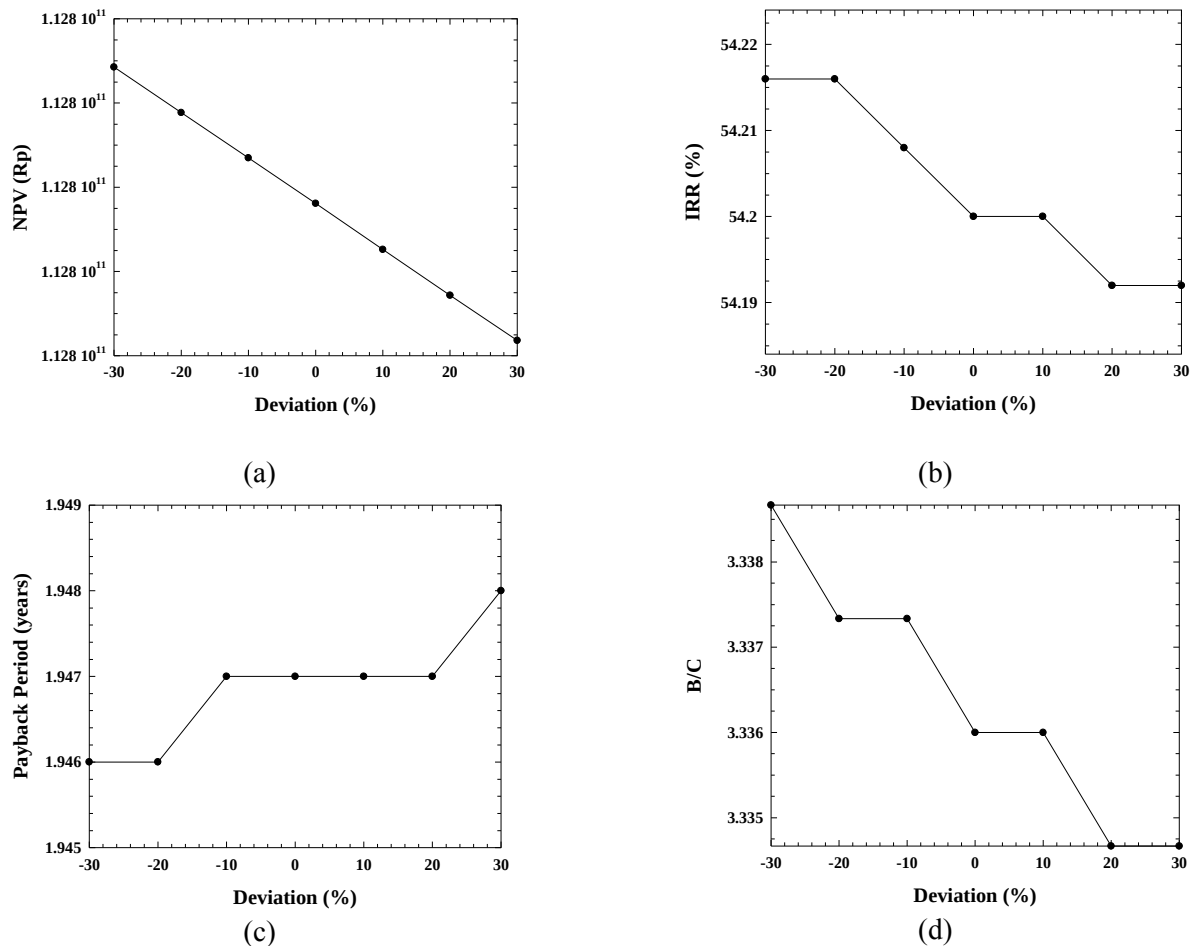


Figure 4. Sensitivity analysis of 10 kg basis substrate prices deviation (a) toward NPV (b) toward IRR (c) toward Payback Period (d) toward B/C

Based on the graphic above, the best variation was obtained at 30th deviation with the price of substrate is about Rp 139.00 and Rp 9,278,365,765.00 of NPV; 37.98% of IRR; 3.66 years of Payback Period; and 1.99 of B/C.

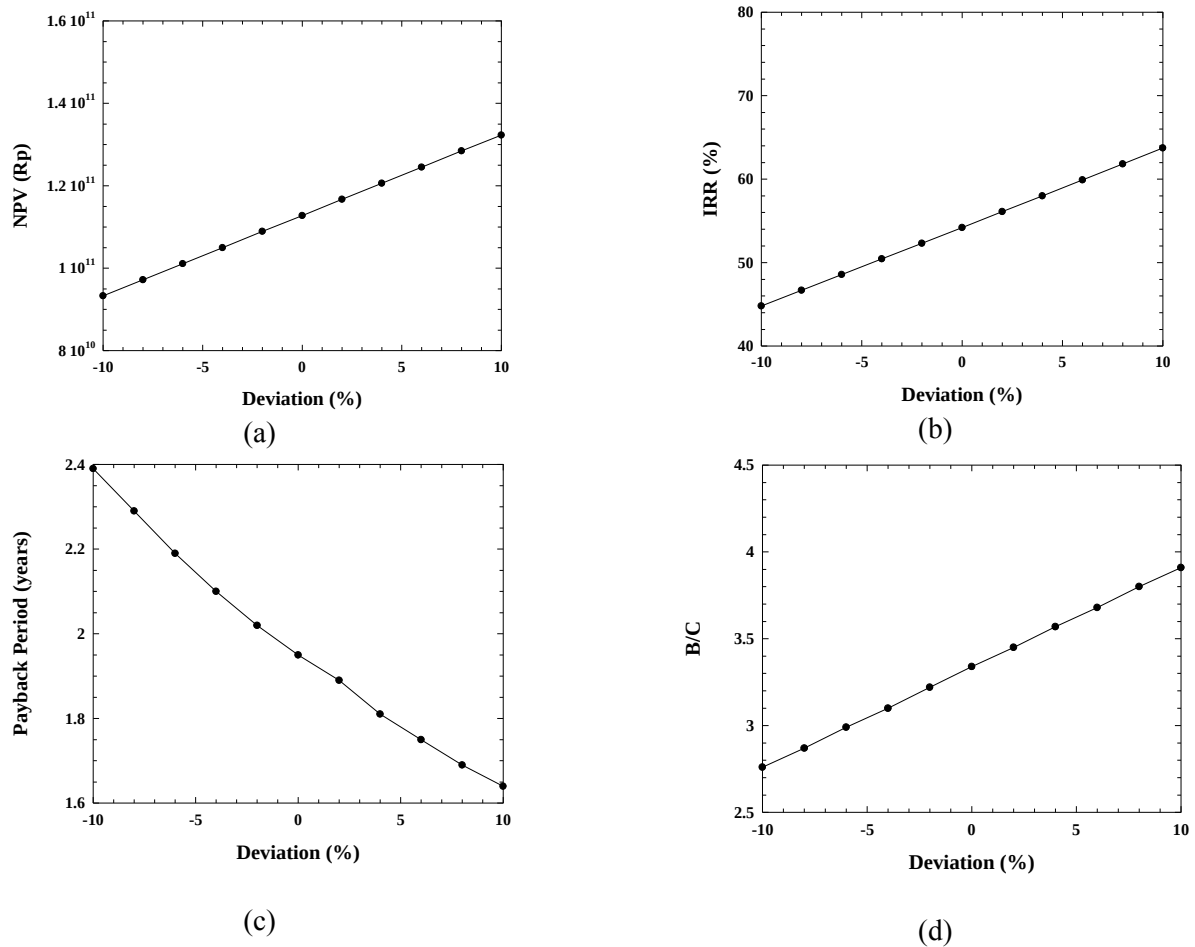
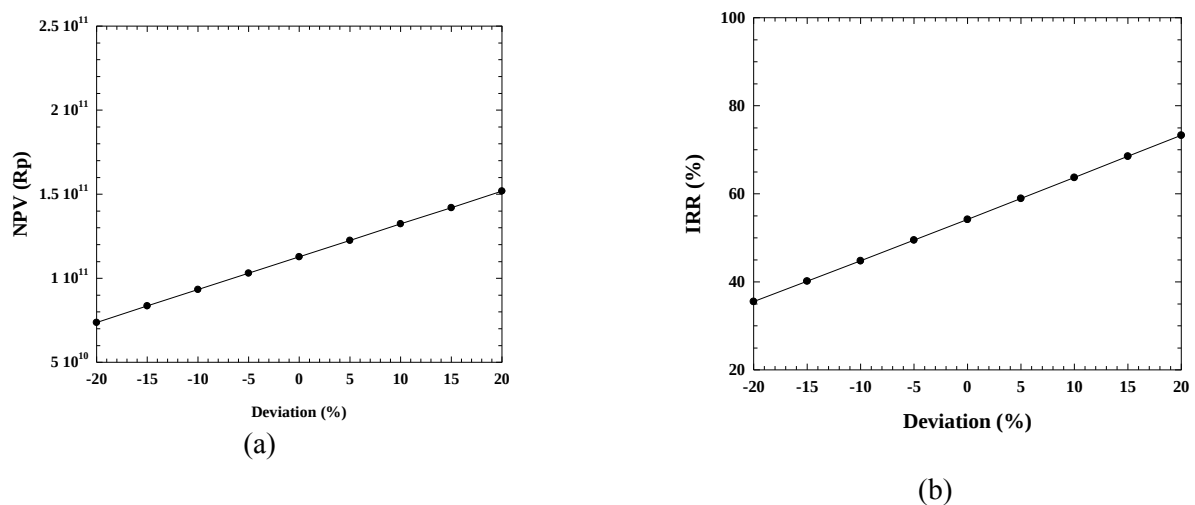


Figure 5. Sensitivity analysis of 10 kg basis enzyme prices deviation (a) toward NPV (b) toward IRR (c) toward Payback Period (d) toward B/C

Based on the graphic above, the best variation was obtained at 10th deviation with the price of enzyme is about Rp 10,924,035.00 and Rp 132,313,586,823.00 of NPV; 63.72% of IRR; 1.64 years of Payback Period; and 3.91 of B/C.



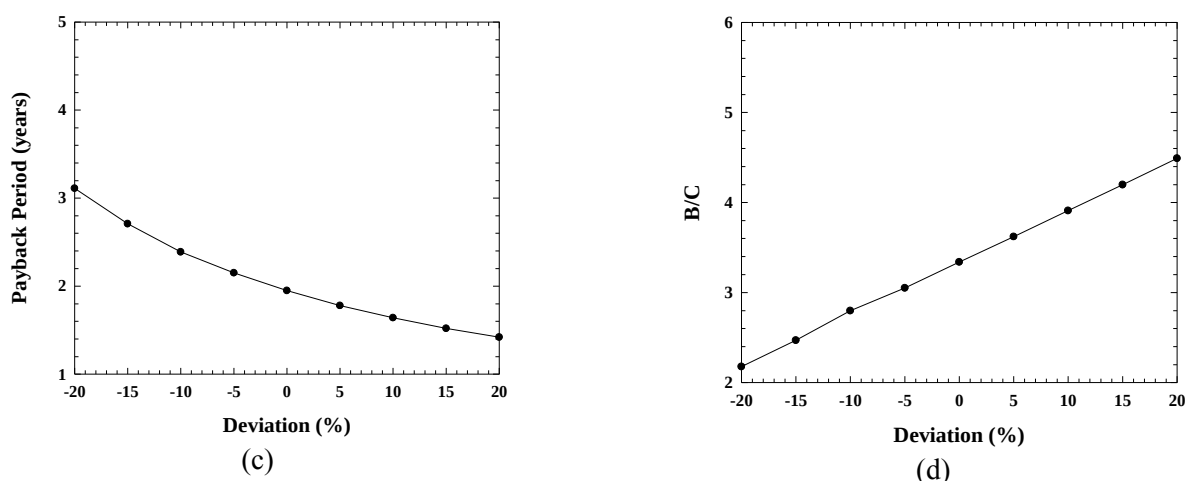


Figure 6. Sensitivity analysis of 10 kg basis rupiah's value deviation (a) toward NPV (b) toward IRR (c) toward Payback Period (d) toward B/C

Based on the graphic above, the best variation was obtained at 20th deviation with the exchange rate of rupiah upon dollar is Rp 15,923.00 and Rp 151,823,286,083.00 of NPV; 73.32% of IRR; 1.42 years of Payback Period; and 4.49 of B/C.

4. Conclusion

To obtain the lipase enzyme product of 1 kg and 10 kg production capacity, requires 1.7 kg and 16.96 kg of agro-industry waste as the substrate. The results of the simulation using SuperPro Designer is 1 kg of lipase product with 1.7 kg substrate and 9.92 kg of lipase product with 16.96 kg substrate. While, the highest result of NPV, IRR, Payback Period, and B/C on each 1 kg and 10 kg basis is Rp 15,923.00 exchange rate. By Rp 199.00/kg of substrate's price; Rp 9,947,305.00 of enzyme's price; and Rp 13,269.00 of rupiah's value upon dollar; the results for 1 kg basis is Rp 5,377,014,216.00 of NPV; 22.31% of IRR; 7.51 years of Payback Period; and 1.16 of Benefit Cost Ratio. On the other hand, the results for 10 kg basis is Rp 112,796,147.00 of NPV; 54.20% of IRR; 1.95 years of Payback Period; and 3.36 of Benefit Cost Ratio. Therefore, the 10 kg of production capacity is more profitable than 1 kg basis in terms of profitability method of NPV, IRR, Payback Period, and Benefit Cost Ratio.

5. References

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