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# BIOETHANOL PRODUCTION FROM OIL PALM TRUNK WITH SCHEDULING OPTIMIZATION

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## ABSTRACT

*This research focuses on the optimization of bioethanol production from palm waste by minimizing energy consumption and scheduling the production line. Commercial software named ASPEN Plus Suite is used, including Aspen Plus, for studying the bioethanol production process from oil palm trunk, Aspen Batch Process Developer for scheduling the minimum time to get ethanol, and Aspen Energy Analyzer for minimizing energy consumption by pinch analysis. The minimum process operation time can achieve by batch scheduling. The ethanol production process from oil palm trunk has an ethanol capacity of 10,000 liters per day. This raw material is approximately 47,200 kg per day. The production schedule can introduce the system to operate simultaneously between batch and continuous processes by using an overlap operation of subsequent processing batch. It can reduce the idle time of equipment significantly. Three bioreactors of simultaneous saccharification and fermentation (SSF) proposes the target of bioethanol every 24.5 hours and increasing the performance of equipment utility. The result shows that it can increase the performance of equipment utilization to 73.07%. The result of bioethanol from oil palm trunk can conclude that the process with the heat exchanger network has a total cost of 691,481 \$/year, and the process with a base case has total cost 789,374 \$/year. It can conclude that the process with the heat exchanger network has a total cost less than the process with the base case. Therefore, it can reduce costs per year, around 12.40%.*

**Key words:** Bioethanol Production, Scheduling Batch Process, Pinch Analysis, Oil Palm Trunk, Aspen Energy Analyzer

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## 1. INTRODUCTION

Nowadays, the world human community has become a severe concern about global warming and the global petroleum crisis. Therefore, searching for a renewable energy source has become more critical. Bioethanol has become more attractive as an alternative to fossil-based fuel. The fermentation process is the main operation for bioethanol production with the enzyme catalytic reaction. Biomass resources come from various types of raw materials, which can be used to produce bioethanol from the fermentation process by starch and sugar, such as cassava, and sugarcane, and corn. Presently, consumers who concern about the environmental issue also want to know the origin and sustainable development of the production process. Resulting in the industrial sector has to adapt and respond to the needs of consumers by evaluating the life cycle of the product by considering the environmental impact of the product, notably greenhouse gas emissions. This article focuses on the optimization of ethanol production from palm waste by minimizing energy consumption and scheduling the production process. This study related to the bioethanol production from biomass, such as the sustainability of ethanol production from sugarcane[1], ethanol production using corn, switchgrass, and wood; biodiesel production using soybean and sunflower[2], and potential use of *Bacillus subtilis* in a co-culture with *Clostridium butylicum* for acetone-butanol-ethanol production from cassava starch[3]. Palm waste as biomass is in the research focused on waste-to-wealth: green potential from palm biomass in Malaysia[4]. Bioethanol production needs a simulation process before real production. Relevance research proposed the simulation works such as biorefining: computer-aided tools for sustainable design and analysis of bioethanol production[5]. Aspen plus is very popular in the form of a process simulation program. Many kinds of research use Aspen plus to simulate production processes such as simulation of biomass gasification in fluidized bed reactor using ASPEN PLUS[6], the effect of air preheating in a biomass CFB gasifier using ASPEN Plus simulation[7], and simulation of circulating fluidized bed reactors using ASPEN PLUS[8]. Programs are used in this article; there are Aspen Plus, Aspen Energy Analyzer, and Aspen Batch Process Developer. Aspen Plus is used for studying the ethanol production process from palm wastes. Aspen Energy Analyzer is used for minimizing energy consumption by using pinch analysis. There are many types of research that use pinch analysis to reduce energy use, such as simulation of heat exchanger network (HEN) and planning the optimum cleaning schedule[9], simultaneous synthesis of flexible heat exchanger network[10], and recent development in the retrofit of heat exchanger networks[11]. Aspen Batch Process Developer is used for scheduling the production to find a batch process that has minimum time operation in 1 cycle. Minimizing the operation time of the process can reduce by using batch processing. The researches using batch processing method to reduce production time such as state-of-the-art review of optimization methods for short-term scheduling of batch processes[12], continuous-time versus discrete-time approaches for scheduling of chemical processes[13], the effective continuous-time formulation for short-term scheduling[14], and on-line fault diagnosis system support for reactive scheduling in multipurpose batch chemical plants[15].

## 2. MATERIALS & METHOD

Necessary information about bioethanol production from oil palm trunk has studied the composition of oil palm trunk and bioethanol production processes from biomass. Then, flow diagrams using the Aspen Plus program are created to determine all the equipment used in the production process. After that, it would find methods of suitable properties according to the substances contained in the system and conditions of each equipment. After the completion of the ethanol process simulation, the information in Aspen Plus would be exported to calculate in the Aspen Batch Process Developer program for scheduling the batch process. And then, data from Aspen Plus would be analyzed in the Aspen Energy Analyzer program. The proposed energy conservation in bioethanol production can implement the previous Aspen Plus model.

## 3. RESULT & DISCUSSION

### 3.1. Simulation of the Ethanol Production Process from Oil Palm Trunk by Aspen Plus

This research studied the bioethanol production process with a capacity of 10,000 liters per day. The raw material is an oil palm trunk of 47,208 kilograms per day. In the bioethanol production process, it needs to find suitable pretreatments, such as a comparison of different pretreatments for the production of bioethanol and biomethane from corn stover and switchgrass[16]. There are experiments for the optimal bioethanol production process and need to design the optimal production process. Many kinds of research have designed experiments to make bioethanol production the most efficient. There are many relevance reports such as the conceptual design of hydrogen production process from bioethanol reforming[17], design and optimization of a sono-hybrid process for bioethanol production from Parthenium hysterophorus[18], design of an optimal process for enhanced production of bioethanol and biodiesel from algae oil via glycerol fermentation[19], design of the optimal industrial symbiosis system to improve bioethanol production[20], integrated approach for effective bioethanol production using the whole slurry from autohydrolyzed Eucalyptus globulus wood at high-solid[21], industrial-scale bioethanol production from brown algae of pretreatment processes on plant economics[22], modeling and optimization of bioethanol production from breadfruit starch hydrolyzate vis-à-vis response surface methodology and artificial neural network[23], and optimization of bioethanol production from glycerol by Escherichia[24]. The process of ethanol production from the oil palm trunk consists of four main steps: 1) pretreatment by the steam explosion at 210°C,4 bar for 4 mins to increases the porosity of the material. 2) Hot water extraction at 80°C for 30 mins to destroy hemicellulose. 3) Alkaline $H_2O_2$ at 70°C for 30 mins to extract lignin. 4) Neutralize by using water: the substance is 20: 1. 5) Mixing between buffer, that consists of DI, sodium citrate, citric acid, and distillate water, pH 4.8 has concentration 0.05M, buffer: the substance is 1:10 (270ml), yeast extract 10g/LBuffer and substance. 6) Autoclave at 121°C for 20 mins. 7) The sugar fermentation process by SSF is the biochemical change of glucose into ethanol. Many types of research related to SSF. Optimization of simultaneous saccharification and fermentation incubation time using cellulase enzyme for sugarcane bagasse on the second-generation bioethanol production technology[25]. Solid-state fermentation (SSF)-derived cellulase for saccharification of the green seaweed Ulva for bioethanol production[26]. Ultrasonic-assisted simultaneous saccharification and fermentation of pretreated oil palm fronds for sustainable bioethanol production[27]. 8) Autoclave again at 121°C for 20 mins. 9) Purify, in this research, use the pervaporation process to increase the purity of bioethanol to meet the required statement. Besides, ethanol supply chain decisions are an essential factor to consider when setting up an ethanol production plant on an industrial scale, for example, research on ethanol supply chains and economic approaches of ethanol production such as the impact on the optimal design of bioethanol supply chains by a new European Commission proposal[28], integrated decision making for the optimal bioethanol supply chain[29], and Hierarchical economic potential approach for techno-economic evaluation of bioethanol production from palm empty fruit bunches[30]. The flow-chart of all the steps are illustrated in Figure 1.

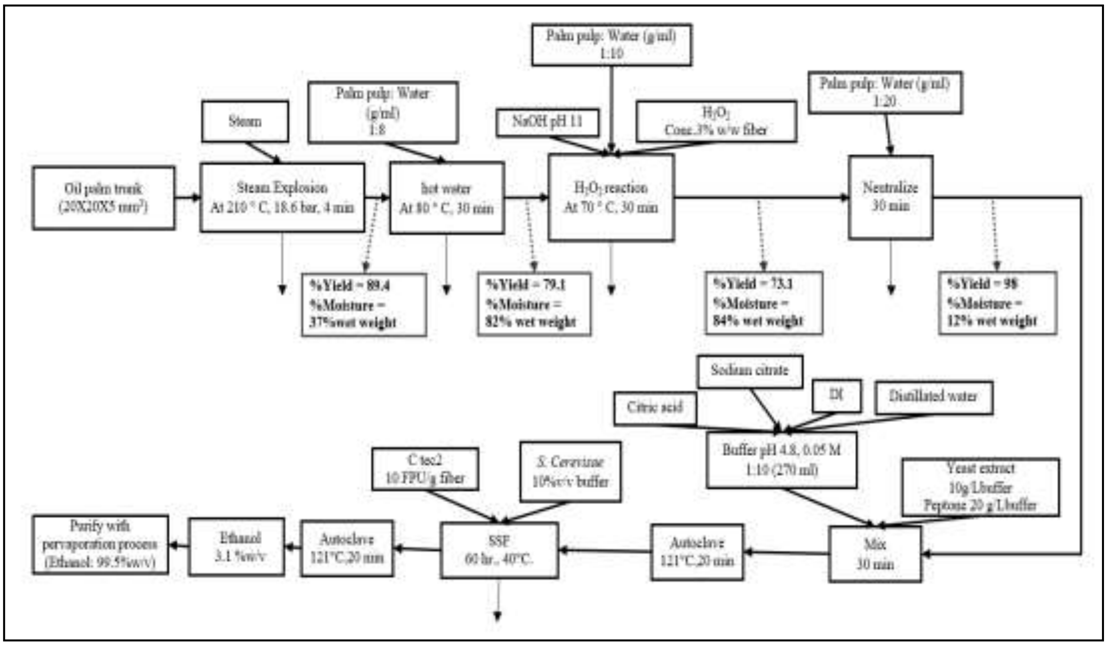

**Figure 1** Model of the bioethanol production process from oil palm trunk from Aspen Plus

## 3.2. Production Scheduling Batch Process by Aspen Batch Process Developer

The Aspen Batch Process Developer model gave a total mass balance in the process and displayed the production sequences. It consists of three main parts: the upper part, the left part, and color. The upper part of the table shows the operating time of each equipment in the system and can be used to indicate the cycle time. The left of the table displays the lists of equipment, and the color bar shows the operating time of the devices. This paper focuses on ethanol production at 10,000 liters per day, with the time between production cycles at 24.5 hours. In each production process, there is all operating time, as shown in Table 1, by assuming that the transfer time between operations is 15 minutes. Therefore, the occupancy time is around 5,369 mins. By considering a subsequent processing mode, the batch can classify into two types. They are the non-overlapping mode only started once the previous one completed, and the overlapping mode lets several batches processing simultaneously. The latter type can reduce the idle time of equipment significantly. This research use overlap mode because of reducing idle time.

To get minimum time to get ethanol, it necessary to find a suitable amount of SSF tanks because this process consumes maximum time, so the comparison consists of an SSF tank, 2 SSF tanks, 3 SSF tanks, and 4 SSF tanks. In case the same capacity of production is required, there must be 12 batches for comparison of the time between batch production of ethanol. From the graph shown in Figure 2 reveals that the time between batch 1 SSF tank at most 60.5 hours. 3 SSF tanks and 4 SSF tanks, the minimum time between batch, is 24.5 hours. So, 3 SSF tanks are used since there are less than a tank 4 SSF tanks and take time to produce ethanol at a minimum.

**Table 1** Operation time each process

| Process | Time (minute) |
|---|---|
| Steam Explosion (SE) | 4 |
| Hot water extraction | 30 |
| Alkaline hydrogen peroxide | 30 |
| Neutralization | 30 |
| Mixing | 30 |
| Autoclave_1 | 20 |
| Simultaneous saccharification and fermentation (SSF) | 3,600 |
| Autoclave_2 | 20 |
| Purification | 1,440 |

As can be seen, if the cycle of increased pretreatment is a steam explosion, hot water extraction, alkaline $H_2O_2$, neutralization, mix, and autoclave, then the product can be operated continuously. The steam explosion, hot water extraction, alkaline $H_2O_2$, neutralization, mix, and autoclave needed a cycle of 23 hrs. Therefore, enhancing and drive to be the continuous process, the sequences of this pretreatment need to be considered before passing through to the SSF, autoclave, and purifying process. There is still time to wait for the operation to occur, known as the idle time of the process. Therefore, to increase the performance of each device, it is necessary to proceed first and keep the substance in the tank before the SSF process after adding more cycles (23 cycles). Therefore, the process can run continuously without waiting for the operation time of each batch. The result shows that equipment utilization overall after improving can increase performance running around 73.07%.

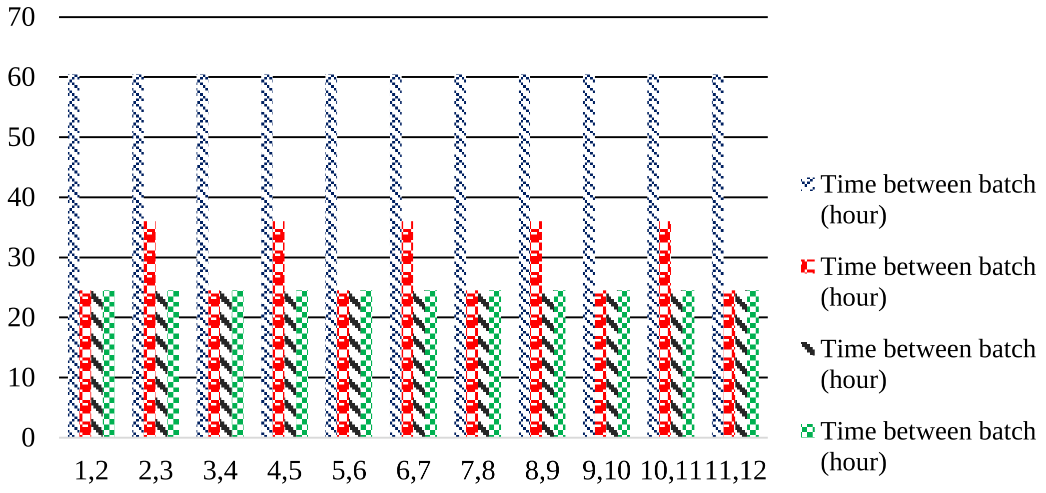

**Figure 2** Comparison time to get ethanol between batches with other scheduling batch processes

## 3.3. Minimize Energy Consumption by Aspen Energy Analyzer

### *3.3.1. Data from the Bioethanol Production Process*

There are 16 actual streams whose characteristics are listed in Table 2. It has been found that the total heat load for the cold streams is 2.56E+07 KJ/hr. And for the hot streams is 3.75E+07 KJ/hr. This implies that current hot and cold utility demands can be reduced to the target by recommended design.

**Table 2** Data from the bioethanol production process for pinch analysis

| **Stream no.** | **Name** | **Type** | **$T_{in}$(°C)** | **$T_{out}$(°C)** | **Enthalpy (KJ/hr.)** |
|---|---|---|---|---|---|
| 1 | PERMEATE_To_INPUMP12 | Hot | 68.00 | 67.50 | 1.58E+05 |
| 2 | AUTOCLAV.S23_To_AUTOCLAV.S1 | Cold | 25.06 | 121.00 | 2.75E+07 |
| 3 | SE.S22_To_SE.S2 | Cold | 25.00 | 210.00 | 1.63E+06 |
| 4 | S82_To_INMEMBRA | Cold | 50.93 | 68.00 | 2.46E+04 |
| 5 | TANKSTOR.S39_To_TANKSTOR.S1 | Hot | 121.00 | 40.00 | 4.37E+06 |
| 6 | B34.S34_To_B34.S39 | Cold | 40.44 | 121.00 | 4.35E+06 |
| 7 | ALKALINE.S1_To_ALKALINE.S3 | Cold | 25.00 | 70.00 | 3.72E+06 |
| 8 | HOTWA.S4_To_HOTWA.S6 | Cold | 25.00 | 80.00 | 3.52E+06 |
| 9 | To Reboiler@COLUMN_TO_S31 | Cold | 81.34 | 81.84 | 4.61E+06 |
| 10 | To Condenser@COLUMN_TO_S35 | Hot | 51.98 | 50.69 | 2.44E+06 |
| 11 | SSF.FERMENT_heat | Hot | 40.00 | 39.50 | 9.98E+04 |
| 12 | SSF2.B2_heat | Hot | 40.00 | 39.50 | 8.72E+06 |
| 13 | SSF3.B2_heat | Hot | 40.00 | 39.50 | 8.72E+06 |
| 14 | SSF3.FERMENT_heat | Hot | 40.00 | 39.50 | 9.95E+04 |
| 15 | SSF2.FERMENT_heat | Hot | 40.00 | 39.50 | 9.95E+04 |
| 16 | SSF.B2_heat | Hot | 40.00 | 39.50 | 8.74E+06 |

### *3.3.2. Utility Streams*

Specify information about the utility streams in the heat exchanger network to cool or heat the process streams. Cooling utility available at 20°C and hot utility as low-pressure steam (LP) available at 125°C, medium-pressure steam (MP) available at 175°C, and high-pressure steam (HP) available at 250°C. The cost index of cooling water, LP steam, MP steam, and HP steam are 2.12E-07, 1.9E-06, 2.2E-06, 2.5E-06, respectively.

### *3.3.3. Economic*

Parameters for calculation of heat exchanger capital cost index value are as follows a=10,000, b=800, c=0.8. This research is assuming the rate of return is 10%, and plant life is 20 years, hours of operation are 7,200 hours/year. From the target view tab, there is the following information, minimum cooling load is 2.56E+07 (kJ/h), and the minimum heating load is 3.75E+07. Equation to calculate the capital cost, as shown in Equation (1):

$$CC = a + b \times (\frac{Area}{N_{shell}})^{c} \times N_{shell} \quad (1)$$

The operating cost is dependent on the calculated energy targets in the HEN, as shown in Equation (2):

$$OC = \sum(C_{hu} \times Q_{hu,min}) + \sum(C_{cu} \times Q_{cu,min}) \quad (2)$$

The TAC accounts for both the capital cost and operating cost associated with the heat exchangers in the HEN. The Equation below is used to calculate the TAC, as shown in Equation (3):

$$TAC = A \times \sum CC + OC \qquad (3)$$

The Equation below is used to calculate the annualization factor, as shown in Equation (4):

$$AF = \frac{\left(\frac{ROR}{100}\right) * (1+\frac{ROR}{100})^{PL}}{(1+\frac{ROR}{100})^{PL}-1} \qquad (4)$$

### *3.3.4. Recommend Heat Exchanger Network Design*

Figure 3 shows the graph comparison cost index of the process with a heat exchanger network between recommending design 1 to design 10, which can conclude that the total cost of design 1 has the lowest total cost. Its total cost around 691,481.9 $/year.

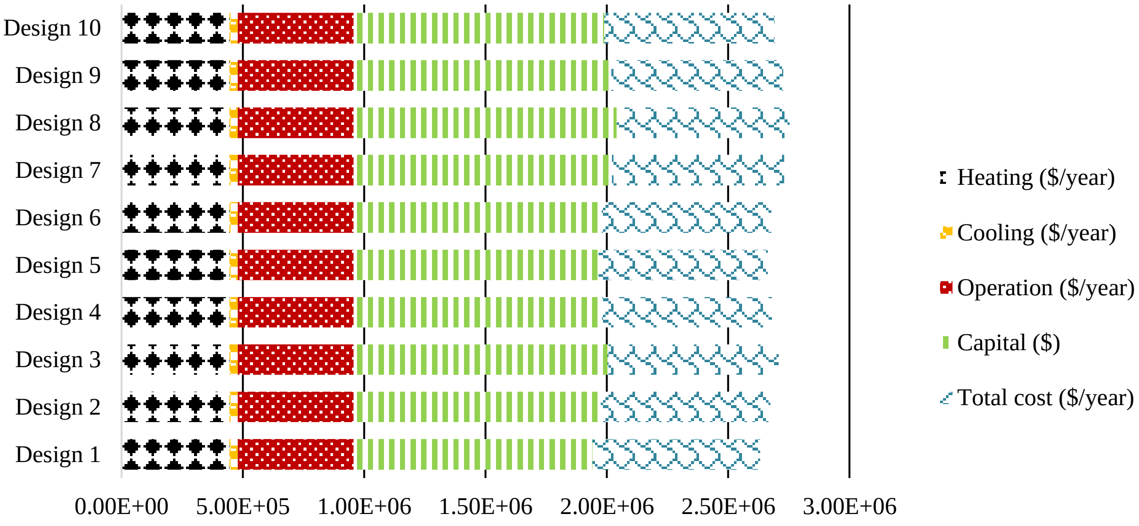

**Figure 3** Comparison cost index of the process with a heat exchanger network between design 1 to design 10

Therefore, heat exchanger network design 1 is used for minimizing energy consumption of the ethanol production process from oil palm trunk. The network is manipulated though the Grid diagram or the worksheet, as shown in Figure 4. It indicates hot steam and cold steam pairing.

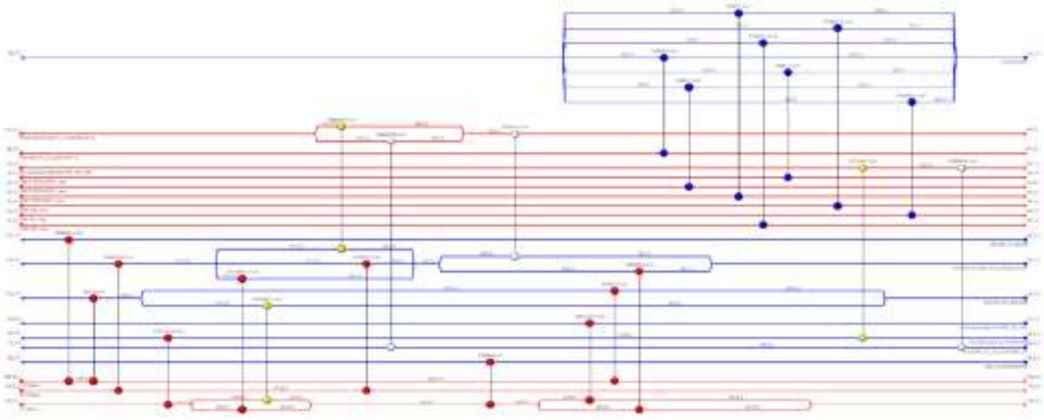

**Figure 4** Heat energy network design 1 of minimum energy consumption

HEN that is paired with utility stream (COOLINGW, LP STEAM, MP STEAM, and HP STEAM) do not need to add heater equipment in the production process for loading utility steam because equipment can load utilities stream into itself. For internal exchange, it is necessary to add HeatX equipment in the production process in order to exchange heat between the hot stream and cold stream. After that, adjust new information with the heat exchanger network in Aspen Plus, as shown in Figure 5.

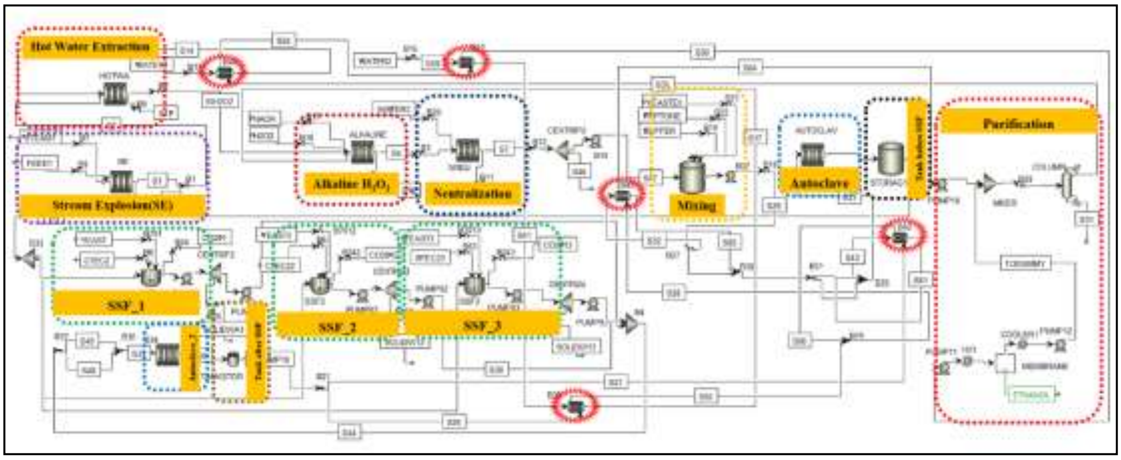

**Figure 5** Bioethanol production process with heat exchanger network

The data of heat energy network design 1 are calculated by Equation (1), Equation (2), Equation (3), and Equation (4). Network cost indexes between the bioethanol production process without heat exchanger network and bioethanol production process with heat exchanger network. From the bioethanol production process without the heat exchanger network and bioethanol production process with the heat exchanger network have the amount of total cost per year is 3,624,995 and 3,209,711$/year. It means that the bioethanol production process with a heat exchanger network can reduce costs around 11.46% per year.

## 4. CONCLUSIONS

Aspen batch process developer program can reduce operation time of the production process by using overlapping method batches, which is a mode in processing subsequent because it can reduce the idle time in the production process. Notice that one cycle of 10,000 liters of bioethanol takes 5,369 mins, but when a continuous production approach, it took 60.5 hours of production after obtained with a 24.5 hrs, for initiating the process. Therefore, the bioethanol production time of 10,000 liters per 60.5 hours is reduced to 24.5 hours, by adding an SSF tank from 1 tank to 3. A suitable storage tank can elaborate on the bottleneck during the pretreatment process for 23 cycles before the SSF process. Therefore, the process can run continuously without waiting for the operation time of each batch. Besides, the size of the equipment in the pretreatment process after the scheduling batch process shows that the equipment size is also smaller, and the result shows that it can increase the performance of equipment utilization to 73.07%.

Finally, Aspen Energy Analyzer can reduce energy usage in the production process by pinch analysis. The heat exchanger network is then implemented. The result can conclude that the process with the heat exchanger network has a total cost of 691,481 $/year, and the process with a base case has a total cost of 789,374 $/year. It can conclude that the process with the heat exchanger network has a total cost less than the process with the base case. Therefore, it can reduce costs per year, around 12.40%. This proposal would introduce to the local industry surrounding the plantation to enhance the income from waste residual.

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## REFERENCES

[1] Goldemberg, J., Coelho, S. T., & Guardabassi, P. (2008). The sustainability of ethanol production from sugarcane. Energy policy, 36(6), 2086-2097.

[2] Pimentel, D., & Patzek, T. W. (2005). Ethanol production using corn, switchgrass, and wood; biodiesel production using soybean and sunflower. Natural resources research, 14(1), 65-76.

[3] Tran, H. T. M., Cheirsilp, B., Hodgson, B., & Umsakul, K. (2010). Potential use of Bacillus subtilis in a co-culture with Clostridium butylicum for acetone–butanol–ethanol production from cassava starch. Biochemical Engineering Journal, 48(2), 260-267.

[4] Ng, W. P. Q., Lam, H. L., Ng, F. Y., Kamal, M., & Lim, J. H. E. (2012). Waste-to-wealth: green potential from palm biomass in Malaysia. Journal of Cleaner Production, 34, 57-65.

[5] Alvarado-Morales, M., Terra, J., Gernaey, K. V., Woodley, J. M., & Gani, R. (2009). Biorefining: Computer aided tools for sustainable design and analysis of bioethanol production. Chemical Engineering Research and Design, 87(9), 1171-1183.

[6] Nikoo, M. B., & Mahinpey, N. (2008). Simulation of biomass gasification in fluidized bed reactor using ASPEN PLUS. Biomass and Bioenergy, 32(12), 1245-1254.

[7] Doherty, W., Reynolds, A., & Kennedy, D. (2009). The effect of air preheating in a biomass CFB gasifier using ASPEN Plus simulation. Biomass and bioenergy, 33(9), 1158-1167.

[8] Sotudeh-Gharebaagh, R., Legros, R., Chaouki, J., & Paris, J. (1998). Simulation of circulating fluidized bed reactors using ASPEN PLUS. Fuel, 77(4), 327-337.

[9] Sanaye, S., & Niroomand, B. (2007). Simulation of heat exchanger network (HEN) and planning the optimum cleaning schedule. Energy Conversion and Management, 48(5), 1450-1461.

[10] Aaltola, J. (2002). Simultaneous synthesis of flexible heat exchanger network. Applied thermal engineering, 22(8), 907-918.

[11] Smith, R., Jobson, M., & Chen, L. (2010). Recent development in the retrofit of heat exchanger networks. Applied Thermal Engineering, 30(16), 2281-2289.

[12] Méndez, C. A., Cerdá, J., Grossmann, I. E., Harjunkoski, I., & Fahl, M. (2006). State-of-the-art review of optimization methods for short-term scheduling of batch processes. Computers & chemical engineering, 30(6-7), 913-946.

[13] Floudas, C. A., & Lin, X. (2004). Continuous-time versus discrete-time approaches for scheduling of chemical processes: a review. Computers & Chemical Engineering, 28(11), 2109-2129.

[14] M. G. Ierapetritou, and C. A. Floudas. "Effective continuous-time formulation for short-term scheduling. 1. Multipurpose batch processes." Industrial & engineering chemistry research. vol.37, no.11, 1998, pp.4341-4359.

[15] Ruiz, D., Canton, J., Nougués, J. M., Espuna, A., & Puigjaner, L. (2001). On-line fault diagnosis system support for reactive scheduling in multipurpose batch chemical plants. Computers & Chemical Engineering, 25(4-6), 829-837.

[16] Papa, G., Rodriguez, S., George, A., Schievano, A., Orzi, V., Sale, K. L., & Simmons, B. A. (2015). Comparison of different pretreatments for the production of bioethanol and biomethane from corn stover and switchgrass. Bioresource technology, 183, 101-110.

[17] Cormos, C. C., Imre-Lucaci, A., Cormos, A. M., Tasnadi-Asztalos, Z., & Lazar, M. D. (2013). Conceptual design of hydrogen production process from bioethanol reforming. In Computer Aided Chemical Engineering (Vol. 32, pp. 19-24). Elsevier.

[18] Bharadwaja, S. T. P., Singh, S., & Moholkar, V. S. (2015). Design and optimization of a sono-hybrid process for bioethanol production from Parthenium hysterophorus. Journal of the Taiwan Institute of Chemical Engineers, 51, 71-78.

[19] Martín, M., & Grossmann, I. E. (2014). Design of an optimal process for enhanced production of bioethanol and biodiesel from algae oil via glycerol fermentation. Applied energy, 135, 108-114.

[20] Gonela, V., & Zhang, J. (2014). Design of the optimal industrial symbiosis system to improve bioethanol production. Journal of cleaner production, 64, 513-534.

[21] Romaní, A., Ruiz, H. A., Pereira, F. B., Teixeira, J. A., & Domingues, L. (2014). Integrated approach for effective bioethanol production using whole slurry from autohydrolyzed Eucalyptus globulus wood at high-solid loadings. Fuel, 135, 482-491.

[22] Fasahati, P., Woo, H. C., & Liu, J. J. (2015). Industrial-scale bioethanol production from brown algae: Effects of pretreatment processes on plant economics. Applied Energy, 139, 175-187.

[23] Betiku, E., & Taiwo, A. E. (2015). Modeling and optimization of bioethanol production from breadfruit starch hydrolyzate vis-à-vis response surface methodology and artificial neural network. Renewable Energy, 74, 87-94.

[24] Adnan, N. A. A., Suhaimi, S. N., Abd-Aziz, S., Hassan, M. A., & Phang, L. Y. (2014). Optimization of bioethanol production from glycerol by Escherichia coli SS1. Renewable energy, 66, 625-633.

[25] Wahono, S. K., Rosyida, V. T., Darsih, C., Pratiwi, D., & Frediansyah, A. (2015). Optimization of simultaneous saccharification and fermentation incubation time using cellulose enzyme for sugarcane bagasse on the second-generation bioethanol production technology. Energy Procedia, 65(2015), 333-336.

[26] Trivedi, N., Reddy, C. R. K., Radulovich, R., & Jha, B. (2015). Solid state fermentation (SSF)-derived cellulase for saccharification of the green seaweed Ulva for bioethanol production. Algal Research, 9, 48-54.

[27] Ofori-Boateng, C., & Lee, K. T. (2014). Ultrasonic-assisted simultaneous saccharification and fermentation of pretreated oil palm fronds for sustainable bioethanol production. Fuel, 119, 285-291.

[28] Mazzetto, F., Simoes-Lucas, G., Ortiz-Gutiérrez, R. A., Manca, D., & Bezzo, F. (2015). Impact on the optimal design of bioethanol supply chains by a new European Commission proposal. Chemical Engineering Research and Design, 93, 457-463.

[29] Corsano, G., Fumero, Y., & Montagna, J. M. (2014). Integrated decision making for the optimal bioethanol supply chain. Energy conversion and management, 88, 1127-1142.

[30] Do, T. X., Lim, Y. I., Jang, S., & Chung, H. J. (2015). Hierarchical economic potential approach for Techno-economic evaluation of bioethanol production from palm empty fruit bunches. Bioresource technology, 189, 224-235.

[31] Cipto and Daniel Parenden, (2019) Corrosion Analysis of Fuel Pump Components Caused by Use of Mixed Fuel Gasoline and Bioethanol, International Journal of Mechanical Engineering and Technology, 10(1), pp. 362–369

[32] Angela O. Mamudu and Tolulope Olukanmi, (2019) Effects of Chemical and Biological Pre-Treatment Method on Sugarcane Bagasse for Bioethanol Production, International Journal of Civil Engineering and Technology, 10(1), pp. 2613–2623