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# QUALITY ENGINEERING OF CRUDE PALM OIL (CPO): USING MULTIPLE LINEAR REGRESSION TO ESTIMATE FREE FATTY ACID

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***ABSTRACT***

*FFA value is the main parameter of crude palm oil (CPO) quality which is naturally organic substances and will undergo acidification reactions because it is separated from the palm oil tree. The higher degree of maturity, the potential increase in FFA will be faster, especially in FFB with over-ripe and empty-bunch grade. Preparation time processing (pre-time) is too long, and the presence of trouble in the equipment mill that will cause downtime also potentially be the cause of decline in the quality of palm oil to be produced. But from the test results of regression model, only two factors that influence the FFA, ie over-ripe and pre-time. These factors also have a very strong correlation to the FFA and its can be described the FFA problem dominantly.*

***Keywords**: Multiple Linear Regression, Crude Palm Oil, Quality Engineering.*

## 1. INTRODUCTION

### 1.1. Background

The palm oil industry today is one of the emerging industries in Indonesia. The products of this industry is one of the main export commodities of Indonesia, especially crude palm oil (CPO). Based on data from the Indonesian Central Bureau of Statistics (BPS), the value of CPO exports reached US $ 17.60 billion in 2012. Meanwhile, in 2007 the value of exports only reached USD 7.87 billion. Thus there is an increase by an average of 20.22% per year. Significant increase was due to an increase in exports of 11.88 million tons in 2007 to 18.85 million tons in 2012, representing an average increase of 10.09% per year. In addition it is also supported by the increase in the oil price of USD 662.60 per tonne in 2007 to USD 934.05 per tonne in 2012, or an increase of 10.40% per year.

In CPO trading standard, quality parameters are taken into account is the concentration of free fatty acids (FFA), moisture and impurity level (a). Moisture and impurity content are quality parameters that can be controlled through treatment in the production process equipment, especially in the clarification station. If both of these parameters on CPO products are produced and stored in the storage tank have been met, then both parameters will remain stable during storage. While FFA parameter is the parameter that will continue to rise naturally. To maintain the quality of CPO, especially FFA, the treatment of fresh fruit bunches (FFB) be arranged in such a way since in the estate, which since FFB harvesting process. Similarly, post-harvest handling, such as transport and processing system in the palm oil mill (POM). Way in the estate FFB treatment greatly affect the quality of CPO produced in POM (b). FFB Treatment in the estate or in the POM by means of curing will result in the increase of FFA that trigger the growth of mold and bacteria in FFB which exceeds the threshold of food safety (c).

In terms of quantity, the oil contained in the already stopped when the FFB is starting to experience the process of maturation, which since 180 days after pollination of flowers (a). Thus, choosing FFB mature, or even tend to pass mature, will only cause POM obtain raw materials which are already high FFA values. The higher the degree of maturity, the potential damage to the fruit will be even greater. This is especially true in the FFB with *over-ripe* and *empty-bunch* grade. FFB with *over-ripe* grade have the characteristics of the outer layer of the fruit was gone, even the fruit of the center is

starting to loss. While *empty-bunch* grade are leaving fruit on the inside only. Both of these grades have started softening his condition so easy bruising. Preparation time process (*pre-time*) is too long, the rate of processing is not balanced by the rate of arrival of FFB in bunches reception stations, and limited damage to the machinery plant will cause a decrease in the rate of processing or even result in interruption of the process that will lead to a stop (*downtime*). These conditions are potentially be the cause of the decline in the quality of palm oil to be produced. Even in many other industries, preparation time (*pre-time*) is also the one of the causes of quality problems, as concluded by (d) which simulate various levels of *pre-time* and how it affects the quality. Similarly, *downtime*, as concluded by (e) is also one of the causes of quality problems, namely the increasing number of defective products.

Through daily statistical data of the mill will be identified how the relationship between the FFB quality grading, ie *over-ripe* and *empty-bunch*, preparation time FFB processing (*pre-time*) and *downtime* to FFA. Through multiple linear regression analysis will be analyzed the effect of the FFB quality grading, which is *over-ripe* and *empty-bunch*, the length of *pre-time* and *downtime* to the level of product quality. Would thus obtained a clear picture of the relationship of the above four factors on the product quality produced. Therefore, it is necessary to do research on improving the quality of palm oil products with multiple linear regression analysis method through the analysis of the relationship between the FFB quality grading, which is *over-ripe* and *empty-bunch*, the length of *pre-time* and *downtime* due to damage machinery and equipment to increase in FFA which is the main parameters of quality of CPO.

### 1.2. Problem Statement

From the results of the identification of the problems mentioned above, it can be formulated in this research problem, namely how to influence the FFB quality grading, which is *over-ripe* and *empty-bunch*, the length of *pre-time* and *downtime* due to damage to machinery and equipment to FFA as the main parameters of quality of CPO?

### 1.3. Discuss Purpose

The purpose of discussion was to determine the effect of the FFB quality grading, especially *over-ripe* and *empty-bunch*, the length of *pre-time* and *downtime* due to damage to machinery and equipment to FFA as the main parameters of quality of CPO.

### 1.4. Limitation of Problem

The discussion only discuss how to influence and relationship between the causal factors of FFA to be indicated by the multiple linear regression model, the coefficient of correlation and the coefficient of determination.

## 2. THEORETICAL BACKGROUND

### 2.1. Quality

Quality is one of the factors that will affect how the attitudes and behavior of customers towards the products produced by a company. The definition of quality in some sense (f), among which are: 1) the features of a product that meet customer needs and thereby provide customer satisfaction; and 2) free of flaw and error that need rework or that generate a field failure, customer dissatisfaction, customer claims, and so on. While (g) says that conventionally, the quality is usually directly describe the characteristics of a product such as performance, reliability, ease of use, aesthetics and so on. While strategically, quality is everything that is able to meeting the needs of customers. In addition, the quality can also be interpreted as anything that determine customer satisfaction and effort to change the direction of continuous improvement, or which is known as *Q-MATCH* (Quality = Meets the Agreed Terms and Changes). The definition of quality as the ratio between performance and expectations of a product (h), which is denoted as $Q = P/E$. If $Q$ is more than 1, it means that the performance of the products exceed customer expectations, while if $Q$ is less than 1, it means that the performance of the product does not meet customer expectations. Determination of $P$ and $E$ are likely to be based on perception, where the performance will be determined by the organization and the customer will determine expectations. While the notion of quality according to the American Society for

Quality as stated by (i) that is the overall quality of the features and characteristics of the products or services capable of satisfying the needs of the visible or disguised. From the definition above qualities, can be drawn a conclusion that quality is a wide range of desired characteristics or required by customers for a product or service that must be met by the companies that produce them. These characteristics may be something tangible or intangible.

According to Garvin, as proposed by [h,j,k], there are nine dimensions of quality as follows: 1) *performance*, which is the basic operating characteristics of a product, such as how well the handling of a car or mileage; 2) *features*, ie additional items are added to the basic features, such as a CD stereo or leather interior in the car; 3) *reliability*, ie the probability that a product will operate well within the expected time period, such as television would work without improvement for about seven years; 4) *conformance*, namely the degree to which a product meets pre-construction standards; 5) *durability*, ie how long the life of the product before replacement, such as a pair of shoes might be expected to be used for life; 6) *serviceability*, the ease of getting fixes, speed improvements, as well as courtesy and competence of personnel who carry out repairs; 7) *aesthetics*, that is how the product looks, feels, sounds, smells, or tastes; 8) *safety*, which guarantees that the customer will not suffer injury or danger of products, such as in a car; and 9) *other perceptions*, ie subjective perception based on brand name, advertising, and the like.

Quality control is the use of techniques and activities to achieve, maintain, and improve the quality of products and services (h). This can be done by integrating engineering and the following activities: 1) specification of what is needed; 2) the design of products or services to meet those specifications; 3) production or installation to meet the objectives of these specifications; 4) examination to determine compliance with specifications; and 5) review the use of in order to provide information to revise the specification if necessary. Utilization of these activities will give the customer the best product or service at the lowest cost.

### 2.2. Crude Palm Oil

Crude palm oil (CPO) is the oil obtained from milking or compression seeds or other parts of the oil source without any further processing except filtration and drying to lower the moisture content. The composition of fatty acids of vegetable oils will differ depending on the type of plants (l). The main constituent substances oil-fats (vegetable and animal) are triglycerides, ie triester glycerol with fatty acids ($C_8$ – $C_{24}$).

When compared with other sources of vegetable oils, palm oil is the highest productivity. CPO productivity reached 2.5 – 4 tonnes per hectare per year (m). While other sources of vegetable oil is only about 0.23 – 1.5 tons per hectare per year. With high productivity makes palm oil a source of vegetable oil that is quite reliable in the world, considering that not all countries in the world can be planted with palm oil. This is because these plants require specific area, such as climate, rainfall and so on.

CPO is processed palm fruits through the boiling process fresh fruit bunches (FFB), threshing, and pressing. CPO is obtained from the fruit of the palm oil mesocarp which has undergone several processes, namely sterilization, pressing, and clarification. This oil is a product of the first level that can provide added value about 30% of the value of fresh fruit bunches (a). CPO can be used as an industrial raw material for cooking oil, soap, margarine and oleochemical. Judging from the proportions, the industry has been absorbing the biggest CPO is the cooking oil industry (79%), then the oleochemical industry (14%), the soap industry (4%), and the remaining margarine industry (3%). CPO separation can produce basic oleochemicals consisting of fatty acids and glycerol. Overall the palm oil production process can produce 73% olein, stearin 21%, 5% palm fatty acid distillate (PFAD), and 0.5% effluent.

CPO quality parameters only include FFA, moisture, impurities and DOBI level (deterioritation of bleachibility index) alone (l). There is also a limit only FFA, moisture, impurities, peroxide and iron content alone (m). However, based on SNI 01-2901-2006, CPO quality requirements only include color is reddish orange, moisture, impurities, FFA

(as palmitic acid) and iodine numbers (n). Based on some of the opinions mentioned above it can be concluded that the CPO quality parameters that are generally used are FFA, moisture and impurities level. As has been explained above authors that moisture and impurities can be controlled through treatment in the production process equipment in the clarification station, while the FFA is a parameter whose value will increase naturally. Therefore we will only examine the parameters of FFA in this paper.

## 3. METHODOLOGY

### 3.1. Definition of Variables

In this paper we will use five variables, namely a dependent variable or variables effect and four independent variables or causal variables. These five variables are: 1) percentage of *over-ripe* FFB grading category; 2) the percentage of *empty-bunch* FFB grading category; 3) preparation time to FFB processing (*pre-time*); 4) when the cessation of the process trouble on machinery and equipment production process (*downtime*); and 5) the content of FFA in CPO production. Which is the dependent variable in this case is the FFA value ($y$) in CPO production. While the other four variables are independent variables or causal variables ($x$). Which became independent variables in this case are *over-ripe* ($x_1$), *empty-bunch* ($x_2$), *pre-time* ($x_3$) and *downtime* ($x_4$).

### 3.2. Classical Assumption Test

Classical assumption test is a necessary precondition to validate the multiple linear regression model. According to the literatures [q,r], if the data to be used already passed the classical assumption test, then the data is valid and fit for use as a multiple linear regression analysis of data. The classical assumptions test include: 1) normality test; 2) heteroscedasticity test; 3) autocorrelation test; and 4) multicollinearity test.

Normality test will be conducted on the residual of the regression model is formed. Normality test is needed to see whether the conditions of the data to be regressed to normal or not (s). If not, then it could be the transformation of data into another form. While the methods to be used in the test for normality in this study is the Chi-squared test. Based on the literature (q), the normality test with Chi-square.

The next classic assumptions test in multiple linear regression model is heteroscedasticity or a variant that is not the same for all variables observation. There are two ways of detecting the presence of heteroskedasticity, namely the method of graphs and statistical methods. In this study will be used statistical methods, namely the *Glesjer* correlation coefficient test.

Autocorrelation test aims to test whether in a linear regression model there is a correlation between the residual on a period with an residual in the previous period. If there is a correlation, then there is a problem called autocorrelation. Autocorrelation arises because successive observations over time are related to each other. This problem arises because the residual is not free from one observation to another observation. It is often found in the time series data due to interference with an individual or group of individuals or groups tend to affect the same in the next period. Good regression model is a regression that is free of autocorrelation. The method will be used to test the autocorrelation in this study is the *Durbin-Watson* test.

Multicollinearity test aims to test whether the regression model found a high correlation between independent variables or perfect. If the multicollinearity between the independent variables occur perfectly, then the regression coefficient of the independent variable can not be determined and the value of the standard residual into infinity. If the high multicollinearity among the independent variables, the independent variable regression coefficient can be determined, but possess a high value of the standard residual, mean regression coefficient value can not be estimated precisely.

### 3.3. Correlation Test

To see the level of the relationship of the four variables cause the FFA variable, it will be tested by correlation analysis, which in this case will be used *Pearson* correlation model of the population (p). The value of the coefficient of correlation ($r$) suggested a link

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between the variables cause the FFA. The coefficient of determination ($r^2$) states how much the variables causes explains the FFA variable in CPO production. Test multiple correlation coefficient ($R$), which is to see how the level of the relationship between the variables cause ($x_1$, $x_2$, $x_3$ dan $x_4$) simultaneously with causal variables ($y$). Acceptance criteria $H_0$ is if $F < F_{\text{table}}$ at 5% level of significance.

While testing the partial coefficient of correlation ($r$), which is to see how the level of the relationship between each causal variables ($x_1$, $x_2$, $x_3$ and $x_4$) partially the result variable ($y$). Acceptance criteria $H_0$ is if $-t_{table} < t < t_{table}$ at 5% level of significance on both sides.

### 3.4. Formulation of Regression Model

To examine the relationship between the four causal variables, ie the percentage of *over-ripe* ($x_1$) and *empty-bunch* ($x_2$), and *pre-time* ($x_3$) and *downtime* ($x_4$) of the FFA variable ($y$) with CPO, it will be testing with multiple linear regression analysis. The multiple linear regression model was used to predict the rate of sedimentation in the river and the results are very useful to anticipate the occurrence of floods (o). The multiple linear regression modeling (p) for the population are as follows:

$$\hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon \quad (1)$$

where $\varepsilon$ is population *error* from estimation of $\hat{Y}$ value to actual of $Y$ value. If it is used to sample, the formula become:

$$\hat{y} = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + e \quad (2)$$

where: $y$ = FFA value
$x_1$ = FFB grading *over-ripe*
$x_2$ = FFB grading *empty-bunch*
$x_3$ = preparation time (*pre-time*)
$x_3$ = *downtime*
$b_1, b_2, b_3, b_4$ = coefficien of regression for $x$ variables ($x_1, x_2, x_3, x_4$)
$b_0$ = *intercept*
$e$ = *residual*

### 3.5. Regression Model Test

To see whether the model of multiple linear regression equation above can be used or not, it will be testing the hypothesis using analysis of variance (ANOVA) to simultaneous test. Simultaneous test done to see if the cause of the four variables ($x_1$, $x_2$, $x_3$ and $x_4$) influence the result variable ($y$) simultaneously or not. Acceptance criteria $H_0$ is if $F < F_{\text{table}}$ at 5% level of significance. While the partial test done to see if each causal variables ($x_1$, $x_2$, $x_3$ and $x_4$) affects variable due to ($y$) partially. Acceptance criteria $H_0$ is if $-t_{table} < t < t_{table}$ at 5% level of significance on both sides.

## 4. DATA ANALYSIS AND DISCUSSION

### 4.1. Classical Assumption Test

Normality test was intended to see if the variable quality to be studied normal distribution or not. Normality test can be performed using Chi-square test.

Heteroscedasticity test intended to see if there is data that has a variance that is not the same for all variables observation. In this study will be used statistical methods, namely the *Glesjer* correlation coefficient test.

Autocorrelation test aims to test whether in a linear regression model there is a correlation between the residual on a period with an residual in the previous period. If there is a correlation, then there is a problem called autocorrelation. The method will be used to test the autocorrelation in this discuss is the *Durbin-Watson* test.

Multicollinearity test aims to test whether the regression model found a high correlation between independent variables or perfect.

Results of the classical assumption test as shown in Table 1.

### 4.2. Corellation Test

Simultaneous coefficient of correlation test done to see if the four causal variables ($x_1$, $x_2$, $x_3$ and $x_4$) have a significant relationship to the result variable ($y$) simultaneously or not.

Partial coefficient of correlation test done to see if the four causal variables ($x_1$, $x_2$, $x_3$ and $x_4$) have a significant relationship to the result variable ($y$) partially or not. Results of the correlation test as shown in Table 2.

From Table 2 shown that *over-ripe* ($x_1$) and *pre-time* ($x_3$) have a significant relationship partially with the FFA in CPO production, if the other variables are fixed. While *empty-bunch* ($x_2$) and *downtime* ($x_4$) have not a significant relationship partially with the FFA

in CPO production, if the other variables are fixed.

Table 1. Result of Classical Assumption Test

| Test | Type of Test | Criteria | Results | Conclusion | |
|---|---|---|---|---|---|
| Normality | Chi Kuadrat | $\chi^2 < 12.59$ | 11.43 < 12.59 | Accepted | Data normal |
| Heteroscedasticity | Uji Glesjer | $-1.968 < t < 1.968$ | $x_1$ : 1.489<br>$x_2$ : – 0.433<br>$x_3$ : – 1.160<br>$x_4$ : 0.348 | Accepted<br>Accepted<br>Accepted<br>Accepted | Nothing heteroscedasticity |
| Autocorrelation | Durbin-Watson | $d > 1.76$ | 2.15 > 1.76 | Accepted | Nothing autocorrelation |
| Multicolinearity | VIF | VIF < 10 | $x_1$ & $x_2$ : 1.003<br>$x_1$ & $x_3$ : 1.023<br>$x_1$ & $x_4$ : 1.012<br>$x_2$ & $x_3$ : 1.003<br>$x_2$ & $x_4$ : 1.343<br>$x_3$ & $x_4$ : 1.000 | Accepted<br>Accepted<br>Accepted<br>Accepted<br>Accepted<br>Accepted | Nothing multicolinearity |

Table 2. Result of Correlation Test

| Test | Type of Test | Criteria | Results | Conclusion | |
|---|---|---|---|---|---|
| Simultaneously | $F$ | $F < 2.405$ | 440.686 | Rejected | Any correlation |
| Partially | $t$ | $-1.968 < t < 1.968$ | $x_1$ : 23.153<br>$x_2$ : – 0.936<br>$x_3$ : – 4.055<br>$x_4$ : 0,345 | Rejected<br>Accepted<br>Rejected<br>Accepted | Any correlation<br>Nothing correlation<br>Any correlation<br>Nothing correlation |

### 4.3. Formulation of Regression Model

To examine the relationship between the four causal variables, ie the percentage of *over-ripe* FFB grading ($x_1$) and *pre-time* ($x_3$) to the FFA variable ($y$) with the CPO, it will be testing with multiple linear regression analysis. From the data contained in the appendix, the regression model is obtained as follows:

$$\hat{y} = 1.952 + 0.126\, x_1 - 0.123\, x_3 \qquad (3)$$

Equation (3) has a correlation coefficient $R$ = 0.856 and the coefficient of determination $R^2_{y.13}$ = 0.733, which means that 73.3% of the causes of FFA in CPO production values can be explained by two variables causes ($x_1$ and $x_3$) that, while the remaining 26.7% are caused by other factors. To see whether the multiple linear regression equation can be used or not, it will be tested by regression model test.

### 4.4. Regression Model Test

To see if the multiple linear regression equation above, the equation (3) can be used or not, it will be testing the hypothesis using analysis of variance (ANOVA) to test simultaneously. Simultaneous test done to see if the four causal variables ($x_1$ and $x_3$) influence the result variable ($y$) simultaneously or not.

Partial test done to see if the four causal variables ($x_1$ and $x_3$) influence the result variable ($y$) partially or not.

Table 2. Result of Regression Model Test

| Test | Type of Test | Criteria | Results | Conclusion | |
|---|---|---|---|---|---|
| Simultaneously | $F$ | $F < 2.405$ | 371.980 | Rejected | Any influence |
| Partially | $t$ | $-1.968 < t < 1.968$ | $x_1$ : 26.556<br>$x_3$ : – 4.167 | Rejected<br>Rejected | Any influence<br>Any influence |

### 4.5. Discussion

From the classical assumption test results shown that the available data are normally distributed, each variable has the same variance, there is no autocorrelation and contains no multicollinearity. This means that the available data are eligible to be analyzed using multiple linear regression method. Therefore, this method allows to be used as a method to estimate the value of FFA as the main parameter CPO quality.

From the test results simultaneously seen that four variables have a very strong correlation to the FFA. It is characterized by the coefficient of correlation $R$ = 0.857. Thus the coefficient of determination $R^2$ = 0.734, which means that 73.4% of the causes of FFA can be explained by four variables, while 26.6% is explained by other factors. While partially seen that the only *over-ripe* variable ($x_1$) and *pre-time* variable ($x_3$) who have a significant relationship to the FFA, whereas the other variables did not have a significant relationship.

From the regression model formed seen that simultaneously, *over-ripe* variable ($x_1$) is dominant. It is characterized by the coefficient $b_1$ = 0.126. *Pre-time* variable ($x_3$) turns out to have a negative effect on the value of the FFA. This means that the increase in the value of the variable will decrease the value of the FFA. However, all four of these variables must be controlled in order to keep the quality of the CPO resulting will also be good. It is characterized by the coefficient of correlation $R$ = 0.856. Thus the coefficient of determination $R^2$ = 0.733, which means that 73.3% of the causes of FFA can be explained by two variables, while 26.7% is explained by other factors.

## 5. CONCLUSION

Based on the discussion, it can be concluded that the FFB quality grading, especially *over-ripe* and the length of *pre-time* or preparation time processing have an influence on the CPO quality, ie the FFA content. The *over-ripe* influence is positive and the *pre-time* influence is negative. The relationship of these factors to the FFA is also very strong and can be determined the FFA problem dominantly.

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