Simulation of Illipe Butter Purification Originated from West Kalimantan by SuperPro Designer

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Abstract. Tengkawang is one of the commodities of non-timber forest products which has been a life of support for people around the forest. Seeds produced by Tengkawang trees are one of the export commodities. However, unfortunately, the process of exporting Tengkawang seeds abroad often requires a long time to reduce the quality of the Tengkawang seeds. Processing of Tengkawang seeds into oil is a solution to the decline in quality of Tengkawang seeds. Like standard crude vegetable oil, Tengkawang oil also contains impurities. Therefore, a purification process to remove these impurities is needed. This research was conducted to produce purified Tengkawang fat optimally. Purification stages include degumming, neutralization, and bleaching. This research will focus on the simulation of purified Tengkawang fat production. In this case, the simulation is carried out as an estimator of the feasibility value roughly whether a fat purification plant can be realized or not

1. Introduction

Tengkawang is a typical tropical wet climate plant, which is one of the evidence of biodiversity in Indonesia, especially on Kalimantan Island [12]. Tengkawang is categorized in the Plantae Kingdom (plant), subkingdom Tracheobionta (vascular plant), super division of Spermatophyta (producing seeds), Magnoliopsida division (split into two pieces/dicotyl), sub-class Dilleniidae, order eales, Dipterocarpaceae family, and genus Shorea [4]. Tengkawang is one of the commodities of non-timber forest products which has been a life of support for people around the forest [12]. Seeds produced by tengkawang trees are one of the export commodities. [13]. In the 1985 - 1989 period, Tengkawang exports generated a foreign exchange of US $ 7,439,167.75 from 10,667.01 tons of tengkawang seeds [2].

Unfortunately, the process of exporting Tengkawang seeds abroad often requires a long time to reduce the quality of the Tengkawang seeds. Processing of Tengkawang seeds into oil is a solution to the decline in quality of Tengkawang seeds. Besides, the processing of Tengkawang seeds into oil can increase its selling value and can open up more significant business opportunities. In 1992 in West Kalimantan, the volume of Tengkawang oil production had reached 5,358.2 tons [6]. Tengkawang oil has a high melting point value so that it is widely used as a substitute for chocolate oil, lipstick, oil for
food and medicine [1]. Because of its characteristic, Tengkawang fat has a higher selling price than vegetable oils like coconut oil [15].

Crude vegetable oil generally contains substances such as phospholipids, free fatty acids, metal ions and metal complexes, substances that are easily oxidized and water that can reduce the quality of the oil [11]. Therefore, a purification process to remove these impurities is needed. The purification process in Illipe butter is based on the purification process in vegetable oil that has been conducted by Ketaren consisting of degumming, neutralization, bleaching, and deodorization [7]. Degumming is an early stage purification process whereby the principle is to remove or separate gum (sap or mucus) without reducing the amount of free fatty acids in fat [9]. The neutralization stage aims to remove free fatty acids that will be released in the form of soap. Free fatty acids it is easily oxidized and can cause rancidity [16]. The bleaching stage aims to remove the colour pigments contained in the oil with activated bentonite addition as an adsorbent and finally the deodorization stage, which aims to remove odours and unpleasant taste in oil. The bleaching and deodorization stage is mostly carried out for use as food [3].

This study was conducted to produce purified Tengkawang fat optimally. Purification stages include degumming, neutralization and blanching. This research will focus on the simulation of purified Tengkawang fat production. In this case, the simulation is carried out as an estimator of the feasibility value roughly whether a fat purification plant can be realized or not.

2. Methods

In this research, SuperPro Designer® is used as process simulation software. Intelegent Inc produces superPro Designer®. This software is used to predict plant construction before carrying out its construction, so it can be predicted that the plant will be profitable or not before the sustainable development process. In this study, two variations of bentonite activation were used, which are thermal activation and acid activation.

Degumming aims to remove gum from Illipe butter. Illipe butter was first melted to achieve a liquid state. 1% (w/w) of 20% of phosphoric acid was added to the melted Illipe butter. Neutralization aims to separate free fatty acids (FFA) through a chemical reaction with alkaline. 10% of 1 M NaOH was added to Illipe butter from degumming process. The mixture was stirred for 30 minutes in blending tank to homogenize the reaction. Then the mixture was separated using a decanter.

In thermal activation, bentonite was activated at the temperature of 200°C for 2 hours [14]. Bentonite was thermally activated using a furnace. Thermal activation aims to remove water-bound between molecular gaps by evaporation, thus increasing the porosity [5]. Moreover, for the acid activation process, 0.1 M hydrochloric acid was added to bentonite clay with the ratio of 5:1 at room temperature. The mixture was agitated for 30 minutes to maximize contact between bentonite and HCl. After 30

![Figure 1. Process flow diagram of Illipe butter purification using thermally-activated bentonite (A) and acid-activated bentonite](image-url)
minutes, the mixture was separated using microfilter. The activated bentonite then ground to obtain fine structure for the bleaching process.

For the bleaching process, 20% (b/b) of activated bentonite was added to Illipe butter that undergone pre-treatment process \[8\][10]. Then the mixture was separated by plate and frame filtration. After running the simulation process, the data from each variation was compared. The comparison was carried out based on scheduling data, product quality, product quantity, and economic evaluation which can be obtained from SuperPro simulation.

3. Results and Discussion

Production capacity that should be done by this simulation is about 535.8 ton Illipe butter/year or equal to 1.48 ton Illipe butter/day. This number is the result from Tengkawang oil production per year as the latest production of Tengkawang lipid in West Kalimantan is 5,358 ton/year, and 10% from that number becomes the production capacity of this simulation process. Two variations of bentonite activation are using thermal activation and acid activation.

The desired product from this process is Illipe fat which has a high concentration of Illipe oil. Illipe fat produced in this process has a flow rate of 14.469 kg/batch with an Illipe oil flow rate of 13.8 kg/batch, carotene flow rate of 0.66 kg/batch, and a stearic acid flow rate of 0.00006 kg/batch. The product has eliminated the composition of gum which is in the raw material of raw Illipe fat and has reduced the value of carotene and acid number composition.

Both of the bentonite activations have the same quality, which is determined from the product’s purity and the same quantity, which is determined from the production flow rate. The purity of Illipe oil in the product has a value of 95.4% (w/w). Illipe oil composition in the product is more significant than Illipe oil composition in the feed that is equal to 48% (w/w). Free fatty acids contained in Illipe fat amounted to 0.0002% (w/w) and following the quality standard of Illipe fat in SNI 2903-2016 which stated that maximum free fatty acid value of Illipe fat is 3.5% (w/w). In the aspect of quality, the product is following SNI 2903-2016 standards so that the product can be used and marketed.

Waste treatment is one of the vital things to maintain safety for the workers and the environment. In this process, several wastes need to be treated before being released into the environment because they contain hazardous materials. These wastes come from the decanting process, activation of bentonite, and filtration of Illipe oil using bentonite. This waste treatment is carried out by waste management, and the company paid about $ 1.3 per m3 for the treatment processes.

CAPEX consists of several components: the costs of equipment, installation, piping, instrumentation, insulation, electricity, buildings, land development, supporting facilities, engineering costs, construction costs, contractor fees, emergency costs, working capital, and startup costs. After totalling, the CAPEX value for thermal pre-treatment is 571,000 USD, and for acid, pre-treatment is 641,000 USD which are dominated by construction and equipment costs.
Table 1. Comparison of Capital Expenditure for Thermal and Acid Pretreatment

| Component          | Thermal | Percentage | Acid | Percentage |
|--------------------|---------|------------|------|------------|
| Equipment Cost     | $89,000 | 16%        | $91,000 | 14%        |
| Installation       | $35,000 | 6%         | $37,000 | 6%         |
| Process Piping     | $31,000 | 5%         | $32,000 | 5%         |
| Instrumentation    | $36,000 | 6%         | $36,000 | 6%         |
| Insulation         | $3,000  | 1%         | $3,000  | 0%         |
| Electrical         | $9,000  | 2%         | $9,000  | 1%         |
| Buildings          | $40,000 | 7%         | $41,000 | 6%         |
| Yard Improvement   | $13,000 | 2%         | $14,000 | 2%         |
| Auxiliary Facilities| $36,000 | 6%         | $36,000 | 6%         |
| Engineering        | $73,000 | 13%        | $74,000 | 12%        |
| Construction       | $102,000| 18%        | $104,000| 16%        |
| Contractor's Fee   | $23,000 | 4%         | $24,000 | 4%         |
| Contingency        | $47,000 | 8%         | $48,000 | 7%         |
| Working Capital    | $7,000  | 1%         | $67,000 | 10%        |
| Startup Cost       | $27,000 | 5%         | $27,000 | 4%         |
| **TOTAL**          | $571,000| 100%       | $641,000| 100%       |

OPEX consists of several components: raw materials, workers, facilities, laboratories, waste treatment, utilities, maintenance, and depreciation. However, in this case, the calculation of maintenance and depreciation costs is ignored. After being totalled, OPEX values that obtained annually for thermal pre-treatment are 820,059 USD, and for acid, pre-treatment is 852,086 USD which are dominated by the cost of raw materials and facilities.

Table 2. Comparison of Operational Expenditure for Thermal and Acid Pre-treatment

| Component       | Thermal | Percentage | Acid | Percentage |
|-----------------|---------|------------|------|------------|
| Raw Materials   | $642,000| 78%        | $642,000| 75%        |
| Labor           | $64,000 | 8%         | $91,000 | 11%        |
| Facility        | $101,000| 12%        | $103,000| 12%        |
| Laboratory      | $10,000 | 1%         | $14,000 | 2%         |
| Waste Treatment | $59     | 0%         | $86   | 0%         |
| Utilities       | $3,000  | 0%         | $2,000 | 0%         |
| **TOTAL**       | $820,059| 100%       | $852,086| 100%       |

For-profit analysis, the parameters determined include gross margin, ROI, PP, IRR, and NPV. This parameter can be used as a reference to see whether a project is feasible enough to be implemented. Based on the fundamental economic analysis, it can be concluded that the Illipe fat purification project has a higher profit if it uses thermal pre-treatment where the NPV value reaches 174,000 USD with a 5.5 year PP and an IRR of 11.17%.

Table 3. Comparison of Profit Parameters for Thermal and Acid Pre-treatment

| Component          | Thermal | Acid |
|--------------------|---------|------|
| Gross Margin       | 11.18%  | 7.77%|
| Return on Investment (ROI) | 17.97%  | 14.81%|
| Payback Period (PP) | 5.56 years | 6.75 years|
| Internal Rate of Return (IRR) | 11.17%  | 7.89%|
| Net Present Value (NPV) | $174,000 | $37,000|
4. Conclusion
Based on the simulation run in SuperPro Designer 9.0, the purification of 535.8 ton/year Illipe butter can produce 26.3 ton/year of purified Illipe butter with the purity of 95.4%. In one year, the plan can operate for 8,000 hours with the batch time of 10 hours for acid activation and 12 hours for thermal activation. The economic analysis shows that the purification process using thermally-activated bentonite is more profitable with NPV 174,000 USD, the payback period of 5.5 years, and IRR 11.17%.

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