Student Editorial

Process Design and Economic Stu Production of

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Introduction

In this study, the designed chemical plant shown in ***Figure 1*** is presented which aims to produce ascorbic acid with 95% purity, which is also known as Vitamin C, up to 500 tonnes annually. Meanwhile, sodium hydroxide and carbon dioxide are also produced as by-products of the fermentation process. In the fermentation process, the raw materials involved are D-sorbitol and sodium bicarbonate with mixing up of oxygen. Two-step fermentation with single culture was identified and selected due to its advantages of low production cost as well as minimal energy and water consumption. Moreover, the technology of two-step fermentation has fewer controlling and monitoring tasks. Furthermore, this process was designed based on the proper procedure of ISO 14000 Environmental Management. Processes involving thermodynamic and chemistry data for equipment are described in Table 1. SuperPro Designer software was utilized to generate plant process flow diagrams and plant-wide simulation flowsheets for production simulation purposes.

Results and discussion

The material and energy balances for optimization were done in this study. The optimization of the fermentation process was carried out by applying the recycling of sorbose via mass integration, and heat integration. It was found that the designed process could be increased by 24 % via the recycling of sorbose, while 20% of total energy consumption could be reduced upon heat integration. Additionally, economic, profitability, and sensitivity analyses were conducted on the designed process to predict the profitability and market conditions' effect on the investments considering the best and worst cases. Economic analysis using the Lang Factor method shows that total capital investment and production cost considering the best scenario are approximately USD 52.22M and USD 43.56M annually, respectively with an investment return rate of 78.73% and a 1.17-year payback period. Profitability analysis was performed by adjusting market condition parameters in the model considering product selling price, cost of raw materials, and taxation rate. The best scenario under profitability analysis considers an increment of 20% in product selling price and a decrement of 20% in cost including raw material and taxation rate. Hence, the total annual revenue and net present value (NPV) for the best case are USD 102.89M and USD 7,817.3M, respectively. The total production cost would be USD 43.11M with 78.72% of the return of investment and a payback period of 1.2 years. However, when the product selling price is reduced by 20% and both the raw material cost and tax rate are raised by 20%, it marks the worst case scenario.

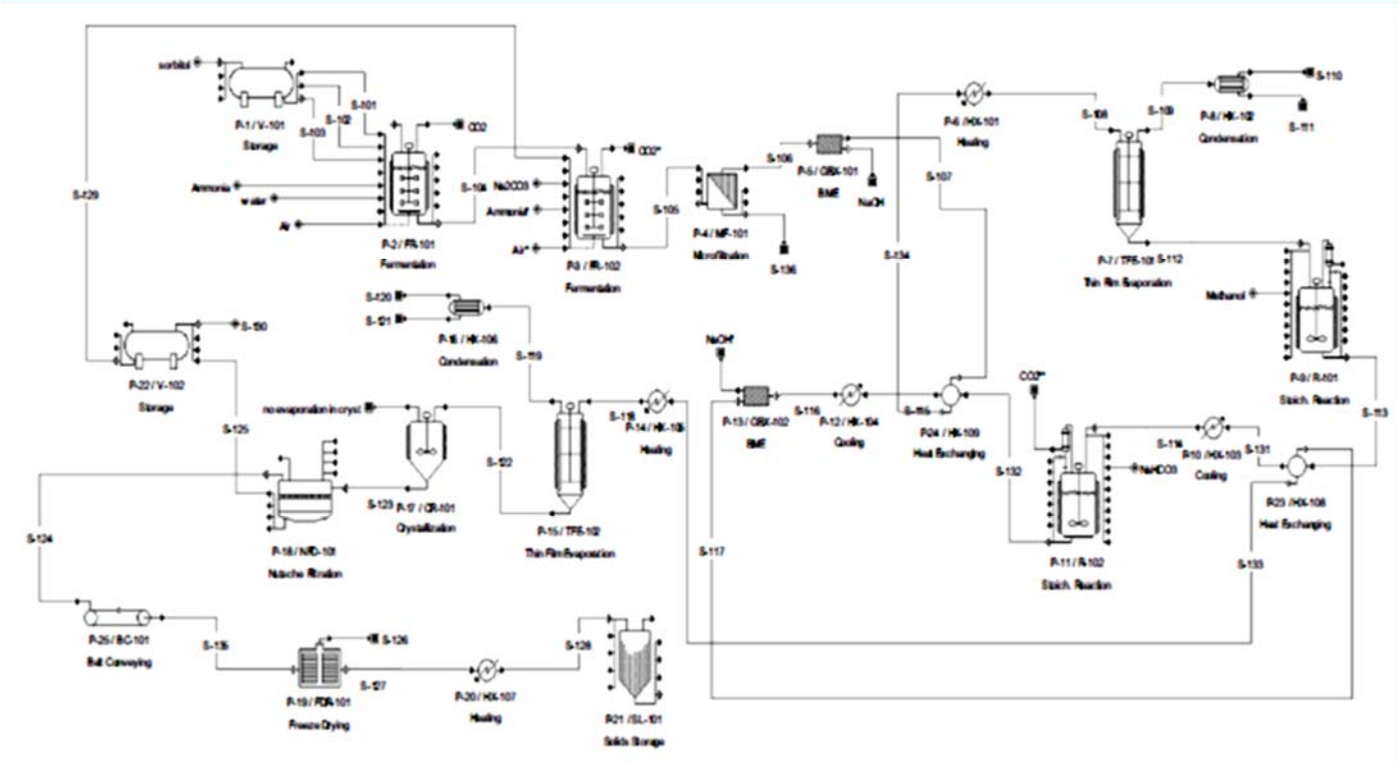

Figure 1: Simulated flow sheet from SuperPro Design

dies of Two-Step Fermentation for Ascorbic Acid

Jiun Tiong, Mun Min Goon, Roger Jhee Cheng Lau,
u and Nabisab Mujawar Mubarak

Table 1: Thermodynamics and chemistry data for equipment

Equipment	Process chemistry and thermodynamics
Fermenter FR-101	Conversion of sorbitol to sorbose by *Gluconobacter oxydans* *Main reaction:* Sorbitol + Oxygen → Sorbose + Water $C_6H_{14}O_6 + 0.5O_2 \rightarrow C_6H_{12}O_6 + H_2O$ *Metabolism reaction:* Sorbitol + Oxygen + Ammonia → Biomass + Carbon dioxide + Water $C_6H_{14}O_6 + 2.666O_2 + 0.732NH_3 \rightarrow 3.66CH_{1.79}O_{0.5}N_{0.2} + 2.34CO_2 + 4.822H_2O$ Heat of reaction is mainly governed by heat of metabolism and sensible heat where, Heat of metabolism, $Qmet = V\mu C_c \frac{1}{Y_\Delta}$ Heat generation coefficient, $Y_\Delta = \frac{Y_{C/S}}{(\Delta H_s - Y_{C/S}\Delta H_c)}$ Heat of combustion of sorbitol, $\Delta H_s = 16.55$ kJ/gC Heat of combustion of bacteria, $\Delta H_C = 24.2672$ kJ/gS Cell yield coefficient, $Y_{c/s}$ is = 0.6 gC/gS V is the working volume of fermenter, μ is the bacteria specific growth rate and Cc is the concentration of the biomass Cell accumulation rate, μCc = 2.17 g/dm^3 h Sensible heat, $Q_{sen} = Q_{product} - Q_{reactants} = -1.233$ kJ/g (sorbitol)
Fermenter FR-102	Conversion of sorbose to sodium keto-gluconic acid by *Pseudoglyconobacter Saccharoketogenes* *Main Reaction:* Sorbose + Oxygen + Sodium carbonate → Sodium keto-gluconic acid + Water + Carbon dioxide $C_6H_{12}O_6 + O_2 + 1/2Na_2CO_3 \rightarrow C_6H_9NaO_7 + 3/2H_2O + 1/2CO_2$ *Metabolism Reaction:* Sorbose + Oxygen + Ammonia → Biomass + Carbon dioxide + Water $C_6H_{12}O_6 + 0.73NH_3 + 2.157O_2 \rightarrow 3.66CH_{1.79}O_{0.5}N_{0.2} + 2.34CO_2 + 3.804H_2O$ Heat of reaction is mainly governed by heat of metabolism and sensible heat where sensible heat, $Q_{sen} = -2.691$ kJ/g (sorbose)
Bipolar Membrane Electrodialysis GBX-101	Conversion of sodium keto-gluconic acid to keto-gluconic acid through hydrolysis Sodium keto-gluconic acid + Water → Keto-gluconic acid + Sodium hydroxide $C_6H_9NaO_7 + H_2O \rightarrow C_6H_{10}O_7 + NaOH$ *Heat of reaction:* −629 J/g (Sodium keto-gluconic acid)
Reactor R-101	Conversion of keto-gluconic acid to methyl gluconate through esterification process Keto-gluconic acid + Methanol → Methyl gluconate + Water $C_6H_{10}O_7 + CH_3OH \rightarrow C_7H_{12}O_7 + H_2O$ *Heat of reaction:* −240 J/g (Keto-gluconic acid)
Reactor R-102	Conversion of methyl gluconate to sodium ascorbate Methyl gluconate + Sodium bicarbonate → Sodium ascorbate + Methanol + Water + Carbon dioxide $C_7H_{12}O_7 + NaHCO_3 \rightarrow C_6H_7O_6Na + CH_3OH + H_2O + CO_2$ *Heat of reaction:* −4.298 kJ/g (Methyl gluconate)
Bipolar Membrane Electrodialysis GBX-102	Recovery of ascorbic acid from sodium ascorbate through hydrolysis reaction Sodium ascorbate + Water → Sodium hydroxide + Ascorbic Acid $C_6H_7O_6Na + H_2O \rightarrow NaOH + C_6H_8O_6$

Conclusion

The study shows that the condition for the best case could yield total revenue and NPV at USD 68.67M and USD 8.45M respectively with 3.4 years of payback period. Hence, this designed plan is worth to be invested and set up.

Reference

Shi Min Lim, Michelle Siao Li Lau, Edward Ing Jiun Tiong, Mun Min Goon, Roger Jhee Cheng Lau, Wan Sieng Yeo, Sie Yon Lau and Nabisab Mujawar Mubarak. "Process design and economic studies of two-step fermentation for production of ascorbic acid", SN Applied Sciences 2:816. https://doi.org/10.1007/s42452-020-2604-8.

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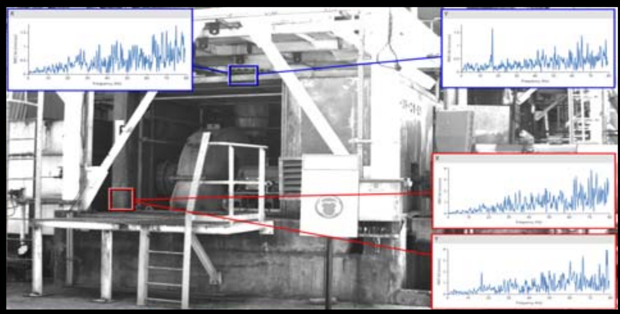
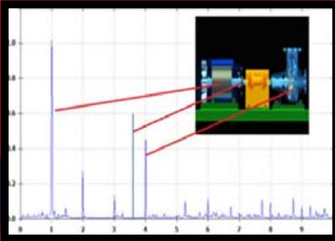
HIGHLIGHTS

- Advanced Vibration Troubleshooting on A Rotating Equipment.
- Application of FTIR Structural Analysis for Dried Coating Failure Investigation in Oil & Gas Industry.
- Utilization of Natural Fiber Towards Structural Applications Under Dynamic Loading Through MWCNT Enhanced Polymer Nanocomposite.





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