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

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Abstract

Biodiesel production is inseparable from raw materials availability, 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. In this study, we analyzed the use of raw materials against 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 methods, it could be found errors of study or out of control production hence further action can be taken to overcome problems. 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.

Keywords: Biodiesel, Conversion, Statistical Process Control (SPC),Control Chart

Abstrak (Indonesian)

Produksi biodiesel tidak terlepas dari ketersediaan bahan baku, sampai sekarang bahan baku yang memenuhi kebutuhan kapasitas produksi adalah minyak sawit (CPO). Penelitian ini bertujuan untuk mengetahui seberapa besar persentase konversi biodiesel jika menggunakan bahan baku lain seperti: minyak CPO, minyak jagung, minyak VCO, dan minyak goreng bekas serta menganalisa dan mengendalikan kualitas produk. Analisa yang digunakan adalah analisa pengunaan bahan baku terhadap nilai konversi biodiesel menggunakan metode *Stastical Process Control* (SPC). Metode *Statistical Process Control* (SPC) dapat digunakan untuk menganalisa, mengelola, mengendalikan, dan memperbaiki suatu produk dan proses menggunakan ilmu statistik. Dengan metode statistik dapat ditemukan kesalahan dalam suatu penelitian ataupun produksi yang dapat mengakibatkan produk yang tidak baik (*out of control*) sehingga dapat diambil tindakan lebih lanjut untuk mengatasinya. Hasil yang didapatkan menunjukkan produk yang diluar batas kendali yaitu biodiesel yang berbahan baku CPO dan minyak goreng bekas. Hasil analisis menggunakan diagram sebab akibat dapat mengetahui faktor penyebab kerusakan dalam proses produksi, yaitu berasal dari faktor pekerja/manusia, mesin produksi, metode kerja, material/bahan baku dan lingkungan kerja.

Kata Kunci: Biodiesel, Konversi, Statistical Process Control (SPC), Peta control

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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 kilolitres in a year, while the need of domestic diesel fuel is 16 million kilolitres 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 kilolitres 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 raised 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, and crude palm oil), animal fat (beef tallow, lard, and 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.

Indonesia has the largest coconut plantation in the world, which is around 3,781,600 hectares, but the export value of Indonesian coconut oil is still below the Philippines, namely Indonesia's exports 32.2% and the Philippines 45.6% of total world exports. Indonesian exports are still in the form of ordinary coconut oil or Ordinary Coconut Oil (OCO), while the Philippines has exported in the form of Virgin Coconut Oil (VCO) which has three times the price of OCO [3]. Therefore, the availability of abundant coconuts in Indonesia can be used to produce VCO which is much needed by local and world markets. VCO is coconut oil which is processed without using high temperatures and adding chemicals. VCO contains medium chain saturated fatty acid (MCFA) which consists of lauric acid, capric acid, caprylic acid, and myristic acid. The quality of VCO is determined by lauric acid, which reaches 45% [4]. The advantages of this oil are clear, colourless, not easily rancid, lasting up to two years, and the components are still intact.

Corn (*Zea mays*) is an important food crop in Indonesia. In 2016, the corn harvest area was 3.5 million hectares with an average production of 3.47 tons/ha, national maize production of 11.7 million tons. Corn oil is a triglyceride which is accompanied by glycerol and fatty acids. The percentage of triglycerides is around 98.6% while the rest is ash, dyes or wax which are non-oil ingredients. The fatty acids that make up corn consist of saturated and unsaturated fatty acids. In 100 kg of corn with 16% water content, it will produce around 64 kg of granulated flour and 3 kg of corn oil [5]. Corn oil contains high unsaturated fatty acids, contains essential fatty acids (omega 3 and omega 6), and vitamin E. Corn oil content in the core of corn kernels (corn germ) is as much as 83% with a humidity of 14%. In corn oil the most fatty acid content is C18: 2 linoleic acid (unsaturated fatty acids/unsaturated fatty acids) which can be used as raw material for making biodiesel. Furthermore, waste cooking oil has a large enough potential to be processed into biodiesel oil considering the consumption of cooking oil is very high, so that the remaining oil that has been used (waste cooking oil) is very good both from the household sector, food processing industry and restaurant / hotel.

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, analyse, manage, and improve the quality of the raw materials that will be used in making biodiesel [6]. The SPC method is expected to be effective to produce quality of biodiesel products and high conversion percentage values [7], [21], [15].

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 [8]. 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 [9]. 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 [10]. 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 [11]. 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 [12].

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 [13]. Thus this study is intended to spell out the concept of SPC for the benefit of those intending to use it their processes [14].

SPC uses product or service checks when the goods are still being produced (work in process) [16]. Periodic samples are taken from the output of the production process. If after the sample examination there is reason to believe that the characteristics of process quality have changed, the process will be terminated and the cause sought [17]. The cause can be a change in the operator, machine or material. If this cause has been stated and corrected, the process can be restarted. Monitoring the production process through random sampling, constant control can be maintained[18[. Process control is based on two important assumptions, namely: (a) Fundamental variability for each production process. No matter how perfect the design process is, there must be variability in the quality characteristics of each unit [18]. Variations during the production process are not completely avoidable and can never be completely eliminated. But some of these variations can be searched for causes and corrected. (b) The production process is not always in a controlled state, because of weak procedures, operators that are not trained to maintain machines that are not suitable, the production variation is usually much greater [4], [19].

Factors affecting quality according to Montgomery [4, 23], 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" [20]. 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 behavior of the process is characterized by the level or one or several qualitative values [21]. 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 [22]. Control charts also include criteria for comparing sample characteristics [10]. These criteria are control limits:

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

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

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

MATERIALS AND METHODS

Chemicals

The other chemicals were supplied from Merck and Sigma Aldrich such as methanol (CH_3OH), ethanol, sodium hydroxide (NaOH) and potassium hydroxide (KOH).

Equipments

The samples were taken periodically for analysis conversion using transesterification process. The transesterification process is carried out in reactor column for one hour.

Methods

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.

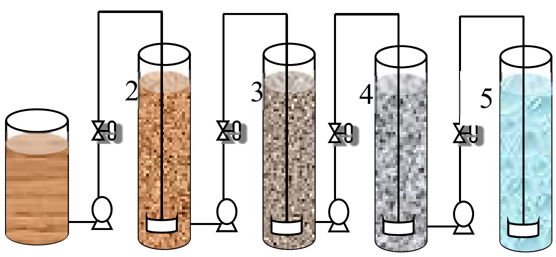

Figure 1. Tool Series Design

Tool Descriptions:
(1). Mixer for mixing catalysts and solvents
(2). Reactor column for biodiesel manufacturing
(3). Separator column
(4). Washing column
(5). Tank for biodiesel products

The separation and washing process using distilled water was conducted at a temperature of 40^{0}C. Analysis was carried out according to biodiesel quality standards.

RESULT AND DISCUSSION

The data used to make control chart X and R on the conversion of biodiesel made from CPO raw materials are shown in Table 1. Biodiesel conversion data was taken 6 batches of 3 samples.

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

Batch	X1	X2	X3	Total	$\bar{X}$	Range (Xmaks-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

The X and R control chart for the average conversion result of the target value or target value is 67.57% of the three sampling at each observation. For the R value of 2.77. In X control chart there is a UCL value of 70.40, LCL value of 64.74 and Cl value of 67.57 can be seen in Figure 2 that there is 1 point that is outside the control limit.

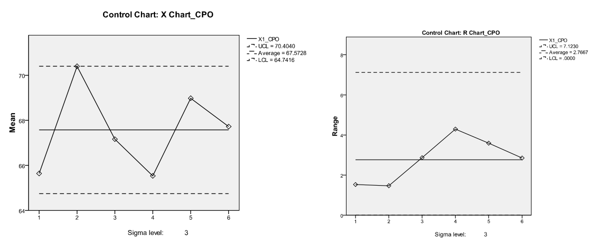

Figure 2. X and R control chart for CPO Biodiesel

Based on the control chart in Figure 2, it is known that the process is not controlled because there is one point that is outside the control limit. The point that is outside the control indicates that the process has experienced a tendency to decrease the production process, a decrease can be seen when at the second point that is outside the upper control limit.

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

Batch	X1	X2	X3	Total	$\bar{X}$	Range (Xmaks-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**

The data used to make control X and R chart on the conversion of biodiesel made from VCO raw materials are presented in Table 2. Biodiesel conversion data was taken in 6 batches and 3 times in retrieval where the average value of X was 80.03% while the value of Range (R) to 3.19.

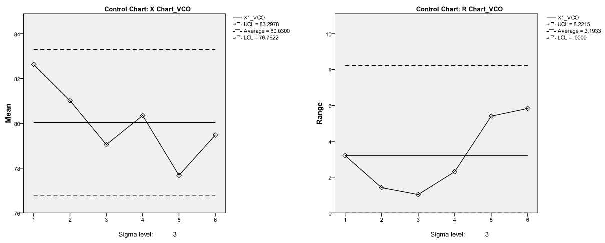

Figure 3. X and R Control Chart on VCO Biodiesel

Figure 3 shows that X and R control charts are still in good process control because there are no points that indicate beyond the control limits. The average UCL value on the X control map is 83.3, the CL value of 80.03 and LCL is 76.76.

The data used to make control X and R maps on the conversion of biodiesel made from corn oil is found in Table 3. Biodiesel conversion data was taken in 6 batches and as many as 3 samples.

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

Batch	X1	X2	X3	Total	$\bar{X}$	Range (Xmaks-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

The control chart is used to measure the proportion of nonconformities in the inspected process. It is seen in figure 4 that the X and R control maps are still in good process control because there are no points that indicate beyond the control limits.

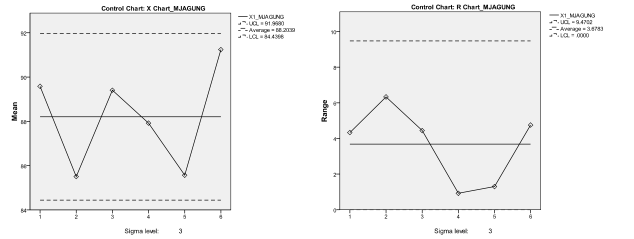

Figure 4. X and R Control Chart on Corn Oil Biodiesel

The data used to make control X and R chart on the conversion of waste cooking oil-based biodiesel are shown in Table 4. Biodiesel conversion data was taken in 6 batches and 3 times in retrieval with an average value (X) of 81.59% and value Range (R) is 2.95.

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

Batch	X1	X2	X3	Total	$\bar{X}$	Range (Xmaks-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**

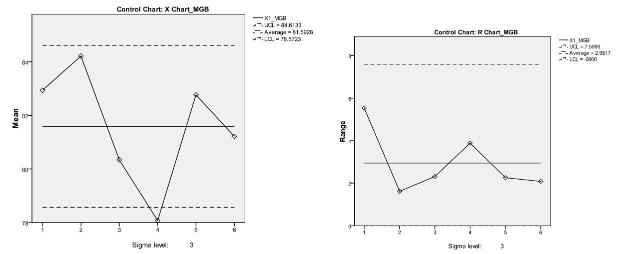

Figure 5. Control Chart of X and R on Waste Cooking Oil Biodiesel

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 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 analysed 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.

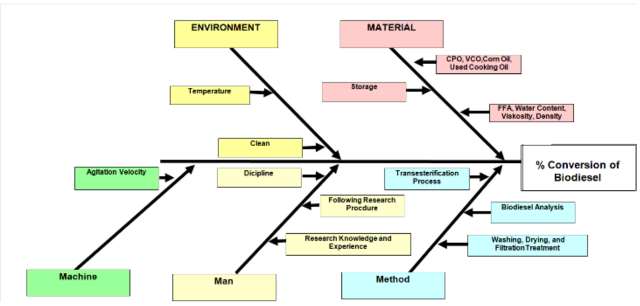

Figure 6. Fishbone Diagram for Biodiesel Conversion

CONCLUSION

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. 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) has very good product quality while in CPO and used cooking oil biodiesel products are still the quality needs to be improved. 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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