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Analysis of Biodiesel Conversion on Raw Material Variation Using Statistical Process Control Method

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Abstract. Biodiesel is a promising alternative fuel that can be obtained from vegetable oils or animal fats through transesterification reactions with alcohol. Biodiesel has numerous advantages compared to diesel oil, namely: it is a renewable energy resource, it is not toxic, and it is environmentally friendly because the raw material does not contain sulfur and low emissions. Biodiesel production is inseparable from the availability of raw materials until now the raw materials that meet the needs of production capacity are palm oil (CPO). To overcome this problem, in this study we want to find out how much biodiesel conversion percentage if we use other raw materials such as: CPO oil, corn oil, VCO oil, and waste cooking oil. The analysis used in this study was the analysis of the use of raw materials to the value of biodiesel conversion using the Statistical Process Control (SPC) method. SPC method was used to analyze, manage, control, and improve a product and process using statistics. The objective of this study was to produce high conversion percentage biodiesel and analyze and control the quality of research products. By having this statistical method, it could be found errors in a study or out of control production so that further action can be taken to overcome them. In this study, it was found that the product which was outside of the control limit was biodiesel made from CPO and waste cooking oil. The results of the analysis using cause and effect diagrams could determine the causes of damage in the production process, which come from the factors of workers/humans, production machines, working methods, materials/raw materials and work environment.

1. Introduction

Based on the Regulation of Minister of Energy and Mineral Resources Number 29 in 2015, it was stated that transportation, industrial, commercial and power generation sectors are required to increase the use of biodiesel by at least 15% (B-15) in diesel fuel mixes, the obligation has been implemented in September 2017. Currently, the production capacity of diesel in Indonesia is 13 million kiloliters in a year, while the need for domestic diesel fuel is 16 million kiloliters in a year. So that, to cover its shortcomings, Indonesia imports 3 million kiloliters in a year of diesel fuel, so that it is targeted to reduce diesel fuel imports by 2 million kiloliters in 2017, while in 2018, Pertamina is optimistic that it will increase to 20% of biodiesel utilization in a mixture of diesel fuel and it is hoped that Indonesia will not import diesel fuel because the demand is sufficient. Biodiesel production is inseparable from the availability of raw materials until now the raw materials that meet the needs of production capacity are palm oil (CPO). Based on data from GAPKI (Association of Indonesian palm oil entrepreneurs) in 2017, CPO production in 2016 is projected to decline compared to the previous year.

It was noted, in 2017 national CPO production reached 31.5 million tons, and rose to 32.5 million tons. In 2017 production is projected to rise. For 32 million tons of CPO products, it is estimated to produce 81 million tons of liquid waste with the content of fat and oil in the waste around 29-29.5% [1].

Biodiesel production developed at this time is generally made from plant oil (soybean oil, canola oil, crude palm oil), animal fat (beef tallow, lard, chicken fat) and even from used cooking oil. The processes used are diverse reactions, using basic catalysts for transesterification (NaOH, KOH), acid catalyst esterification (H_2SO_4), and supercritical methods. Diesel oil types are the most widely used fuels by Indonesian people [2]. Therefore if we want to reduce the number of uses derived from fossil fuels, the way is to reduce the use of diesel fuel by switching to biodiesel. Biodiesel has been produced from the reaction process of transesterification of triglycerides (vegetable oils) to methyl esters with methanol using sodium or potassium hydroxide is dissolved in methanol as a catalyst.

The raw material that has been used is Crude Palm Oil (CPO). Based the explanation above, this study tries to vary other raw materials such as corn oil, vco oil, and waste cooking oil as raw material for making biodiesel. We will see how much the conversion value is produced from biodiesel products to the variation of raw materials using statistical process control (SPC) method. SPC is a technique used to find out, analyze, manage, and improve the quality of the raw materials that will be used in making biodiesel. The SPC method is expected to be effective to produce the quality of biodiesel products and high conversion percentage values.

2. Statistical Process Control (SPC)

Statistical Process Control (SPC) is a powerful collection of problem-solving tools useful in achieving manufacturing process stability and improving capability through the reduction of variability [3]. Statistics is a decision-making technique in an analysis of information contained in a sample of the population. Statistical methods play an important role in quality assurance. Statistical methods provide the main ways in product sampling, testing and evaluation, and information in the data used to control and improves the manufacturing process. Quality control is a technical and management activity which measures the quality characteristics of a product or service, then compares the measurement results with the desired product specifications and takes appropriate improvement measures if differences in actual and standard performance are found. Production quality control can be done in various ways, for example with the use of good materials/materials, the use of machinery/equipment that is adequate, a skilled workforce and the right production process. The concept of quality is an effort from producers to meet customer satisfaction by providing what is needed, expectations, and even expectations from customers, where these efforts are visible and measurable from the end product produced.

Statistical process control is a technique used for decision making about a process based on the analysis of information contained in a sample. Statistical methods play an important role in quality assurance. This statistical method provides the main ways in product sampling, testing and evaluation and information in the data is used to control and improve the manufacturing process [4]. Thus this study is intended to spell out the concept of SPC for the benefit of those intending to use it their processes. The literature on the implementation of SPC mostly concentrates on the development of statistical tools like control charts [5].

Factors affecting quality according to Montgomery [4], the factors that influence quality control in a company are:

1. Process capability the limits to be achieved must be adjusted to the ability of the existing process. There is no point in controlling a process within the limits that exceed the ability or capability of the existing process.
2. Applicable specifications and production specifications to be achieved must be valid if viewed from the aspect of process capability and consumer desires or needs to be achieved from the production results. In this case, it must be ascertained in advance whether the specification can apply from the two aspects mentioned above before quality control in the process can begin.
3. An acceptable level of suitability. The purpose of controlling a process is to reduce the product that is below the minimum standard. The level of control imposed depends on the number of products that are below acceptable standards.
4. Quality costs. Quality costs greatly affect the level of quality control in producing products where quality costs have a positive relationship with the creation of quality products.

In statistical process control, there are known "seven tools". Seven Tools of statistical process control is the simplest graphical method to solve problems. These seven tools are:

1. Observation sheet
2. Run chart
3. Histogram
4. Control chart
5. Pareto diagram
6. Cause and effect diagrams
7. Scatter diagram

Control charts (RD) are the most frequently used tool in the statistical regulation of processes. They allow more accurate distinguishing of random from systematic causes of fluctuations in the value of a mark of quality, i.e., they facilitate regulation and improvement in the quality of the process. When applying Control charts, it is assumed that the behaviour of the process is characterised by the level or one or several qualitative values. We call these values regulated values. Control charts are used in monitoring processes and when ascertaining the need for corrections or changes in the process, in order to achieve a better mean value of the process or in order to reduce variability in the process. In control charts, the horizontal axis contains the times when statistical sampling of regulated values took place, and the vertical axis contains calculated values of the appropriate sample characteristics. Control charts also include criteria for comparing sample characteristics [6]. These criteria are control limits:

$$\text{UCL} = \bar{\bar{X}} + A_2\bar{R} \quad (1)$$

$$\text{LCL} = \bar{\bar{X}} - A_2\bar{R} \quad (2)$$

$$\text{CL} = \bar{\bar{X}} \quad (3)$$

3. Experiments
First of all, raw materials for Crude Palm Oil (CPO), corn oil, VCO and used cooking oil are weighed 1 L in an analytical balance and then filtered first, carried out by precipitation and filtering using filter paper to eliminate impurities that are contained in the raw material. After weighing, enter the raw material into a three-neck flask and heated at a temperature of 50-55^{0}C while stirring using a stirrer. Prepare 35%wt methanol and 1% catalyst (NaOH or KOH) from the total raw material. After the temperature reaches 55^{0}C put the methanol and catalyst mixture and then reflux for an hour at 65^{0}C, the temperature is maintained until the reaction is complete. After that, the solution is poured into a separating funnel to separate biodiesel, glycerol and residual catalyst. The solution is left for 24 hours to get the transesterification product, the next day the results can be seen, glycerol at the bottom and what is formed in the upper layer is biodiesel. Then separated and then washed with distilled water at a temperature of 40^{0}C. Analyze according to biodiesel quality standards.

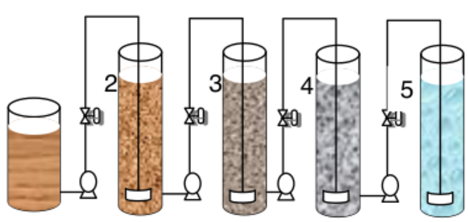

Figure 1. Tool Series Design

Tool Descriptions:
(1). Mixer for mixing catalysts and solvents

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(2). Reactor column for biodiesel manufacturing
(3). Separator column
(4). Washing column
(5). Tank for biodiesel products

4. Result and Discussion

Table 1. X and R Control Chart Data Processing on CPO biodiesel

Batch	X1	X2	X3	Total	$\bar{X}$	Range (Xmax-Xmin)
1	64.75	65.89	66.28	196.92	65.64	1.53
2	71.27	69.80	70.12	211.19	70.40	1.47
3	68.31	65.44	67.74	201.49	67.16	2.87
4	63.60	65.11	67.89	196.6	65.53	4.29
5	69.75	70.39	66.80	206.94	68.98	3.59
6	66.27	67.78	69.12	203.17	67.72	2.85
Total					**405.43**	**16.6**
Average					**67.57**	**2.77**

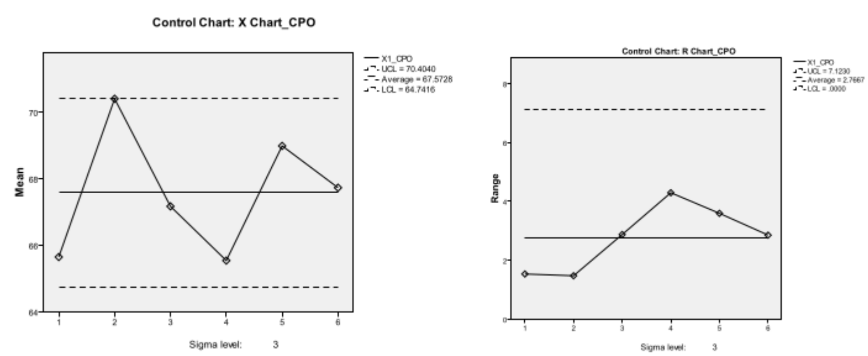

Figure 2. X and R control chart for CPO Biodiesel

Table 2. Processing of X and R Control Chart Data on VCO Biodiesel

Batch	X1	X2	X3	Total	X	Range (Xmax-Xmin)
1	80.5	83.68	83.70	247.88	82.96	3.2
2	81.66	80.25	81.12	243.03	81.01	1.41
3	79.58	78.56	79	237.14	79.05	1.02
4	79.24	80.26	81.54	241.04	80.35	2.3
5	75	77.63	80.40	233.03	77.68	5.4
6	82.73	78.79	76.90	238.42	79.47	5.83
Total					**480.18**	**19.16**
Average					**80.03**	**3.19**

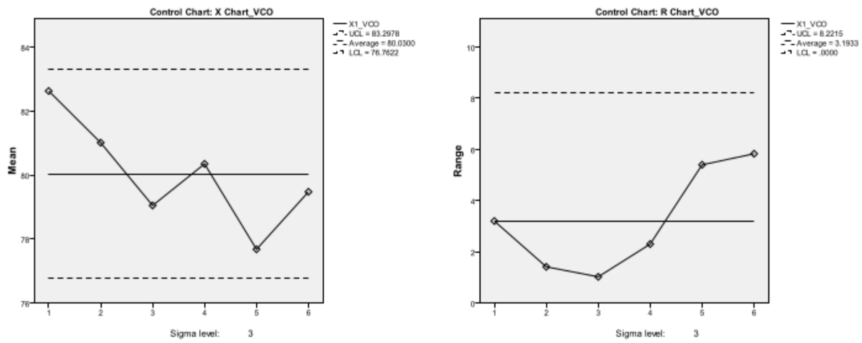

Figure 3. X and R Control Chart on VCO Biodiesel

Table 3. Processing of X and R Control Chart Data on Corn Oil Biodiesel

Batch	X1	X2	X3	Total	X	Range (Xmax-Xmin)
1	91.54	90	87.21	268.75	89.58	4.33
2	88.83	85.19	82.50	256.52	85.51	6.33
3	91.65	89.36	87.21	268.22	89.41	4.44
4	88.34	88	87.42	263.76	87.92	0.92
5	85.40	86.30	85	256.7	85.57	1.3
6	93.9	90.67	89.15	273.72	91.24	4.75
Total					**529.22**	**22.07**
Average					88.20	3.68

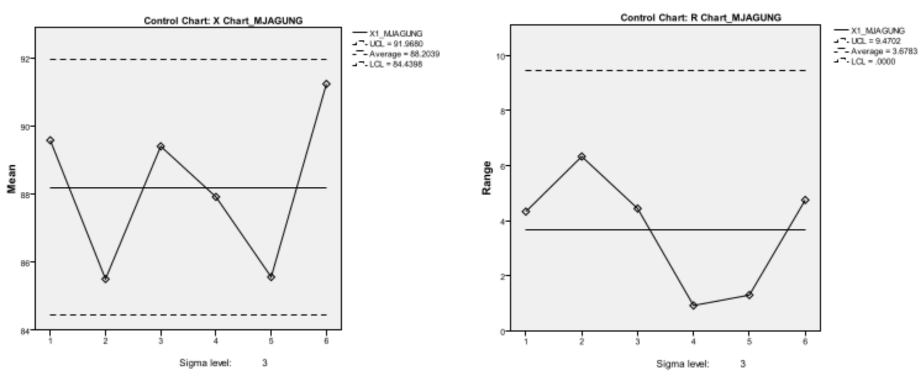

Figure 4. X and R Control Chart on Corn Oil Biodiesel

Table 4. Processing Data of X and R Control Chart on Used Cooking Oil Biodiesel

Batch	X1	X2	X3	Total	X	Range (Xmax-Xmin)
1	83	85.67	80.14	248.81	82.94	5.53
2	84.63	83.20	84.82	252.65	84.22	1.62
3	79.24	80.23	81.56	241.03	80.34	2.32
4	77.04	76.65	80.54	234.23	78.08	3.89
5	83.69	81.43	83.18	248.3	82.77	2.26

6	82.24	80.15	81.26	243.65	81.22	2.09
Total					**489.56**	**17.71**
Average					**81.59**	**2.95**

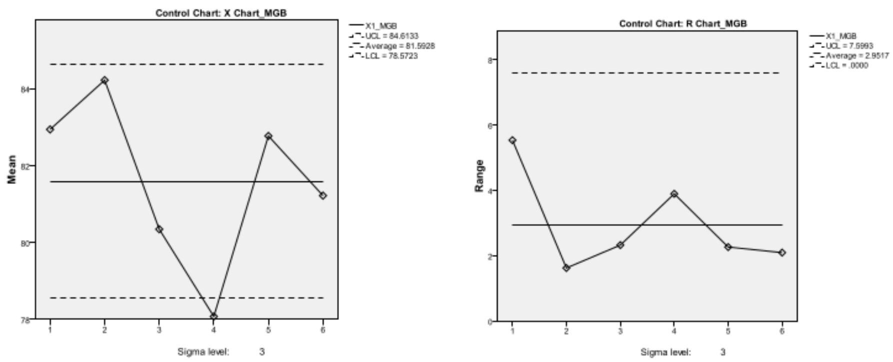

Figure 5. Control Chart of X and R on Waste Cooking Oil Biodiesel

From the results of X and R control chart analysis on biodiesel made from waste cooking oil and biodiesel made from Crude Palm Oil (CPO), there is one point that is outside the control limit (UCL and LCL). Whereas at the fifth point it is still within the control limits so that it can be said that the process is uncontrolled because of the fluctuating and irregular points this shows that the quality control for biodiesel products in used cooking oil and crude palm oil still needs to be improved. If an organization operates in a third world economy and needs to compete on a global scale, embracing SPC is a necessity. When SPC is utilized properly, it enables the manufacturer to prevent problems, control their production processes, and ultimately increase profits and customer satisfaction.[7]

Analysis of Cause and Effect Diagrams

Analysis of the biodiesel conversion factor which gives the largest contribution to the cause of the process is out of controlled and analyzed using a causal diagram (fishbone diagram). The analysis is carried out with several factors that influence the percentage of biodiesel conversion, including raw materials, environment, machinery, people and work methods. Furthermore, evaluation of various problem solving is carried out so that the production process becomes controlled. The cause and effect diagram of the biodiesel conversion percentage can be seen in Figure 6.

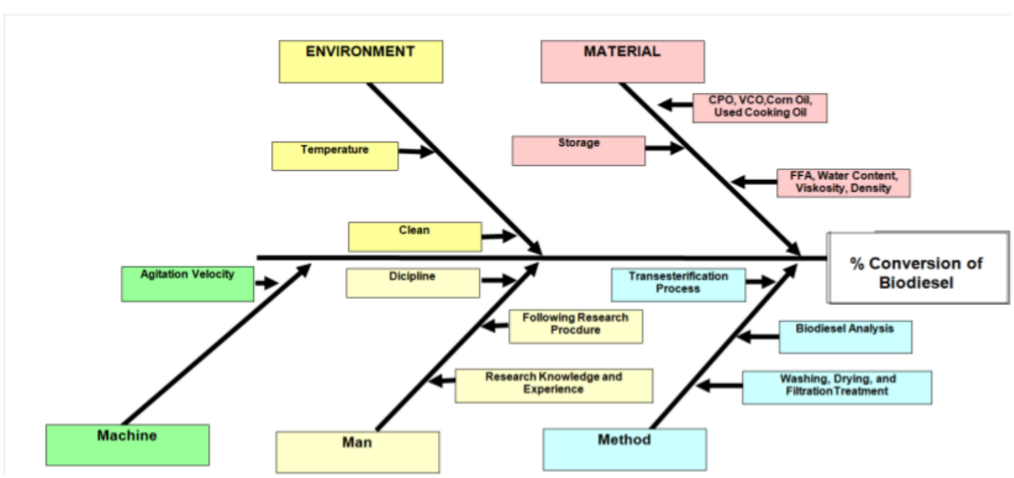

Figure 6 Fishbone Diagram for Biodiesel Conversion

5. Conclusion

1. Based on the results of the p control chart, it can be seen that the quality of the biodiesel products is beyond the control limit, namely in biodiesel products made from CPO (Crude Palm Oil) and used cooking oil.
2. The results of the quality test using the SPC process states that the conversion value of biodiesel products made from corn oil and VCO (Virgin Coconut Oil) had very good product quality while in CPO and used cooking oil biodiesel products are still the quality needs to be improved.
3. Based on the results of the causal diagram analysis, it can be known the factors that cause damage in the production process, which comes from workers / human factors, production machinery, working methods, materials/raw materials and work environment.

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