

CPO Product Quality Control at PT. Kurnia Mitra Sawit Using The T² Hotelling Method

Rio Anggara Panjaitan

Universitas Islam Negeri Sumatera Utara, Medan, Indonesia

ABSTRACT

This study aims to analyze the stability of the Crude Palm Oil (CPO) production process at PT. Kurnia Mitra Sawit through a multivariate quality control approach using the T² Hotelling method. The background of this study is based on the importance of maintaining CPO quality in accordance with company standards, especially for key quality parameters such as Free Fatty Acid (FFA), moisture content, and dirt content. Uncontrolled parameters can reduce product quality and affect the selling price of CPO in the market. The research was conducted by collecting production data and performing statistical tests using the T² Hotelling diagram to detect simultaneous process variations. Initial analysis results showed that several samples were outside the upper control limit (UCL), indicating specific causes in the production process. However, after repeated improvements and controls, all data points were finally within the control limits, with a UCL value of 18.68 and a median of 3.70. This indicates that the production process is statistically controlled and contains only natural variation. Thus, this method is effective for monitoring the stability of the CPO production process and preventing quality deviations in the future.

Keywords: T² Hotelling, Generalized Variance, Crude Palm Oil, Quality Control, Statistical Process Control

Email Address: rioanggara190203@gmail.com

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Introduction

The palm oil industry is one of the strategic sectors in the Indonesian economy because it plays an important role as a contributor to foreign exchange and a driver of regional economic growth. The main product of palm oil processing, Crude Palm Oil (CPO), has high economic value and is the main raw material for various derivative industries such as food, cosmetics, and energy. However, the quality of CPO is highly dependent on the stability of the production process, which involves various important variables such as free fatty acid content, moisture content, and dirt content[1]. Uncontrolled variables can cause a decline in CPO quality, rancidity, and a decrease in selling prices on the international market. Therefore, quality control is a crucial aspect to ensure consistency in production results[2].

Previous studies have shown that multivariate quality control can provide a comprehensive overview of the stability of processes that are simultaneously influenced by more than one variable. One effective method in this context is T² Hotelling, which can be used to detect statistical process deviations and identify the factors causing variation. Based on this phenomenon, this study was conducted at PT. Kurnia Mitra Sawit, a CPO processing plant in North Labuhan Batu Regency, with the aim of determining the stability of the CPO production process and ensuring that the process is statistically controlled through the application of the T² Hotelling method. The main questions in this study are to what extent the CPO production process is under control, and how the T² Hotelling method can help companies detect and minimize special causes of variation in the production system[3].

Research Methodology

This study uses a quantitative approach with the T² Hotelling multivariate quality control method to analyze the stability of the Crude Palm Oil (CPO) production process at PT. Kurnia Mitra Sawit. The main purpose of this method is to detect simultaneous process deviations in several mutually correlated quality variables, namely Free Fatty Acid (FFA), Moisture, and Dirt. These three variables were selected because they are the main indicators that determine the quality of CPO in accordance with palm oil industry standards[4]. The data used in this study is secondary data obtained from CPO quality laboratory test results during a specific period at PT. Kurnia Mitra Sawit. The analysis steps began with data collection and cleaning, followed by normality and correlation tests between variables to

ensure that the data met the assumptions of the Hotelling's T^2 method[5]. After that, the T^2 statistical value was calculated. The Hotelling T^2 control chart for data in subgroup form can be formulated with a specific equation used to monitor the stability of multivariate processes in each data group involving p variables[6].

$$T_1^2 = (x_i - \bar{x})' S^{-1} (x_i - \bar{x})$$

The value T_i^2 is the Hotelling's T^2 statistic for the i -th sample or observation. Before constructing a Hotelling's T^2 control chart, a normality test between variables is first performed for all observation data. If the test results show that the data are normally distributed[7], then the process of creating a Hotelling's T^2 control chart can continue. Based on its application, there are two types of Hotelling's T^2 control charts, namely for grouped data and individual data with $m=1$, where m indicates the number of samples in each data subgroup. The formula for Hotelling's T^2 statistic for grouped observations is as follows:

$$T^2 = (x_i - \bar{x})' S^{-1} (x_i - \bar{x})$$

steps in constructing a T^2 Hotelling Individual control chart consist of two main stages. The first stage is the calculation stage, while the second stage is the control stage, which is the process of interpreting the results of the control chart that has been created [8].

System Developmen Methods

Hotelling's T^2 calculation stage:

1. Calculate the average value of each characteristic using the formula below:

$$x_i = [x_1, x_2, \dots, x_n]$$

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}$$

2. Calculate the covariance matrix using the formula:

$$S = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})(x_i - \bar{x})'$$

$$S = \begin{bmatrix} S_{11} & S_{12} & \dots & S_{1k} \\ S_{21} & S_{22} & \dots & S_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ S_{n1} & S_{n2} & \dots & S_{nk} \end{bmatrix}$$

3. Calculating Hotelling's T^2 statistic

$$T_i^2 = \begin{bmatrix} (x_1 - \bar{x})' S^{-1} (x_1 - \bar{x}) \\ (x_2 - \bar{x})' S^{-1} (x_2 - \bar{x}) \\ \vdots \\ (x_n - \bar{x})' S^{-1} (x_n - \bar{x}) \end{bmatrix}$$

4. Calculating the UCL value

$$UCL = \frac{(n-1)^2}{n} \beta a, \frac{k}{2}, \frac{(n-k-1)}{2}$$

$$LCL = 0$$

$\beta a, \frac{k}{2}, \frac{(n-k-1)}{2}$ representing the Beta distribution with degrees of freedom, where n is the amount of data and k is the number of variables.

5. Compare the UCL value with T^2 Hotelling

Results And Discussion

A boxplot is a form of statistical visualization used to describe data distribution and identify outliers.

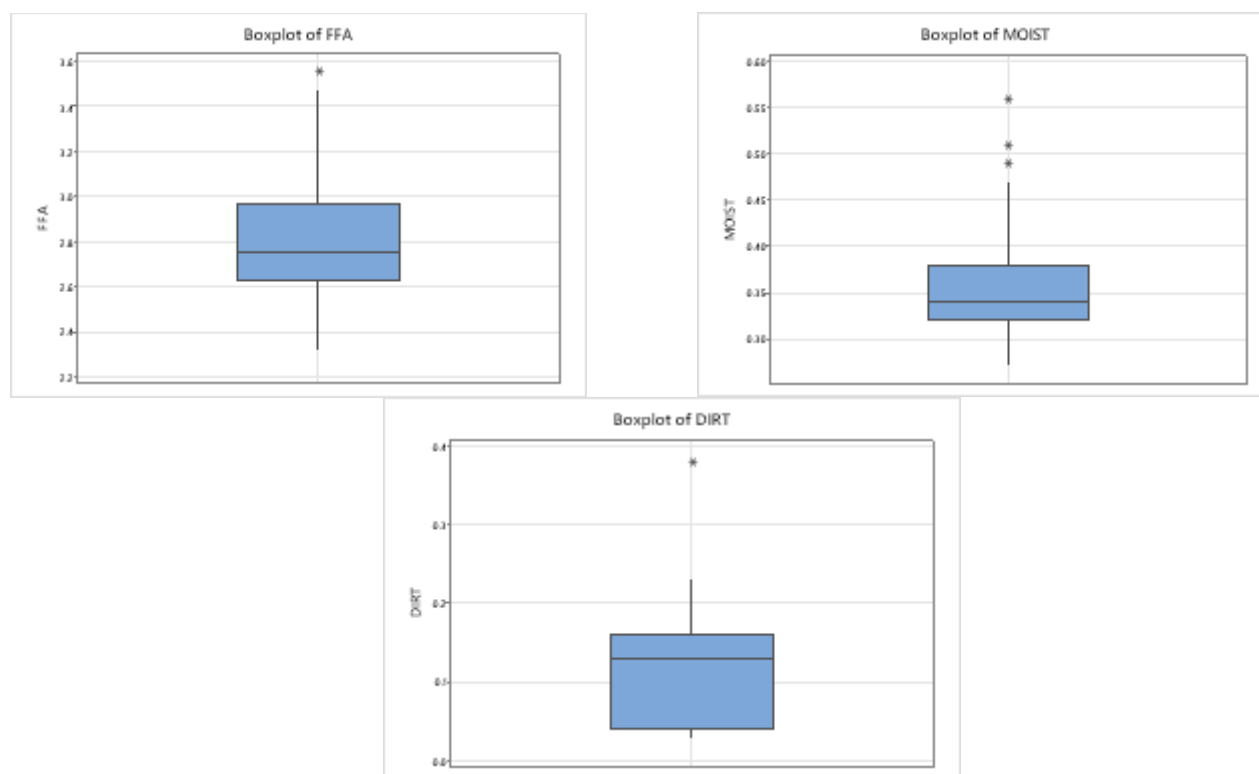


Figure 1. Boxplot of Variabel

This diagram displays five key values, namely the minimum (lowest value without outliers), the first quartile (Q1) as the lower limit of the initial 25% of data, the median (Q2) as the middle value of the data, the third quartile (Q3) as the upper limit of the final 25% of data, and the maximum (highest value without outliers). In addition, symbols such as asterisks (*) are usually used to indicate the presence of outliers, which are values that are far from most of the data and can provide important information about variations or anomalies in the data distribution. In the boxplot of the FFA, MOIST, and DIRT variables, the data distribution shows a relatively normal distribution despite the presence of several outliers. In the boxplot of the FFA, MOIST, and DIRT variables, the data distribution shows a relatively normal distribution despite the presence of several outliers. In the FFA variable, there is one outlier at the top around 3.6, indicating that there are samples with free fatty acid levels higher than the average. However, overall, the FFA data distribution appears to be fairly symmetrical and stable. For the Moist variable, there are three outliers at the top with water content exceeding 0.50, indicating that most of the water content data is within the normal range, but some samples have high water content, causing the data distribution to skew slightly to the right (positively skewed). Meanwhile, in the Dirt variable, only one outlier was found at the top around 0.38–0.40 with the data distribution pattern remaining symmetrical overall.

Tabel 1. Table of Descriptive Statistics

Variabel	Mean	Median	Q1	Q3	IQ	Min	Max
Range							
FFA	2.79753	2.75	2.625	2.965	0.34	2.32	3.56
MOIST	0.354824	0.34	0.32	0.38	0.06	0.27	0.56
DIRT	0.117176	0.13	0.04	0.16	0.12	0.03	0.38

Based on the descriptive statistics table obtained from the exploration results through the boxplot diagram, it can be explained in more detail that this analysis provides an overview of the data characteristics of the three CPO quality variables, namely FFA, Moist, and Dirt. Through these exploratory results, it is possible to determine measures of central tendency such as the mean and median, as well as measures of dispersion such as the first

quartile (Q1), third quartile (Q3), interquartile range (IQR), minimum value, and maximum value.

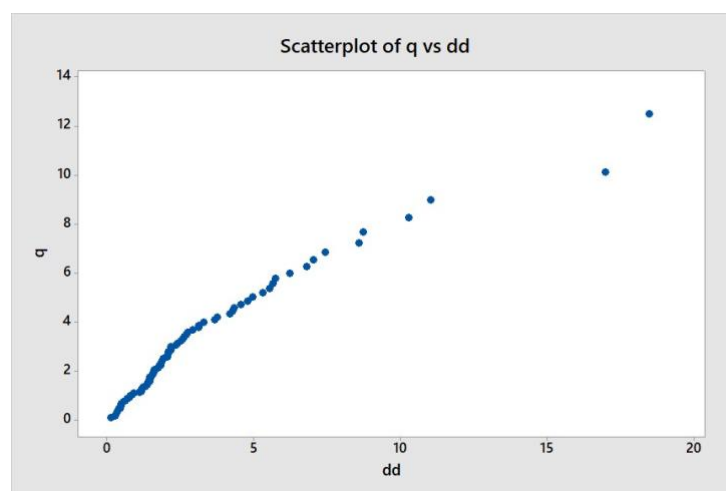


Figure 2. Scatterplot of q vs dd

Based on the results of the multivariate normal distribution test using the Q-Qplot shown in the figure, it can be seen that the data points on the scatter plot tend to form a straight line pattern. This indicates that the data is normally distributed in a multivariate manner. To assess the level of linearity of the Q-Qplot results, the correlation coefficient between variables (d^2_i) was calculated using Minitab.

Based on the calculation of the squared distance (d^2_i), it is known that 62.3% (proportion 0.6235) is more than 50%, so H_0 is accepted. The data exceeds the threshold value of 2.366, which is the value of ($X^2_{3,0.5}$) in the Chi Square table. Thus, out of a total of 85 data points, there are 53 points within the ellipse (as expected) and 32 other points outside the ellipse. These results indicate that the null hypothesis (H_0) is accepted, so it can be concluded that the FFA, Moist, and Dirt data for the May, June, and July periods follow a multivariate normal distribution[9].

Generalized Variance

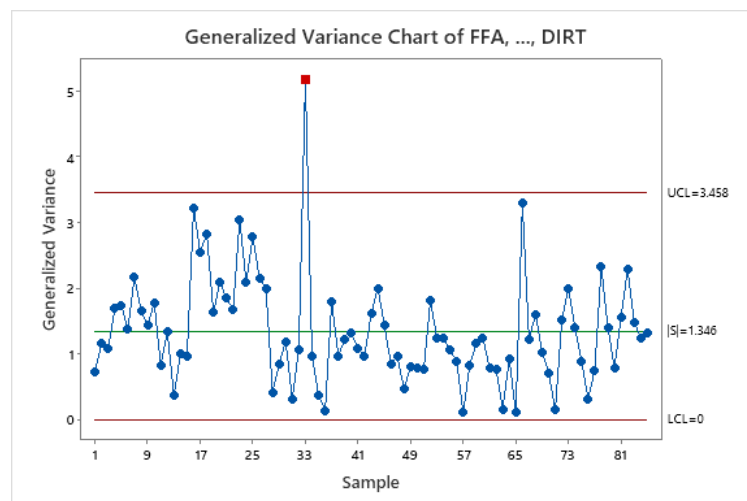


Figure 3. Generalized variance Before Process Improvement

The graph shows the Generalized Variance for CPO quality parameters, namely FFA, Moisture, and Dirt. This graph is used to monitor the stability of the production process in a multivariate manner, by observing the joint distribution between the three variables over time. Based on observations from 85 samples, most data points are within the upper control limit (UCL = 3.458) and lower control limit (LCL = 0), indicating that, in general, the production process is statistically controlled. However, there is one data point, namely sample 33, which exceeds the upper control limit. Overall, the CPO processing process at the company is still relatively stable, but investigation and corrective action are needed for samples that exceed the control limits to prevent excessive variation.

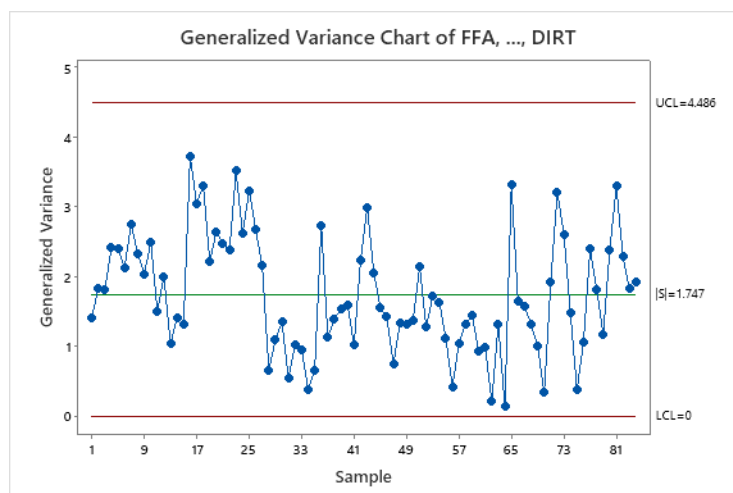


Figure 4. Generalized variance After the 33rd point was removed

The graph above shows the quality of CPO consisting of FFA, Moisture, and Dirt with 84 samples. This graph is used to monitor the stability of production process variability in a multivariate manner, namely by looking at how much the data for these three variables spread together over time. Based on the observations, all data points are within the upper control limit ($UCL = 4.486$) and lower control limit ($LCL = 0$), with a generalized variance average value of $|S| = 1.747$. This condition indicates that no points exceed the control limits, so the production process is statistically controlled, with no indication of extreme variation or major disturbances in the production system[10].

T2 Hotelling Control Chart

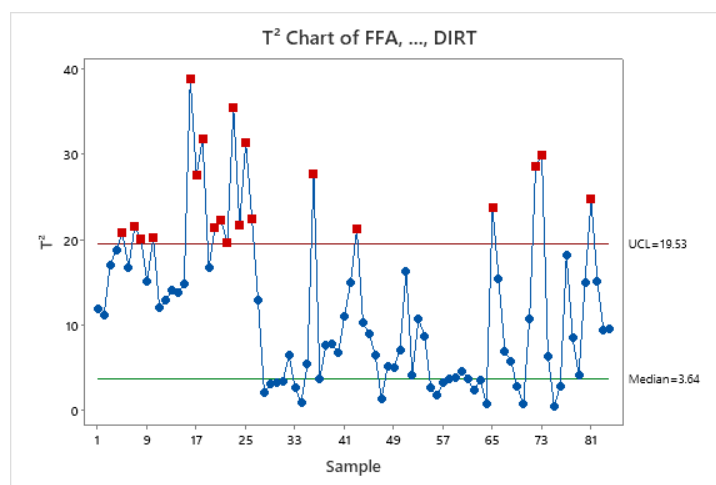


Figure 5. T2 Hotelling Before Process Improvement

The Hotelling's T² graph above shows CPO quality parameters including Free Fatty Acid, Moisture, and Dirt. Based on the graph, there are several red dots indicating that the samples exceed the upper control limit (out of control) with a UCL of 19.53, especially in the range from the initial sample to around the 25th sample and several samples approaching the 70th. Points that exceed the control limits are marked with a red symbol, indicating that during that period there was a significant deviation from normal process conditions. Thus, the CPO production process still experiences multivariate average instability, requiring further evaluation and investigation of samples that exceed the control limits to identify the source of variation.

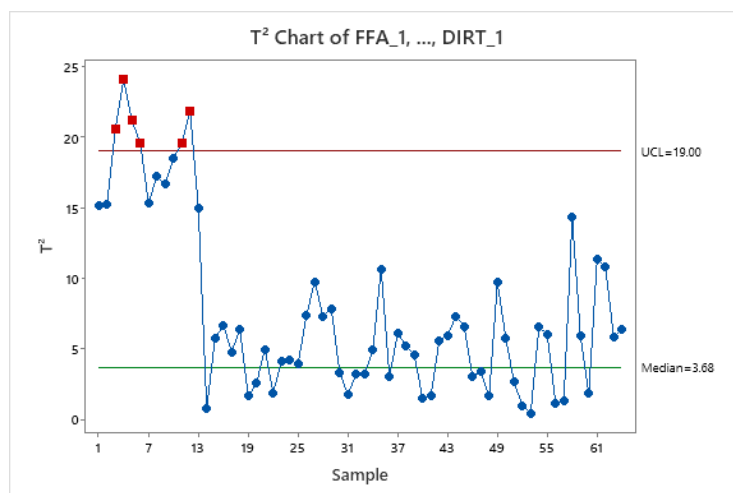


Figure 6. T² Hotelling After process improvement

It can be seen that most of the observation points are within the statistical control limits, but there are several samples at the beginning of the process (samples 3, 4, 5, 6, 11, and 12) that exceed the upper control limit (UCL = 19.00). These red points indicate a significant deviation from normal production process conditions, which indicates that during this period there was instability in CPO quality. After the 12th sample, the T^2 value began to decline and was below the UCL, with most of the values around the median = 3.68, indicating that the production process began to stabilize and was statistically controlled. Nevertheless, further evaluation and investigation are needed for samples that exceed the control limits.

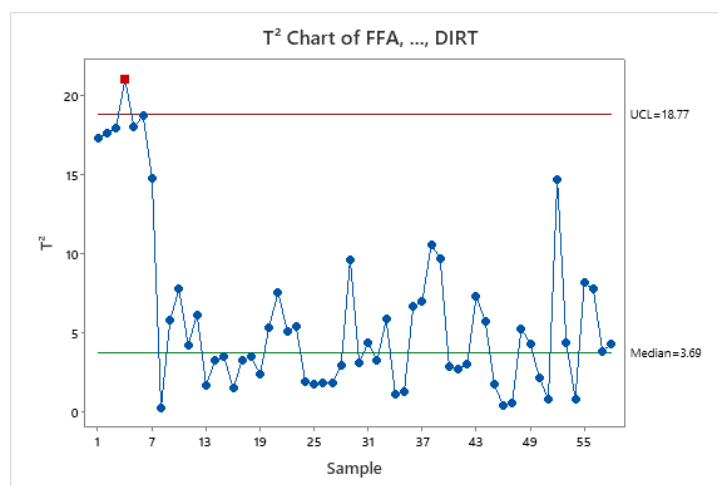


Figure 7. T² Hotelling After points 3, 4, 5, 6, 11, and 12 are removed

Based on the T^2 Hotelling graph above, which monitors the multivariate relationship between the variables FFA, moisture, and dirt, it can be seen that most of the observation points are below the upper control limit (UCL = 18.77), indicating that the CPO production process is generally stable and statistically controlled. However, there is one data point at the beginning of the observation (sample 4) that exceeds the upper control limit, marked by a red dot on the graph. After that point, the T^2 value decreased significantly and tended to fluctuate around the median value of 3.69. This indicates that the subsequent process ran consistently and under control. Thus, it can be concluded that the quality control system is working well, although it is necessary to evaluate the initial sample to ensure that no repeated deviations occur in the future.

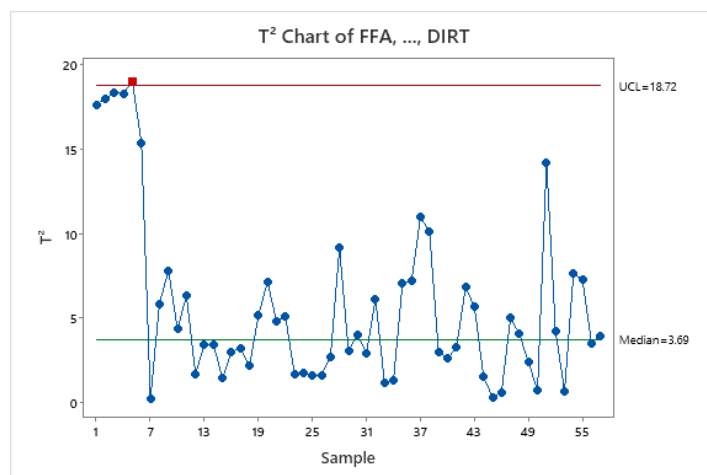


Figure 8. T² Hotelling After the 4th point is removed

The Hotelling's T² graph above illustrates the multivariate relationship between the variables FFA, Moisture, and Dirt with a total of 58 samples. Almost all observation points are within statistical control limits with an UCL of 18.72 and a median of 3.69. Only one point at the beginning of the observation (sample 5) exceeded the upper control limit, indicating specific variation or process deviation at the beginning of production. Evaluation and corrective action are needed at the early stages of production.

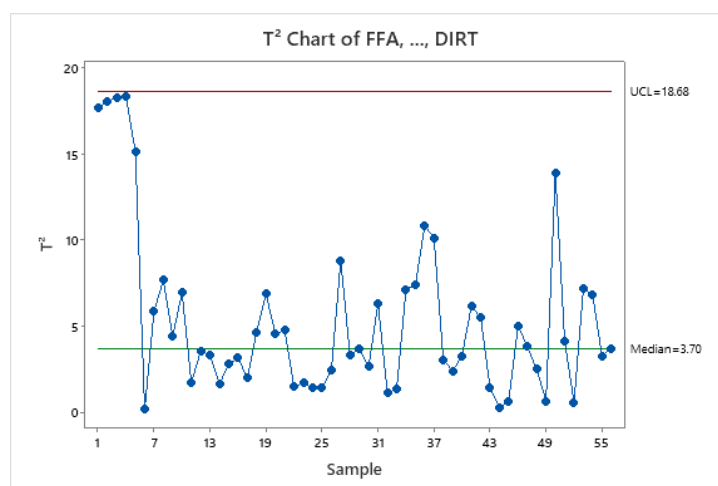


Figure 9. T² Hotelling After the 5th point is removed

It can be seen that all observation points are within statistical control limits, with a UCL of 18.68 and a median of 3.70. None of the points exceed the upper control limit, indicating that the CPO production process is stable and under multivariate control. There are 56 data points observed in this chart. Although at the beginning of the observation the T² value appeared relatively high, it was still below the control limit, so that the variation could be categorized as natural variation (common cause variation) that did not indicate a significant disturbance in the process. Overall, this graph shows that the quality control process has been running well, and there are no indications of major deviations that could affect the final product quality.

Conclusion

From the correlation test results, the FFA variable has a dominant effect on CPO quality with a moderate negative correlation to impurity levels ($r = -0.422$), while water content has a weak correlation ($r = -0.211$). These results are in line with the theoretical model in Statistical Process Control (SPC) that quality characteristics with high correlations require multivariate monitoring so that the relationships between variables are not overlooked. Compared to univariate methods, the Hotelling's T² approach is able to provide more accurate detection of process deviations because it considers the covariance between quality variables.

Overall, this study shows that the T² Hotelling method is effective as a diagnostic tool for detecting process variations and ensuring production quality stability. In practical terms, the results of this study can be used as guidelines for PT. Kurnia Mitra Sawit in conducting continuous quality monitoring, identifying sources of process deviations, and improving the efficiency of the CPO quality control system. For further research development, it is recommended to compare the T² Hotelling method with other multivariate methods such as MEWMA or PCA Control

Chart in order to obtain a more comprehensive process evaluation.

References

- [1] Rahayu, S. R. I. (2022). Quality Control of Crude Palm Oil (CPO) Using a Statistical Quality Control (SQC) Approach at PT Perkebunan Nusantara XIV PKS Luwu.
- [2] Gratia, T., Tarigan, R., Sukarsono, B. P., Industri, D. T., Teknik, F., Diponegoro, U., Soedarto, J. P., & Tembalang, K. U. (2021). Quality Control Of Crude Palm Oil (Cpo) Products Using The Six Sigma Method (Case Study of PT Supra Matra Abadi).
- [3] H. Dewi & Y.S. Annisa. (2023). Vol. 12, No. 1, Year 2023. Analysis Of Crude Palm Oil (Cpo) Production Quality Control Using The Statistical Quality Control (Sqc) Method c c c Cvcx, 12(1), 11–19.
- [4] Hanum Salsabiella. (2020). Product Quality Control Using the T2 Hotelling Individual Control Chart. 1–78.
- [5] Ekorini, D. (2014). HOTELLING T² CONTROL GRAPH WITH BOOTSTRAP APPROACH ON MULTIVARIATE NON-NORMALLY DISTRIBUTED DATA (pp. 7–8). Brawijaya University.
- [6] Yuneidi, B., Rahmi, I., & Yozza, H. (2012). Creation of a Multivariate T2 Hotelling Control Chart for the Lecture Process. Journal of Mathematics, Andalas University, Padang Vol.1.
- [7] Awitasari, D. A. (2018). Hotelling T2 Multivariate Control Chart for Quality Control of Student Grades in Four Core Courses in the Statistics Department at the Islamic University of Indonesia. Islamic University of Indonesia.
- [8] Primastuti, N. B., Sudarno, S., & Suparti, S. (2014). Product quality control using the multivariate np (Mnp) control chart method in quality improvement efforts (Case study at PT Coca Cola Amatil Indonesia (CCAI) Semarang). Gaussian Journal, 3(1), 111–120. <http://ejournal-s1.undip.ac.id/index.php/gaussian>
- [9] Austin, D., Lauro, M. D., & Herwindiati, D. E. (2020). Designing a Multivariate Control Chart Using the T-Hotelling Method for GPA and Length of Study of IT Students at Tarumanagara University. Journal of Computers and Informatics, 15(1), 317–325.
- [10] Lestari, D. P., & Rahmi Hg, I. (2023). Application of T 2 Hotelling multivariate control charts for evaluating online learning of compulsory courses in statistics for undergraduate (S1) mathematics study programs at Andalas University. UNAND Mathematics Journal, 12(2), 78–85.
<http://jmua.fmipa.unand.ac.id/index.php/jmua/article/viewFile/912/703>
- [11] Anggraini, D. astrie. (2021). Analysis of Crude Palm Oil (CPO) Quality Control at PT. Kampar Tunggal Agrindo Using Statistical Process Control. Jurnal Surya Teknik, 8(2), 327–332.
<https://doi.org/10.37859/jst.v8i2.3278>