Preliminary design and sustainability study of rosella jam factory utilizing renewable solar energy

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Abstract. Rosella is a flower with red and purple hue, having antioxidant pigments called anthocyanins, which is promising for health improvement. It actually could be potentially developed as a health-promoting food in the form of rosella jam. As the market for rosella jam in Indonesia is not established yet, and in the advent on the development of renewable energies in the 21\textsuperscript{st} century, it is a fascinating idea to design a rosella jam factory employing solar energy as one of the renewable energies in the future that might lead the sustainable food business in Indonesia. The rosella jam factory is designed to produce 40000 bottles of rosella jam (weight: 250 g) per month, sold for Rp. 25000, rendering income of Rp. 1 billion per month. It needs a one-off capital cost of Rp. 2.56 billion for production equipments and machines (not including solar panels), with monthly manufacturing cost of 624 million (included 20 kW electricity) that will reach break-even point (BEP) at 13\textsuperscript{th} month. Solar panels (mainly consists of 840 solar panels, 200 Wp working for 4 hours) worth of 2.64 billion is recommended to be installed on the 19th month to avoid negative cumulative net present value (CNPV).

Keywords: rosella; renewable energy; solar energy; solar panel; BEP; CNPV

1. Introduction

Jam is a food product made from fruits having gel or semi-solid content (that came from pectin originated from fruits, or externally added), sugar and some acid, usually citric acid \[1, 2\]. The mixture of those ingredients is evaporated to reach minimum of 65\% total solids \[3, 4\]. Among all fruits that have been processed into jam, rosella (\textit{Hibiscus sabdariffa}) is one of the plants that is seldom explored as a jam, despite of high potentials it possesses. Rosella is a food plant with high potentials as an antioxidant \[5\], and its buds have high antioxidative activity to inhibit free radicals \[6\]. One of the antioxidant in its buds is anthocyanins. Moreover, there is also high concentration of vitamins to boost the immune system of human \[7\].

In Indonesia, the jam processing has a bright prospect, followed by steady increase of jam consumption, as shown in Table 1. It could be observed that the production of jam in Indonesia is smaller by around 60\% than that of the demand, which must be fulfilled by the import of jam. Therefore, this phenomenon could be a huge opportunity to build a rosella jam factory in Indonesia. It is decided to design a rosella jam factory having capacity of 40000 bottles (250 g each) per month, equals to 10 tonnes per month, or 120 tonnes per year, designed to capture
13% of the national market of the jam import. If the price is IDR 25000 per bottle, then the sales would be IDR 1 billion per month, or 12 billion annually.

| Year | Demand (tonnes) | Production (tonnes) | Import (tonnes) |
|------|-----------------|---------------------|-----------------|
| 2012 | 1,470.74        | 609.37              | 861.37          |
| 2013 | 1,595.61        | 723.64              | 871.97          |
| 2014 | 1,728.72        | 855.16              | 873.56          |

This paper will first discuss the preliminary design of the rosella jam factory, as the Methodology from the perspective of formulation, process flow diagram, mass balance, and also factory layout, in order to determine the required electricity consumption of the rosella jam factory. In the Results and Discussion, the obtained electricity consumption will be further tuned from the point of view of alternative process of employing solar cells, and also completed with economical analysis.

2. Methodology

Rosella jam is composed of fresh rosella, and other ingredients such as sugar, citric acid, sodium benzoate and pectin. The jam will be produced with composition as shown in Table 2. It would not be added with artificial coloring, since it already has high concentration of anthocyanins, naturally providing the unique dark red hue of the jam. Furthermore, the jam would be having 12 months of shelf life when stored in room temperature. The rosella jam factory will be built in Balaraja, Tangerang, in Banten province, Indonesia, with area of 3000 m2 (price IDR 250000 per m2= IDR 75000000). The capacity of the factory is 40000 bottles (250 g each) per month, or 10 tonne per month, equals to 120 tonnes per year. It is broken down into 5 production batches having 100 kg per batch processed for two hours, conducted for 20 working days per month.

| Ingredients       | Quantity per bottle | Monthly quantity (40000 bottles) | Unit price (IDR) | Total price (IDR) |
|-------------------|---------------------|---------------------------------|-----------------|-------------------|
| Sugar             | 250 g               | 10000 kg                        | 8800/kg         | 88,000,000       |
| Water             | 150 mL              | 6000 L                          | 500/L           | 3,000,000        |
| Fresh rosella flower | 250 g         | 10000 kg                        | 15000/kg        | 150,000,000     |
| Na benzoate       | 0.1 g               | 4 kg                            | 27500/kg        | 110,000         |
| Citric acid       | 0.1 g               | 4 kg                            | 60000/kg        | 240,000         |
| Pectin powder     | 3 g                 | 120 kg                          | 207000/kg       | 24,840,000      |
| Label             | 1 piece             | 40000 pcs                       | 400/pcs         | 16,000,000      |
| Bottle            | 1 piece             | 40000 pcs                       | 3000/pcs        | 120,000,000     |

Total monthly expenditure (IDR) 402,190,000

Total annual expenditure (IDR) 4,862,280,000

With total sales of IDR 1 billion per month, with monthly expenditure for IDR 402 million, the gross profit margin would be 148%. This is an excellent margin, illustrating the prospect of rosella jam production. However, this margin will be trimmed down due to the purchases of equipments, investments, maintenance cost, etc. The details of the equipments needed to be procured to perform the production process are tabulated in Table 3. The total cost of equipment is IDR 808963200, and along with property cost of IDR 750000000, and building cost of IDR 10000000000, the total investment cost is IDR 2808963200. This rosella jam factory is designed with the layout shown in Figure 1, which is based on the production flow (completed with the mass balance) as shown in Figure 2.
Table 3. Detail of equipments and their costs for rosella jam production

| No  | Name                        | Capacity      | Usage per day | Usage per batch | Quantity | Unit price (IDR) | Total price (IDR) |
|-----|-----------------------------|---------------|---------------|-----------------|----------|------------------|-------------------|
| 1.  | Mixer                       | 200 L / Process | 1000 L        | 200 L           | 1        | 72,450,000       | 72,450,000        |
| 2.  | Sealing                     | 1200 pcs / hour | 2000 pcs      | 400 pcs         | 1        | 6,300,000        | 6,300,000         |
| 3.  | Evaporator                  | 100 L / Process | 1000 L        | 200 L           | 2        | 25,000,000       | 50,000,000        |
| 4.  | Size reduction              | 100 kg / hour  | 500 kg        | 100 kg          | 1        | 7,300,000        | 7,300,000         |
| 5.  | Retort (sterilization)      | 1.14453 m³ / process | 0.561 m³ | 0.1122 m³ | 1 | 67,120,000 | 67,120,000 |
| 6.  | Milling and grinding        | 110 kg / hour  | 550 kg/hour   | 110 kg/hour     | 1        | 8,500,000        | 8,500,000         |
| 7.  | Conveyor Belt               | 16 m          | 16 m          | 16 m            | 1        | 8,022,700        | 8,022,700         |
| 8.  | Balance                     | 1 tonnes      | 100 kg        | 100 kg          | 1        | 10,700,000       | 10,700,000        |
| 9.  | Filling machine             | 50 bottles/ minutes | 2000 bottles | 400 bottles     | 1        | 348,634,000      | 348,634,000       |
| 10. | Labelling                   | 600 pcs/ hour | 2000 pcs      | 400 pcs         | 1        | 17,490,000       | 17,490,000        |
| 11. | Carton sealer               | 20 m/ minutes  | 51.5 m        | 10.3 m          | 1        | 15,790,000       | 15,790,000        |
| 12. | Cold storage                | 250 kg        | 500 kg        | -               | 2        | 10,700,000       | 21,400,000        |
| 13. | Heater                      | 0.2 m³/s      | 1000 L        | 200 L           | 1        | 40,081,500       | 40,081,500        |
| 14. | Code writer                 | 90 pcs/ min   | 2000          | 400             | 1        | 1,570,000        | 1,570,000         |
| 15. | Water filter                | -             | -             | -               | 1        | 133,605,000      | 133,605,000       |
|     | Total cost of equipments    |               |               |                 |          | 808,963,200      |                   |

Figure 1. Layout of rosella jam factory
3. Results and discussion

In the production process, we absolutely need the utilities, such as water, electricity, fuel and steam. Electricity for industries usually is supplied from generator operated by steam or fossil fuel and also supply from Indonesian electricity company (PLN) [15]. The utilized electricity is Grade B-2TR 2017 priced at IDR 35000/month, with IDR 1466/kWh. The detail of the electricity cost is written in Figure 3, and also combined in Table 4 with different costs.

However, this conventional generation of electricity by using fossil fuel or relying PLN will sacrifice a big portion of profit, due to the trend of increasing cost of energy. This condition motivates the usage of renewable electricity that will significantly impact the reduction of CO2 gas emission to the atmosphere (due to burning of fossil fuel), where one of the renewable electricity is currently developed globally is solar energy [16]. It is generated by using solar cell to convert solar energy become electricity. It consists of silicon as semiconductors that could absorb photon from solar rays. In 2012, the solar panels were still uneconomically feasible for mass utilization. However, these days they are starting to be economic, at US$ 1/Watt peak (Wp) or US$ 1,000/kilowatt peak (kWp).

![Figure 2. (a) Schematic diagram of rosella jam production process, and (b) mass balance of rosella jam production](image-url)
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Table 4. Detailed cost of energy for each equipment

| No | Tools            | Power (kW) | Quantity | Operation time | Electricity consumption (kWh) | Cost (IDR) |
|----|------------------|------------|----------|----------------|-------------------------------|------------|
| 1  | Mixer            | 1.5        | 1        | 1 h            | 1.5                           | 2,200.50   |
| 2  | Sealing machine  | 0.12       | 1        | 20 min         | 0.04                          | 58.68      |
| 3  | Size reduction   | 0.37       | 1        | 30 min         | 0.185                         | 271.40     |
| 4  | Retort           | 2.6        | 1        | 1 h            | 2.6                           | 3,814.20   |
| 5  | Squasher and filter | 1.5     | 1        | 1 h            | 1.5                           | 2,200.50   |
| 6  | Conveyor belt    | 0.3        | 15       | 2 h            | 9                             | 13,203.00  |
| 7  | Filling machine  | 4          | 1        | 30 min         | 2                             | 2,934.00   |
| 8  | Label printer    | 0.12       | 1        | 20 min         | 0.04                          | 58.68      |
| 9  | Carton sealer    | 0.18       | 1        | 10 min         | 0.03                          | 44.01      |
| 10 | Cold storage     | 4.5        | 4        | 4.8 h          | 86.4                          | 126,748.80 |
| 11 | Code writer      | 0.09       | 1        | 5 mins         | 0.0075                        | 11.00      |
| 12 | Water filter     | 0.09       | 1        | 2 h            | 0.18                          | 264.06     |
| 13 | Heat plate exchanger | 2.2   | 1        | 2 h            | 4.4                           | 6,454.80   |
| 14 | Pump             | 0.5        | 4        | 2 h            | 4                             | 5,868.00   |
| 15 | Lighting         | 0.045      | 50       | 4.8 h          | 10.8                          | 15,843.60  |
| 16 | Air cooler       | 1.17       | 5        | 2 h            | 11.7                          | 17,163.90  |

Total per shift (IDR) 134,38. 
Total per day (IDR) 671.91. 
Total per month (IDR) 13438.00. 
Total per year (IDR) 161259.00. 

Table 5. Energy cost and operational cost in rosella jam factory

| No | Name                  | Cost (IDR/month) | Cost (IDR/year) |
|----|-----------------------|------------------|-----------------|
| 1  | Electricity           | 19,713,913       | 236,566,953     |
| 2  | Water                 | 1,314,000        | 15,768,000      |
| 3  | Gas                   | 1,000,000        | 12,000,000      |
| 4  | Battery (for gas)     | 2,500            | 30,000          |
| 5  | Operational cost      | 200,000,000      | 2,400,000,000   |
|    | **Total**             | **IDR 222,030,413/month** | **IDR 2,664,364,953/year** |

Table 6. Specification of solar panel for rosella jam factory

| No | Product Specification |
|----|------------------------|
| 1  | Max Power Voltage (Vmp) | 26.5 V |
| 2  | Solar Panel Voltage (V) | 24 V |
| 3  | Max Power (Pmax)       | 200 W |
| 4  | Max Power Current (Imp)| 7.55 A |
| 5  | Open - Circuit Voltage (VOC) | 32.8 V |
| 6  | Short Circuit Current (Isc) | 8.05 A |
| 7  | Module Efficiency      | 13.7 % |
| 8  | Operating Temperature  | -40°C ~ 85°C    |
| 9  | Max. System Voltage    | 1000 V (DC)     |
| 10 | Max. Series Fuse Rating| 16 A |
| 11 | Power Tolerance        | 0 - 5 W%        |
| 12 | Dimension              | L 148 × W 98.2 × T 3.5 cm³ |
| 13 | Price per unit         | IDR 2,000,000   |

Based on Table 5, it is stated that the total energy cost monthly and annually is IDR 19,713,913 and IDR 236,566,953. With additional operational cost (e.g. salary, pest control, office supplies etc.) of IDR 200,000,000, then the total maintenance cost is IDR 222 million or
IDR 2.6 billion. Furthermore, it could be seen that the electricity cost stands for around 80% of total energy demand in the rosella jam factory. If it could be reduced by using renewable energy, e.g. using solar panel, there will be a significant independence of fossil energy as a component of production cost. Indonesia is placed at the equator and has a potential of 500 GWp of solar energy [18, 19]. Therefore, the utilization of solar panel would spread wider margin of profit and simultaneously provides a environmentally-friendly production process to battle the global warming and also for the brand positioning as a green food manufacturer for both national and international markets. The specification of the solar panel that will be used in this rosella jam factory in tabulated in Table 6.

The solar panel will be installed on the roof of the rosella jam factory. In Table 4, it is shown that one unit of solar panel could supply approximately 200 Wp for a day (optimum of 4 h). Therefore a unit could supply 800 Wp. With electricity requirement per day= 671912.5 W, it is therefore around 840 units are needed. With area of around 1.5 m2 per solar panel, the required area for installation is 1260 m2. Based on the layout in Figure 2, it is estimated that the area of the factory and office will have roofs with area of 1955 m2, out of 3000 m2 total property area. Therefore, the required area for installation of solar panel is fulfilled. The solar panels will require battery to save energy supply that was converted from solar energy. The utilized battery would be the type of deep cycle, 48 V, 600 Ah. The solar panels would be equipped with inverter 48 V, 3200 W pure sine wave. The required amount of battery to supplement the inverter is

$$\text{Amount of Inverter battery} = \frac{\text{Battery voltage}}{\text{Inverter voltage}} = \frac{48 \text{ V}}{48 \text{ V}} = 1 \text{ unit} \quad (1)$$

$$\text{Solar panel battery} = \frac{\text{Number of solar panel} \times \text{Capacity of solar panel} \times \text{Power voltage}}{\text{Voltage battery} \times \text{Power of battery}} = \frac{840 \times 200 \text{ Wp} \times 48 \text{ V}}{48 \text{ V} \times 600 \text{ Ah}} = 280 \text{ units} \quad (2)$$

Moreover, there is additional equipment called BCR (battery charge regulator) to control the current that flows into the battery. The specification of the BCR is MPPT 100 A / 120 V. Having 840 units of solar cells with short circuit current of 8.05 A (based on Table 6), there will be a total of 6762 A of current to be regulated. The required amount of 100 A BCRs to handle 6762 A current are therefore 68 units. The detailed costs of installation of solar cells are shown in Table 7.

Table 7. Costs of installation of solar cells for rosella jam factory

| No. | Equipments                        | Quantity (unit) | Unit price (IDR) | Total price (IDR)     |
|-----|-----------------------------------|-----------------|------------------|-----------------------|
| 1.  | Solar panels, 200 Wp             | 840             | 2,000,000        | 1,680,000,000         |
| 2.  | Battery, VRLA 48V 600Ah          | 280             | 1,500,000        | 420,000,000           |
| 3.  | BCR, MPPT 100 A / 120V           | 68              | 5,000,000        | 340,000,000           |
| 4.  | Inverter, 3200 W pure sine wave  | 1               | 22,946,000       | 22,946,000            |
| 5.  | Cables, socket, other accessories | 1               | 10,000,000       | 10,000,000            |
| 6.  | Bracket for rack for solar cells  | 840             | 75,000           | 63,000,000            |
| 7.  | Rack for batteries               | 280             | 75,000           | 21,000,000            |
| 8.  | Installation costs               | 840             | 100,000          | 84,000,000            |
| Total|                                 |                 |                  | 2,640,946,000         |

As there will be a huge investment for the sustainable energy in the future, this issue must be carefully analyzed in terms of cash flow, or specifically as cumulative net present value (CNPV). CNPV accumulates the net present value of any costs, taxes and also interests. There are several considerations taken in this CNPV analysis for rosella jam factory with future addition of solar panels, as listed in Table 8. Negative values are for the outward cash flow,
while positive values mean inward cash flow. In this analysis, the cash flow of the rosella jam factory without and with installation of solar panel (at predetermined month) will be analyzed. The discount factor is factored in as inflation and interest will play an important role in the calculation of feasibility analysis of the rosella jam factory. The feasibility calculation will be simulated for 72 months, where the discount factor for a given interest of 10% p.a. every n month is written as follows:

$$\text{Discount factor} = \left(1 + \frac{10\%}{12}\right)^{-\frac{1}{12}n} \quad (3)$$

Net present value = cash flow \times discount factor \quad (4)

| Criteria                          | Subtotal     | Total            |
|----------------------------------|--------------|------------------|
| % Capacity                       | 100%         |                  |
| Investment cost 1 (process equipments, IDR) | -2,558,963,200 |
| • Process equipments             | - 808,963,200 |
| • Land                           | -750,000,000  |
| • Building                       | - 1,000,000,000 |
| Variable costs (IDR)             | -624,220,413  |
| • Materials                      | -402,190,000  |
| • Energy                         | -22,030,413   |
| • Operational (salary, maintenance, etc.) | -200,000,000  |
| Sales                            | +1,000,000,000 |
| % Tax                            | 10% p.a.     |                  |
| Discount factor                  | 10% p.a.     |                  |
| Investment cost 2 (solar panel, IDR) | -2,640,946,000 |
| (timing to be determined)        |              |                  |
| Production of electricity (IDR)  | +19,713,913   |                  |

As the discount factor is a reciprocate function with negative power, it will show a behavior of exponential decay, and thus will diminish the net present value. Therefore the investment must be decided wisely by considering these factors. The result of the CNPV analysis is illustrated in Figure 3.

![Figure 3. CNPV analysis of rosella jam factory with additional investment of installation of solar panels at various time](image_url)
Based on the result of CNPV analysis in Figure 3, it could be clearly seen that initially, without any installation of solar panels, the rosella jam factory will reach BEP (break-even point, point of outward cashflow is equally paid by inward cashflow) at the 13th month. However, if the installation of the solar panels is conducted at the first month of operation, the factory will never be able to reach BEP, with negative CNPV, ever after 72 months of operation. Similar trend is also obtained for investment that will be taken at month 5 and 10, where that of month 15 will barely reach net CNPV value of zero after 72 months of operation. The earliest possible investment is at month 19, where the CNPV after 72 months of operation will reach IDR 540 million, and the investment at month 19 will not give negative CNPV, where the investment of solar panel before month 19 will directly drop the current CNPV to negative region.

4. Conclusions
This factory for production of one of a kind rosella jam will be a prospective business, at gross profit margin of 148%, with sales of IDR 1 billion per month, worth of 120 tonnes of jam per year (equals to 13% market share of imported jams to Indonesia). The process flow diagram, mass balance, and the layout of this rosella jam factory have been designed. With initial capital cost of IDR 2.56 billion, and variable cost of IDR 624 million, this factory will reach breakeven point at month 13. To achieve sustainability in energy, this rosella jam factory will also be utilizing solar panels to generate renewable electricity, transforming itself into an environmental friendly factory. An investment worth IDR 2.64 billion is prepared, and simulated to be proceeded in month 19, as the earliest time. This duration was decided based on CNPV simulation result, where investment of IDR 2.64 billion of solar panels at month 19 and beyond will not bring instant deficit of CNPV. Therefore, this rosella jam factory will be not just a profitable factory but also a sustainable one, that would be a good example for many industries in Indonesia.

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