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Product Sampling Time and Process Residence Time Prediction of Palm Oil Refining Process

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The quality of product produced in palm oil industries is important due to customer need and world demand. It is crucial to monitor and predict the quality of Refine Bleached Deodorised Palm Oil (RBDPO) produced. One of the most significant driving forces behind the demand for quality prediction of RBDPO is the reducing production cost of RBDPO. Palm oil had the highest manufacturing cost in that scenario, mainly because of the higher demand for ethanol in the pre-treatment step. The development of rapid and non-destructive measuring technique is needed to enhance the efficiency of palm oil quality monitoring. Today in the Lahad Datu Edible Oil Sdn. Bhd. (LDEO) company, the cost production of RBDPO is much higher and can be double or triple than the usual cost production due to the need of recycle process for getting the desired quality of RBDPO. The current production of RBDPO takes a lot of time. This show how important the quality predict of RBDPO in meeting the needs of the LDEO Company to reduce the need of recycle process due to the cost production and time consuming. This study aims to develop a statistical analysis that can predict the sampling time and residence time for the whole refinery process using autocorrelation and cross-correlation in MATLAB. The data analysis of Crude Palm Oil (CPO) and RBDPO is based on five parameters, percentage of the free fatty acids (% FFA), the percentage of the moisture, the deterioration of bleachability index (DOBI), iodine value (IV) and peroxide value (PV), which are used to monitor the RBDPO quality provided by the LDEO Company. For the 65 sample size data, the sampling time and residence of the whole refinery process are 2 h and 2.4 h. Both data are required in developing a tool to predict the RBDPO quality.

1. Introduction

In crude palm oil industry, the contamination of CPO is a major concern as it can greatly affect the efficiency of the refining process and quality of the processed oil RBDPO. The degradation and deteriorate of CPO can greatly affects its quality and could occur at several stages depending on the processing method and may occur after the milling stages. The quality prediction of RBDPO at the beginning of the process is very helpful in order to overcome this problem as the company can identify the output just by assessing the input quality through a few parameters which are (Young et al., 2015):

a) percentage of fatty acid (FFA);
b) the percentage of the moisture;
c) the deterioration of bleachability index (DOBI);
d) iodine value (IV) and;
e) peroxide value (PV).

Another important parameter that need to be precisely predicted are product sampling time and process residence time. The values of these parameters are assigned based on the experience that one may slightly

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question on it (Hamdan et al., 2015). In order to improve the performance of the industry in term of technical and economics, a systematic procedure must be developed. The sampling time for data collecting and analysis of RBDPO is determined by using autocorrelation from MATLAB. The determination of residence time required to process the input palm oil into output product is done by using correlation from MATLAB. All the data analysis is from Lahad Datu Edible Oil Sdn. Bhd. only which then used to develop a tool to predict RBDPO quality.

2. Literature Review

2.1 Sampling time

In this study, sampling time is defined as the time gap between each sampling of the data. Sampling time is determined by experience or the order from the authority which consider the economic aspect of the company. A study by Pour (2013) uses the method of try and error where the experiment is run at various parameters from period of 1 to 15 min to obtain the optimum time**.** This method seems to be tedious if there are numerous number of parameters. In this study, the optimum sampling time is determined by using autocorrelation.

2.2 Residence time

Residence time is the average length of time during which a substance, a portion of material, or an object is in a given location or condition, such as adsorption or suspension. The tracer injection and response method was widely used to study the mixing characteristics of a reactor. The moment method and curve-fitting method are the most commonly used to analyse the tracer response signals (Zhang et al., 2007). Although this method seems promising, it is not cost effective.

At LDEO, it is calculated by dividing the capacity with the volumetric flowrate to obtain the time. The current method does not take into account the parameter such as percentage of free fatty acid (% FFA), the percentage of the moisture, DOBI, (IV) and (PV). Cross-correlation analysis was carried out to obtain the residence time in which the output parameter follows the desired specification.

2.3 Autocorrelation

In this research, autocorrelation is used to calculate the sampling time by analysing the sample data. Autocorrelation represent a cross-correlation signal with itself at different lag of time which knows as serial-correlation or cross-correlation. Autocorrelation is used to detect the non-random data and determine the time series for the non-random data. It also called as correlation coefficient, which represent the correlation between two variables and also correlation for same variable but at different point of time. The formula to calculate autocorrelation is shown in Eq(1).

$$r_k = \sum_{t=k+1}^{n} (y_t - \tilde{y})(y_{t-k} - \tilde{y}) \Bigg/ \sum_{t=1}^{n} (y_t - \tilde{y})^2 \quad (1)$$

2.4 2.4 Cross-correlation

Cross-correlation is used to determine the residence time. In probability and statistics, the term cross-correlations is used for referring to the correlations between the entries of two random vectors X and Y. Cross-correlation analysis is basically a generalisation of standard linear correlation analysis, which provides a good starting point.

Cross-correlation commonly used in the analysis of multiple time series. The formula to compute the cross-correlation is shown in the Eq(2).

$$r_{xy} = \sum_{i=1}^{n} (x(i) - \ddot{x})(y(i) - \tilde{y}) \Bigg/ \sqrt{\sum_{i=1}^{n} (x(i) - \ddot{x})^2 \sum_{i=1}^{n} (y(i) - \tilde{y})^2} \quad (2)$$

3. Methodology

The data obtain from the LDEO Company was analysed using multiple statistical method. These methods are, boxplot plotting, autocorrelation and cross-correlation which is performed using software MATLAB. The flowchart for data preparation and analysis for this phase is shown in Figure 1.

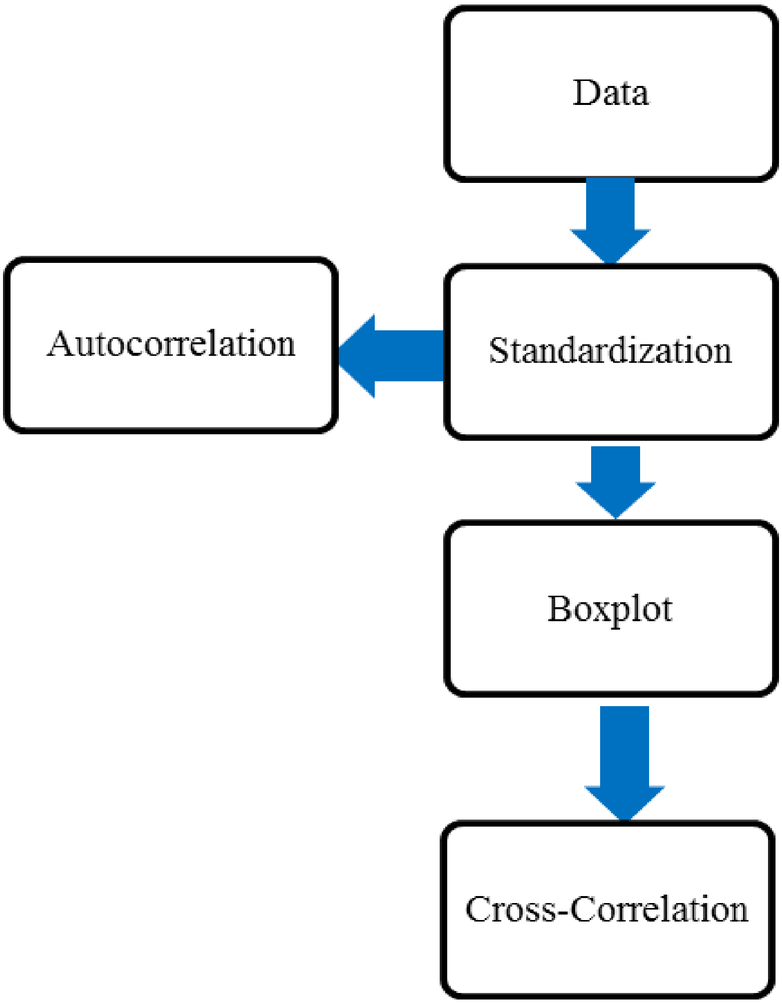

Figure 1: Flowchart for data preparation and analysis

Standardisation of data was done to organise all the attributes and relations for entire data in order to minimise the redundancy of data. Standardisation aims to adjust the value of all data in a reliable scale without losing any data or information. For a random variable X with mean μ and standard deviation σ, the z-score of value x is shown in Eq(3).

$$z = (x - \mu)/\sigma \quad (3)$$

Z-scores measure the distance of a data point from the mean in terms of the standard deviation. The standardised data set has mean 0 and standard deviation 1, and retains the shape properties of the original data set.
After data standardisation, the data is used in boxplot analysis. In this case the boxplot is used to determine the sample size (N) or population of all parameter for collecting data of RBDPO. N is the minimum number of data that will satisfy the central limit theorem. The larger the number of data is better. The cost to obtain the data will also spiked up.
It is crucial to get the minimum number of data that will satisfy the central limit theorem. The boxplot is used to see the randomness of the data distribution. The shape or the whisker of the box will determine the best sample size for the data. In this study, the boxplot is plotted based on 65 sample size for each parameter as shown in Figure 2.
The standardised data is used in autocorrelation to get the sampling time. Autocorrelation will plot all the input and output data, which then the sampling time of each variable is determined by the time its start and enter the threshold line. Figure 3 shows result of autocorrelation analysis. Cross-correlation is done to determine the residence time of the whole RBDPO process. The cross-correlation is run between the input (CPO) and the output (RBDPO) data as shown in the Figure 4.

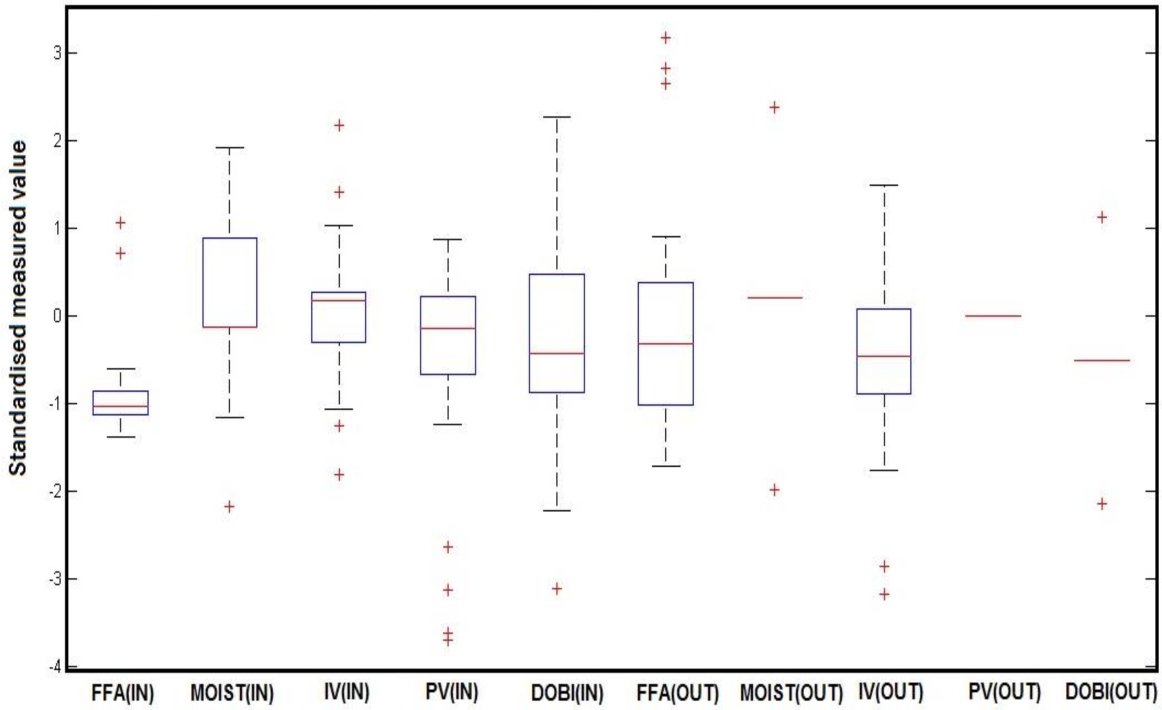

Figure 2: Boxplot of percentage of free fatty acid (% FFA), the percentage of the moisture, (PV), (IV) and DOBI for both input and output

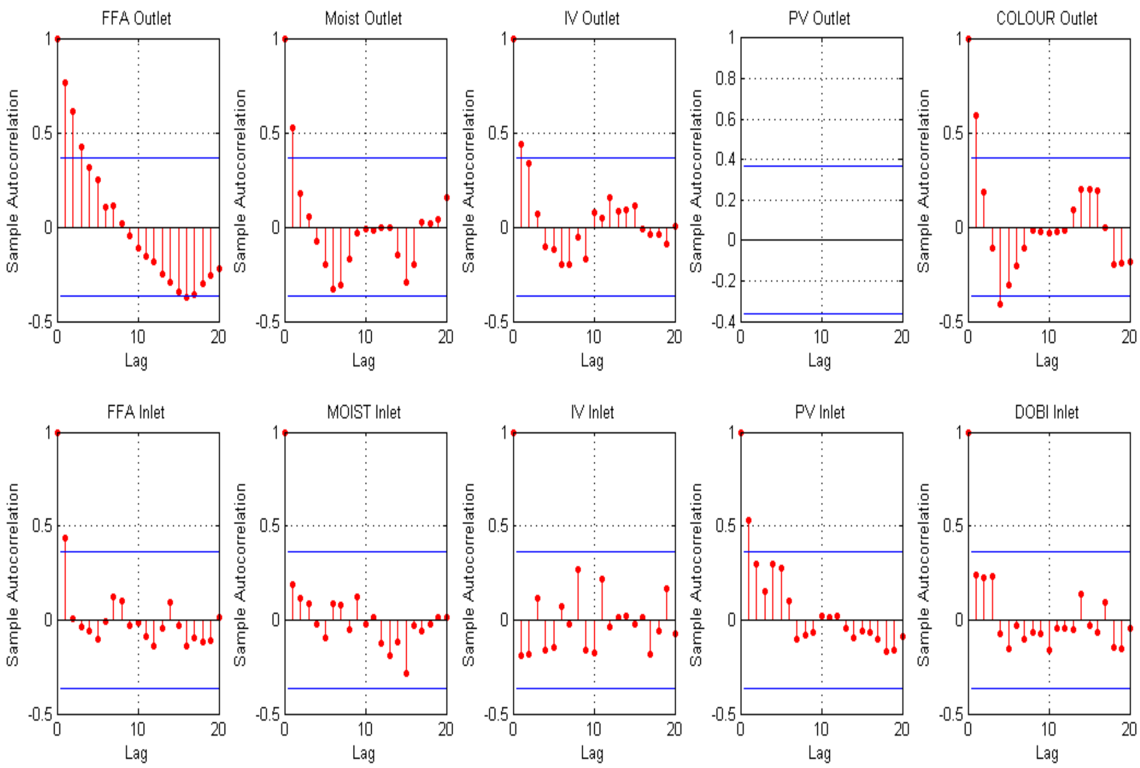

Figure 3: Graph of autocorrelation for percentage of free fatty acid (% FFA), the percentage of the moisture, (PV), (IV) and DOBI for both input and output

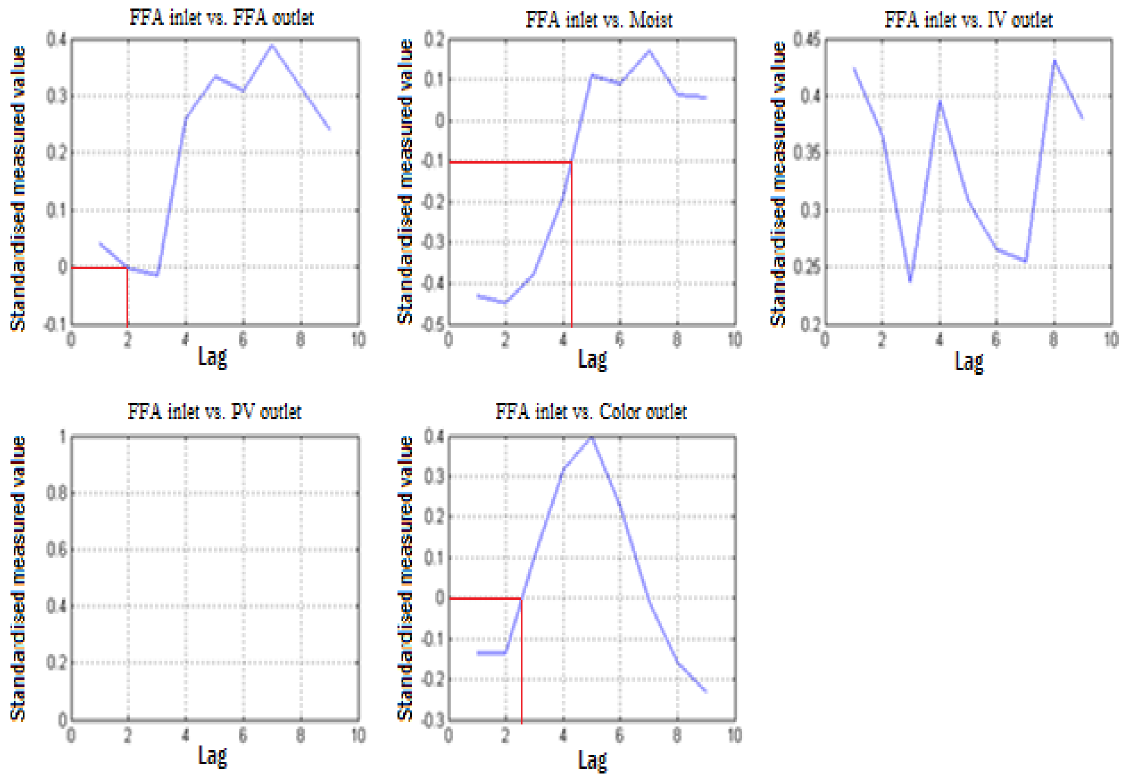

Figure 4: Graph of cross-correlation for percentage of free fatty acid (% FFA), the percentage of the moisture, (PV), (IV) and DOBI for both input and output

4. Discussions

In order to determine the sample size of data, boxplot was plotted using MATLAB as shown in Figure 2. The boxplot plotted for each parameter shows some outlier which occurred when the value of parameter is surprisingly high or low from other observation. All parameters are within specification although there are outliers present in plotted boxplot. Positive outliers indicate the value of parameter is higher than the other observation. For parameter that required the higher value than minimum specification such as DOBI, this type of outlier is indicates the parameter is in better quality. Inverse from positive outliers, negative outliers show that the value of parameter are lower than maximum specification, which means the parameter is in better quality especially for the parameter other than DOBI. There are several reasons which lead to outliers such as increasing the dosage of bleaching earth used during the process and the increasing in flowrate of CPO. The best sample size of data is 30.

The graph autocorrelation is plotted to determine the sampling time of each quality parameter. Sampling time is the time to collect the product sample in order to test for the quality prediction. For this analysis, the data was obtained for every half an hour in order to measure the sampling time using autocorrelation. Based on Figure 3, the sampling time is measured from the data that has cross the threshold value and that value of lag is calculated as the value of sampling time. The sampling time measured is 2 h.

The residence time is the time taken for the CPO to become desired RBDPO and can be manually calculated from the flowrate and operating volume. According to the analysis, the graph of cross correlation plotted in Figure 4 shows that the longest residence time is 2.4 h. The lower value of residence time for cross-correlation explained that the data was taken when the plant was running below the operating capacity.

5. Conclusions

A methodology has been developed to predict the sampling time and residence time of the palm oil refining process in Lahad Datu Edible Oil Sdn. Bhd. By determining the sampling time, the cost for sampling can be reduced and maintain at optimum level. As a conclusion, the sampling time and the residence time of 2 h and

2.4 h is determined by using autocorrelation and cross-correlation which enable us to develop a tool to predict the RDBPO quality.

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