Comparison of mass balance and oil quality in plant refinery I and IV

Irvan¹² *, B Trisakti¹², R Sidabutar¹, CW Situmeang¹, and FMR Siregar¹

¹Chemical Engineering Department, Universitas Sumatera Utara, Indonesia
²Sustainable Energy and Biomaterial Center of Excellence, Universitas Sumatera Utara, Medan, 20155, Indonesia

*Email: irvan@usu.ac.id

Abstract. Refinery process is the process of refining crude palm oil (CPO) to remove Free Fatty Acid (FFA), odors, and reducing color, so that it meets the quality requirements. Fractionation is a process of separating triglycerides based on palm oil based on its melting point which aims to separate the solid fraction (stearin) and liquid fraction (olein). The fractionated oil comes from the refining process. The purpose of the mass balance comparison is to determine the quality and quantity of oil produced from the refinery and fractionation processes. The production capacity at the refinery plant I and IV were 1,700 and 1,800 respectively. The amount of refined bleached and deodorized palm oil (RBDPO) produced based on the mass balance calculation at plant I and IV were 73,597 and 77,377 kg/h respectively with criteria were free of impurities and FFA.

1. Introduction

The palm oil industry is one of the major industries in Indonesia [1][2]. Oil palm plantations are one of the types of plantation crops which occupy important positions in the agriculture and plantation sectors. Palm oil is Indonesia's mainstay commodity which is developing so rapidly [3]. As the world's largest producer of crude palm oil (CPO), with total production reached around 41.5 million tons/year produced from oil palm plantations with an area of 11.6 million hectares in 2018 [4].

XYZ is one of the largest palm oil processing industries in Indonesia which produces Olein, Stearin, fatty Alcohol, PFAD, and etc. These products are processed products of crude palm oil (CPO) and crude palm kernel oil (CPKO) derived from palm oil. Purified CPO will produce cooking oil. The CPO refining process, called refinery, includes degumming, bleaching, and deodorizing.

Refinery is carried out aimed at removing impurities in CPO, such as sap, phosphatides, metal content, water, free fatty acids (FFA), and odor and changing the red color of CPO to golden yellow. The degumming stage uses phosphoric acid to agglomerate the sap, phosphatide, metal content, and others. The impurities lumps (gum) are then absorbed using bentonite soil (bleaching earth/BE) at the bleaching stage. BE which has absorbed gum is separated through the filtration stage. The deodorizing stage uses a high temperature of 255-265°C which can separate water and FFA [6].

2. Selection and Description of Process

There are two processes used in the manufacture of cooking oil with CPO raw materials, namely refinery and fractionation processes. In the selection process it is necessary to consider several aspects such as raw materials, conversion, operating conditions, economy, etc. The selection process is very important to get high-value products with cheap raw materials and low production costs [7].
2.1. Refinery
Refinery process is the process of refining of CPO to remove FFA, odors, and reducing color with the aim of improving quality. Physical Refining can complete several processes such as deacidification, deodorization, and thermal decomposition of carotenoids in one process in a deodorizer with the help of steam. The physical refining process is divided into several stages, namely pretreatment (degumming), bleaching filtration, and deodorization [6].

The materials used in Physical Refining are CPO and the products produced are refined bleached deodorized (RBD) oil and palm fatty acid distillate. Broadly speaking, the physical refining process starts from the pre-treatment (degumming) process, in which the material in the form of CPO enters with the addition of phosphoric acid (concentration 80-85%) at a rate of 0.05-0.2% of the incoming oil feed. Then heated to 90-110°C with a resident time of 15-30 minutes before proceeding to the bleacher with the addition of bleaching earth around 0.8 - 2% (depending on the quality of CPO).

Bleaching process takes place under vacuum pressure (20-25 mmHg) at a temperature of 95-110 °C with a storage time of 30-45 minutes. Then proceed to the filtration process, oil containing bleaching earth and then filtrated to make it clearer. As a measure of quality protection, oil is passed into several filter bags arranged in series, to capture some earth particles from the first filter. This is important because the presence of spent earth particles in oil can reduce oxidative stability RBD oil. Spent earth from the filtration process contains 20-40% oil. This filtration process causes a loss of oil. Refinery process flow was presented in Figure 1.

![Refinery process flow](image)

Figure 1. Refinery process flow

The last process is deodorization process, oil that has been processed before then deodorized. Bleached palm oil (BPO) was initially aerated and followed by heating 240-270°C with a heat exchanger before being pumped to the deodorizer, under vacuum (2-5mmHg). Temperatures above 270°C are avoided to reduce neutral oil losses, tocopherols/tocotrienols, and the possibility of isomerization and unwanted reactions. Under these conditions with the help of steam stripping, FFA which is still present in BPO, is distilled together with more volatile odoriferous compounds and oxidation products such as aldehydes and ketones which can cause unwanted odors and tastes in oil. At the same time, carotenoid residues also decompose, and the final product is BPO. To maximize heat energy recovery, deodorized hot oil is contacted in a heat exchanger with BPO up to 120-150°C. Further cooling is done with water to a temperature of 55-65°C before proceeding to the storage tank (storage).

2.2. Fractionation
Fractionation is the process of separating oil and fat into two or more components based on their solubility and melting point. Palm oil triglycerides consist of a mixture of fatty acids with different chain lengths and degrees of saturation. The crystallization process of oil using a cooler then followed by a separation process will produce a low-melting liquids phase (olein) and high-melting solid phase (stearin). Palm oil contains about 4-8% diglycerides, which can form eutectic mixtures with triglycerides resulting in lower solid content. This can slow down the rate of crystallization. Palm oil also contains monoglycerides but in very small amounts. The monoglyceride content in palm oil is only 1% so it does not have a significant impact on the crystallization process. The cooling rate affects
the nucleation process and oil crystal growth. When the temperature is low enough (32-36°C), the saturated glyceride will crystallize and this crystal acts as a supply for the subsequent crystallization process from the glyceride with a low melting point, resulting in a larger cluster shape. Low cooling rate and the right stirring speed can produce the desired crystal shape. The crystallization process allows similar crystals to be produced. The types of crystals in the oil formed in the crystallization process are α, β’, and β. The crystallization process occurs in the crystallizer tank. After the crystallization process is complete, a liquid or olein fraction is formed and a solid or stearin fraction will be separated using a filter press consisting of plates which are equipped with a membrane filter cloth. Then the results of the filter press will be accommodated in the olein and stearin tanks.

3. Results and Discussions

3.1. Mass Balance of RBDPO production in Refinery I and IV

This practical work was carried out to determine and evaluate of mass balance in refinery plant I and IV. This is done to determine the mass of each component used in the process and the mass of product produced, the flowrate of each production flow and the missing and stored components in system based on mass balance calculations. After obtaining the number of known components, start counting the process variables to be sought. Mass balance is a calculation of the composition of the amount of material entering, leaving and material stored in a processing device in industry. Calculations and details of the amount of these materials are also needed in evaluating the performance of process equipment in the factory. At the refinery plant, heat and mass transfer processes occur, so that the mass of material that comes out will not be the same as the mass of material that will enter the process, because there is a mass of yield retained in the process equipment and also the presence of water content, oil content and impurities lost from raw material. The using of CPO to produce RBDPO in Refinery I was presented in Figure 2.

![Figure 2](image-url)

**Figure 2.** RBDPO production from CPO in Refinery I.

Based on Figure 2, it can be seen that the CPO capacity produced by each tool is irrelevant or fluctuated, this is because there are some tools that do not work optimally. As in bleacher vessel, the quality of CPO has increased due to the presence of new impurities, namely bleaching earth that has been mixed with other impurities. Then from the bleacher vessel to the pulse tube filter, CPO capacity
decrease due to the decomposed impurity content, resulting a purer color quality with amount of 74,768.82 kg/hour. From the filter state to the pulse tube filter the filtration process occurs, so that the metal content remaining in the CPO will be reduced and the CPO capacity will be reduced. The deodorizer takes place in the process of deodorizing and color purification so that it requires a high temperature around 240-260°C so that there is an increase in BPO capacity to 78,368.08 kg/hour. After leaving the deodorizer, it will produce a main product, namely RBDPO with a capacity of 78,368.08 kg/hour. In the deodorizer, RBDPO oil is broken down into oil dots through mesh cracks. Pre-stripper with the aim to facilitate the removal of odors (ketones), Iodine Value (IV), bleaching DBPO colors, and reducing levels of FFA. Then the oil will move overflow through each tray from tray 5 to tray 1 on the stripper. Each tray is injected with 0.5-2 bar pressurization steam. Furthermore, the RBDPO that comes out of the deodorizer is flowed into the filter bag, for the last filtration process so that the resulting product has the desired color level and is free from other impurities. In the filter bag, RBDPO products are produced at 73,597.50 kg/hour. Next we have reviewed the CPO capacity at refinery plant IV with the following mass balance chart. The using of CPO to produce RBDPO in Refinery IV was presented in Figure 3.

![Figure 3](image)

**Figure 3.** RBDPO production from CPO in Refinery IV.

Based on Figure 3, it can be seen that the CPO capacity in refinery plant IV is similar to refinery plant I where the capacity produced by each tool is irrelevant or up and down. In the mixer the CPO capacity decreases from the dryer to 73,537.05 kg/hour. As in the bleacher vessel, the quality of CPO has increased due to the presence of new impurities, namely bleaching earth that has been mixed with other impurities. From the filter state to the pulse tube filter the filtration process occurs, so that the metal content remaining in the CPO will be reduced and the CPO capacity will be reduced. Then the BPO produced from the filter state is flowed into the pulse tube filter for further filtration and filtering the remaining impurities in the BPO.

In a pulse tube filter, the capacity of the BPO becomes 78,517.74 kg/hour, where the BPO is free from the remaining mixture. Then the BPO is flowed to the deodorizer for the process of deodorizing and refining the color so that it requires a high temperature around 240-260°C so that there is an increase in the capacity of the BPO to 81,809 kg/hour. Furthermore, the RBDPO that comes out of the deodorizer is flowed into the filter bag, for the last filtration process so that the resulting product has the desired color level and is free from other impurities. In the filter bag, RBDPO products are generated at 76,819 kg/hour.
4. Conclusions
Production capacity at refinery plants I and IV were 1,700 and 1,800 tons/day respectively, and produced the main product (RBDPO) used as a recycle for the process at refinery plant. At refinery plant IV, heat and mass transfer processes occurred so that the mass of material that comes out will not be same as the mass of material that will enter the process because of the yield mass retained in process equipment and also reducing of water content, oil content, and impurities from raw material. The amount of RBDPO produced based on the mass balance calculation at plant I and IV were 77,377 and 73,597 kg/hour respectively with criteria were free of impurities and FFA.

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References
[1] Irvan, Trisakti B, Tomiuchi Y, Harahap U and Daimon H 2017 IOP Conf. Ser.: Mater. Sci. Eng. 206 012094.
[2] Rifai N, Syaukat Y, Siregar H and Sa’id EG 2014 IOSR Journal of Economics and Finance 4 (5) 27-39.
[3] Irvan, Trisakti B, Maulina S and Daimon H 2018 Rasayan J. Chem, 11 (1) 378-385
[4] Jeong J, Son S, Pyon J and Park J 2014 Bioresource Technology 25 (6) 1-7.
[5] Irvan, Trisakti B, Maulina S and Daimon H 2018 Production of biogas from palm oil mill effluent: Effect of recycle sludge Oriental Journal of Chemistry 34 (1) 161-168
[6] Hardoyo, Edwin A, Permata D, Hartono and Musa 2004 Jurnal Teknik Unila 5 (2) 212-215.
[7] Bani O, Taslim, Irvan and Iriany 2015 Journal of Engineering Science and Technology Special Issue 5 29-39