Quality control of crude palm oil (CPO) using define, measure, analyze, improve, control (DMAIC) and fuzzy failure mode and effect analysis

Khawarita Siregar*, Aulia Ishak and Heru Andi Sinaga
Industrial Engineering Department, Faculty of Engineering, Universitas Sumatera Utara, Medan, Indonesia

*E-mail: khawarita@usu.ac.id

Abstract. In this case, the company Crude Palm Oil (CPO) is still not able to produce palm oil that meets the specifications that can be seen from the free fatty acid content reaches 3.51%. This can affect the quality of the products to be able to compete with a competitor. Therefore, this study aims to conduct quality control of Crude Palm Oil (CPO), to analyse the proportion of disability and ability in the production process, potential failures, to identify the root cause of the defect, and to calculate the value of the highest FRPN. The results of the study showed that the biggest problem faced by parts of machine settings and control machines that are not good due to less rigorous and disciplined operator in charge and has a value of FUZZY FMEA (FRPN) most high at 662.06. While the measurement results the sigma value of the company is 3.16.

The results of the study showed that the biggest problem faced by parts of machine settings and control machines that are not good due to less rigorous and disciplined operator in charge and has a value of FUZZY FMEA (FRPN) most high at 662.06.

1. Introduction
Indonesia is one of the countries in which the kinds of industry thrives, along with the many industry will lead to fierce competition in the field of industry. Indonesia as one of the world's largest agricultural country heavily dependent on the agricultural sector [1]. One of the important sub-sectors of agriculture sector is plantation which contributed greatly to the country's foreign exchange. Palm oil is one of the leading commodity of Indonesian agricultural subsectors that are excellent in international eyes. CPO production is growing rapidly from 29,278,189 tons in 2014 to reach 35,359,384 tons in 2017. Therefore, one of the efforts made is to control the quality of its products to be sold on the market is high quality so that later it will increase the interest of consumers to buy products [2].

Quality is defined as the consistent upgrading or improvement and variation reduction characteristics of a product (or service) that is produced by the company in order to meet the needs that have been specified in order to improve customer satisfaction well as the totality of characteristics of a product that supports the ability to satisfy the needs of specified or implied [3] [4]. Company’s CPO quality parameters are free fatty acid levels, moisture content and impurity content. But in fact, company CPO still produce palm oil that does not meet quality standards have been set. Non-compliance resulting quality standards caused by several factors such as raw material, human (operator), machinery and work methods and stability process that is not well and can not be predicted and the ability of the poor.

FMEA very useful addition as activity "before the event". The advantage that can be gained from the application of Fuzzy FMEA including increased safety, quality and reliability, the company's reputation, customer satisfaction, lower development costs and their historical record of failure events.
Problem-solving method that can be used is a statistical method or DMAIC or (Define, Measure, Analyze, Improve, Control) used is CTQ analysis, Analysis X and R control chart, process capability analysis, Six Sigma analysis, cause-effect diagram analysis method of Failure Mode Effect Analysis (FMEA) and using fuzzy FMEA [7] [8]. The purpose of this study was to improve product quality by identifying the source of disability and disability Crude Palm Oil (CPO) and to identify the signal out of the control that has the largest contributors to cause disability products by applying the DMAIC method and Fuzzy FMEA.

2. Research methods
The research was conducted at Company CPO in September 2018 to October 2018. The object of research is observed Crude Palm Oil. Data obtained by:
Collecting data obtained from direct observations and direct measurements in the data used in the final work is secondary data. Data obtained by:
1. Collecting data test variables during certain periods of the Laboratory section. The data obtained are the percentage of free fatty acid levels, levels of dirt, moisture content.
2. Obtain data on the organization and management of the company as well as data about the production process
The steps in this research which starts from identifying the problems that occur in production. Then conducted a preliminary study to determine the method of solving the problem. The data collection is done for use as input in the research. The type of data collected is of secondary data. Processing data using DMAIC method to analyze the quality standard quality control of CPO, and FMEA FUZZY method used to determine the priority of improvements that need to be done.

3. Result and discussion
Data processing is performed by using the DMAIC method. The stages of the DMAIC method used in data processing are Define, Measure, Analyze, Improve and Control.

3.1. Define
Define phase is the first step in identifying the main problem priority in improving the quality of products and processes in the company. through controlling factors that may affect such, people, machines, materials and methods [9]. From interviews, company documentation and data collection directly by using the method of brainstorming can be seen, there are 3 types of CTQ (Critical To Quality), namely Free Fatty Acid Level (FFA), Moisture and Dirt levels. The CPO product CTQ the quality parameters are free fatty acid content which has an upper limit of 3.5%, the water content has an upper limit of 0.15% and levels of impurities that have an upper limit of 0.02%.

3.2. Measure
3.2.1. Control chart of x bar-s.
Control Chart is made to find a process under control to monitor variations in the process continuously. Chart X and S illustrate the variations that occur in the production process of CPO. Control Chart is created for the free fatty acid content, moisture content and impurity content. Results of revised X and S chart can be seen below.
From the picture above, it can be seen that the process can still be categorized as uncontrolled or can be said to be the actual production has not normal process variation.

3.2.2. Process capability.

The ability of the process is a calculation through comparison between the output of products with the design specifications. If the equipment has the ability to consistently meet the quality expected range, the quality and cost of production can be optimized. Process Capability calculation results of free fatty acid (FFA) is as follows.

**Figure 1.** Revised $\bar{X}$ and S control chart of (a) free fatty acid level (FFA), (b) moisture and (c) manure level.
\[
\text{Capability Process (Cp)} = \frac{USL - LSL}{6 \times \sigma_o} \quad (1)
\]

\[
\text{CPU} = \frac{(USL - \bar{X})}{3 \sigma_2} 
\]

\[
\text{CPL} = \frac{\bar{X} - LSL}{3 \sigma_2} 
\]

\[
\text{Cpk} = \text{Min} \{ (\text{CPU}) \text{ or } (\text{CPL}) \} 
\]

\[
\text{Cpk = Min } \{ (0.69) \text{ or } (1.05) \}
\]

\[
\text{Cpk = 0.69}
\]

Cp value <1.33 means indicates that the production process is not in accordance with the established [10]. The use of Cp in assessing the ability of the process is based on the assumption that the average process right in the middle of the specification limits. In fact, this is not achieved. To fix the above used Cpk ratio, which states the average position of the process compared to the specification limits. The smaller the higher the Cpk value product presentation which lies outside the specification limits.

Process Capability calculation results of the water content is as follows.

\[
\text{Capability Process (Cp)} = \frac{USL - LSL}{6 \times \sigma_o} = 0.15 \quad (2)
\]

\[
\text{CPU} = \frac{(USL - \bar{X})}{3 \sigma_2} = \frac{3.5 - 3.1}{3 \times 0.19} = 0.69
\]

\[
\text{CPL} = \frac{\bar{X} - LSL}{3 \sigma_2} = \frac{3.10 - 2.5}{3 \times 0.19} = 1.05
\]

\[
\text{Cpk = Min } \{ (\text{CPU}) \text{ or } (\text{CPL}) \}
\]

\[
\text{Cpk = Min } \{ (0.69) \text{ or } (1.05) \}
\]

\[
\text{Cpk = 0.69}
\]

Cp values> 1.33 means indicates that the production process in accordance with a predetermined. The use of Cp in assessing the ability of the process is based on the assumption that the average process right in the middle of the specification limits. In fact, this is not achieved. To fix the above used Cpk ratio, which states the average position of the process compared to the specification limits [11]. The higher the Cpk value the smaller the product presentation which is located outside the specification limits.
Process Capability calculation results impurity content is as follows:

$$\text{Capability Process (Cp)} = \frac{USL - LSL}{6 \times \sigma_o} = \frac{0.02}{0.00624} = 3.11$$

$$\text{CPU} = \frac{USL - \bar{X}}{3 \sigma} = \frac{0.02 - 0.0169}{3 \times 0.00104} = 0.96$$

$$\text{CPL} = \frac{\bar{X} - LSL}{3 \sigma} = \frac{0.0169 - 0}{3 \times 0.000104} = 5.74$$

$$Cpk = \text{Min} \{\text{CPU} \text{ or } \text{CPL}\}$$

$$Cpk = \text{Min} \{(0.96) \text{ or } (5.74)\}$$

$$Cpk = 0.96$$

Cp values > 1.33 means indicates that the production process in accordance with a predetermined. The use of Cp in assessing the ability of the process is based on the assumption that the average process right in the middle of the specification limits. In fact, this is not achieved. To fix the above used Cpk ratio, which states the average position of the process compared to the specification limits. The higher the Cpk value the smaller the product presentation which is located outside the specification limits.

3.2.3. Sigma value measurement ($\sigma$).

DPMO calculation is a good measure for the quality of products and processes, because directly related to the costs and time wasted. DPMO value measurement is shown in Table 1.

| Free Fatty Acid Levels | Water content | levels of Impurities |
|------------------------|---------------|----------------------|
| Within PPM Performance | 19140         | 4100                 | 1900                 |
| PPM Overall Performance| 16800         | 4100                 | 1800                 |
| DPMO value             | 35940         | 8200                 | 3700                 |
| **Total DPMO**         | **47 840**    |                      |                      |

Results sigma value calculation is as follows.

$$\text{Sigma Value (} \sigma = \text{Normsinv} \left( \frac{10^6 \cdot 47840}{10^6} \right) + 1.5 = 3.16$$

3.3. Analyze

At this stage of the manufacturing is done using causal diagram and FMEA FUZZY used as a tool to analyze further.

3.3.1. Identification of problems with the cause and effect diagram.

Based on the observations contained some of the main factors causing the decline in the quality of CPO made in Fish Bone Diagram.
Free Fatty Acid Levels

Fatigue factor
The operator is not thorough
Hurried
Undisciplined
Supervision that is not carried out

Quality of raw materials not good
Dirty raw material
Raw material storage area is dirty

Digester doesn't work optimally
Lack of maintenance
The engine is overheating
Non-stop use

Lack of procedures during the inspection stage
Inspection is carried out at the end process
Uncontrolled process

Uncontrolled process
Quality of raw materials not good
Raw material storage area is dirty

Lack of procedures during the inspection stage
Inspection is carried out at the end process
Uncontrolled process

Undisciplined
Supervision that is not carried out

Figure 2. Fish bone diagram levels FFA.

Inspection is carried out at the end process
Lack of procedures during the inspection stage

Organization
Inspection at the end process
Uncontrolled process

Undisciplined
Supervision that is not carried out

Fatigue factor
The operator is not thorough
Hurried

Lack of procedures during the inspection stage
Inspection is carried out at the end process
Uncontrolled process

The engine is overheating
Non-stop use

Lack of maintenance

Sewage doesn't work optimally
Oil Purifier doesn't work optimally

Lack of maintenance
The engine is overheating
Non-stop use

Figure 3. Fish bone diagram water content.
Failure Mode and Effect Analysis (FMEA) is a method used to identify the sources and root causes of quality problems. FMEA Method For that very precise application of fuzzy logic to coordinate the problems posed in the conventional FMEA [12]. Fuzzy Rule describes the level of criticality of an error for each combination of input variables. Automatic procedure here proposed to use the function to measure the riskiness of subjective risk attitude of the maintenance staff. This function connects the values of the NDP achieved by any combination of the values of each mode circuit fuzzy (ie, the membership function) for each input that occurrence (O), Detection (D), Severity (S) with a series of linguistics evaluation of the risk of errors (final / outputs).

| Failure effects | S  | O  | D  | FRPN  | Category | Ranked |
|----------------|----|----|----|--------|----------|--------|
| Free Fatty Acid Levels (FFA) which leads to high quality low oil | 5  | 4  | 597.63 | H       | 5        |
| The water content is quite high and can cause varying oil quality is going down | 6  | 4  | 5  | 339.42 | M        | 6      |
| High levels of impurities that cause the oil is not worthy of further processing | 6  | 4  | 339.42 | M       | 6        |

3.4. Improve

3.4.1. 5W+1H methods.

Improvement plan prepared by conducting brainstorming techniques to look for alternative appropriate plans for problem resolution. The preparation of this improvement plan aided by some of the companies. The improvement plan outlined in the matrix model is based on the principle of 5 W (why, what, where, when, and who) and one H (How), which is made clearly and in detail. The method includes the question: As for the proposed improvement shown in Table 3.
3.4.2. Control.
At this stage, the control of the improvements that have been done to prevent further failure of the process that can lead to product defects. Control mechanism can be seen in Table 3.

| Failure mode                          | Proposed Improvements                                                                 |
|---------------------------------------|---------------------------------------------------------------------------------------|
| Free Fatty Acid Levels (FFA) <3.5%   | Provide training to operators in the selection of the appropriate fruit                |
|                                       | To supervise the sorting operator                                                     |
|                                       | Limiting the boiling time.                                                            |
| Free Fatty Acid Levels (FFA) <5%     | Adjusting the temperature remains at a temperature of about 90-95°C                   |
|                                       | Conduct periodic checks every hour                                                    |
|                                       | Provide training to operators in the selection of the appropriate fruit               |
| Water content <0.15%                  | To supervise the operator steriliser                                                 |
|                                       | Limiting Boiling Time                                                                 |
|                                       | Conduct inspections of temperature, pressure regularly                               |
|                                       | Conduct periodic checks every hour                                                    |
|                                       | Perform cleaning sorting station                                                     |
| levels of Impurities <0.02%          | To supervise the separation operator Oil                                             |
|                                       | Conducting periodic engine maintenance                                              |
|                                       | Conduct periodic checks every hour                                                    |

Table 4. Treatment process control mechanism of crude palm oil.

| Aspect                        | Maintenance plan                                                                                     | Control mechanism                                                                 |
|-------------------------------|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Human                         | Coaching and Training                                                                                 | The management needs to make training both in material terms, and in terms of execution time to improve the knowledge and skills of the operator. |
|                               | Improving the Quality of Human Resources                                                              | the management needs a little time in order to increase worker motivation back. One of them is through full kebersama kearaban |
|                               | Improved Work Motivation                                                                               | Compensation in accordance with the given workload                                |
| Method                        | Inspection stages                                                                                     | Conduct periodic sampling inspection every hour and quantifies the control chart and the calculation of the sigma value in each period on a regular basis to determine the ability of the process to produce flawless products |
| Material standard            | Selection and Handling of Raw Materials                                                                | the proper selection of raw materials should be started at the time of procurement, as well as during storage of materials. |
|                               | Checking Procedures and Use                                                                           | Raw materials should be placed in a closed field, away from the influence of weather conditions and not too long kept. |
|                               | Equipment / Machinery                                                                                 | Develop rules work steps the use of any tools / machines and provide written information in the form of these instructions, especially in engine temperature regulation. |
|                               | Maintenance Engineering (Maintenance)                                                                | Provide training to each operator on the use of equipment / machinery exactly, both for new operators, as well as existing operators |
|                               |                                                                                                      | Make time to ensure that the machine is in good condition to avoid processing errors that can result in damage to the product or the work accident |
4. Conclusion
Based on the results of data processing and analysis has been done can be some conclusions as follows
1. Based on the results of data processing obtained in the define phase, CTQ is to minimize variations in the levels generated by controller factors that may affect such, people, machines, materials and methods. From interviews, company documentation and data collection directly by using the method of brainstorming can be known there are 3 types of CTQ.
2. Cpk measure phase result of Free Fatty Acid (FFA) of 0.69, Cpk Water levels of 0.88 and 0.96 Cpk impurity content, from the chart results obtained from the data control variables are beyond the limits of the system so needs to be revised, from results of process capability Cpk values are still under one showed yet inability of companies produce products according to the specifications and the average value of sigma is 3.16,
3. Phase analyze the results obtained with a value of 624.97 FRPN High category - very high. The main factors that cause decline in the quality CPO Poor quality of raw materials which causing a low quality oil which can affect the taste unpleasant which has a high acid levels
4. Proposed improvements in the quality of product that is doing some improvements to the performance of humans in the sorting of fruit, made some improvements to the machine in order to work optimally, make improvements in the form of checks each parameter standard compliant or not so that the products produced in accordance with the specifications and standards inspections that need to be improved to maintain the stability of the process variation.
5. While the control conduct quality improvement results by conducting a control mechanism based on priorities is needed at the time of repair.

References
[1] Badrun M. 2010. Tracks 30 Years Palm Oil Development. Jakarta: Directorate General of Plantations at the Ministry of Agriculture in cooperation with GAPKI.
[2] Christian Wendy, 2013, Implementation of Quality Control Methods XYZ Scientific Journals Statistics On Surabaya University Students 2 (2)
[3] Dale H, Besterfield. 1998. Quality Control. Fifth Edition. New Jersey: Prentice Hall Inc
[4] Directorate General of Plantation. 2017Statistics Indonesia Commodities Oil Palm Plantation. Directorate General of Estate Crops
[5] Gaspersz, Vincent, 2002. Total Quality Management. Mold 2. PT Gramedia Pustaka Utama. Jakarta.
[6] James R. Evans and William M. Lindsay (2007). An Introduction to Six Sigma & Process Improvement (Introduction to Six Sigma). Jakarta: Four Salemba
[7] Kusumadewi, Sri Purnomo, Hari. 2002. Analysis & Design Using Fuzzy Tool. Box Matlab. Yogyakarta: Graha Science.
[8] Kusumadewi, Sri., Purnomo, Hari. 2002. Application of Fuzzy Logic for Decision Support. Yogyakarta: Graha Science.
[9] Montgomery, C. Douglas. 2009. Introduction to Statistical Quality Control 6th edition. USA: John Wily & Sons, Inc.
[10] McDermott., E, Robin. 2009. The Basic of FMEA. Issue 2. USA: CRC Press.
[11] Pande, Peter S, Neuman, Robert P., Cavanagh, Roland R (2002). The Six Sigma Way. Yogyakarta: Andi Praveen Gupta, The Six Sigma Performance Handbook. New York: McGraw-Hill Inc.
[12] Rusmiati, Emi. 2014. Application of Fuzzy Failure Mode And Effect Analysis (FMEA Fuzzy) In Identifying Failure In Production Process At PT. Daesol Indonesia. Study Program Industrial Engineering and Management, School of Industrial Management. pp 18-34. things. August 12th, 2015