Production Of Activated Charcoal From Bagasse Waste To Reduce Grounding Resistance Of High Voltage Overhead Power Line

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ABSTRACT

Bagasse waste contains 0.79% ash, 27.90% pentose, 22.09% lignin, 37.65% cellulose and 2.0% essence (alcohol, benzene). The cellulose content can be made into active charcoal. The purpose of this study is to determine the effect of time and temperature of bagasse pyrolysis on reducing the grounding resistance value of high voltage overhead power line (SUTT). The bagasse samples were pyrolised at temperature variations of 600ºC, 700ºC, 800ºC, 900ºC, and 1000ºC, for the duration of 30 minutes, 60 minutes, 90 minutes, 120 minutes, and 150 minutes. The activated charcoal samples were then mixed with NaCl with ratio of 0:1; 0.25:0.75; 0.5:0.5; 0.75:0.25; and 1:0 before being planted under transmission tower. The optimum characteristics of activated carbon were obtained in pyrolysis for 149.8 minutes at 992.05ºC, with a characteristic value of 20.79% yield, 14.2% ash content, 1.71% moisture content, 83.71% fixed carbon, 2.09% volatile matter and 1142.1 mg/g iod absorption. These characteristics of activated charcoal meet the standards of activated carbon SNI 06-3730-1995. The results of data analysis show that the activated charcoal : NaCl ratio of 1:0 can reduce the value of SUTT grounding resistance by 76.26%

Keywords: bagasse, activated charcoal, grounding resistance value, SUTT

1. Introduction

Bagasse or bagasse waste is a solid waste derived from the cane sugar industry that contains fiber. The weight of sugarcane milled from a single factory can account for about 35% to 40% of the bagasse produced. The area of sugarcane plants in Indonesia is 490,008 ha, consisting of 182,376 ha in Sumatra Island, 279,727 ha in Java Island, 4,497 ha in Kalimantan, and 23,408 ha in Sulawesi Island, each producing 100 tons of bagasse per day [1]. Activated carbon is an amorphous carbon compound that has properties as an adsorbent and has electrical conductivity, and can adsorb selectively, depending on the size and surface area [2]. The surface area of activated charcoal generally ranges from 300 - 3500 m^2/gram. The activated charcoal is produced from materials containing carbon which are treated in a special way to obtain a wider surface area.

Electrical power in early 1900s was not grounded directly due to their low intensity and harmlessness. However, over time, electric power system has grown, posing a danger to humans, service systems and equipment if not grounded. With the grounding system, the fault current occurred during power system disturbance can be quickly channeled into the ground and spread in all direction [3].

One way to reduce grounding resistance is by deepening and increasing the diameter of the electrode rod by adding material or an additive to the soil [4]. The additives used in general are bentonite, gypsum and zeolite. A cheaper alternative is a mixture of activated charcoal bagasse and salt which reduced the grounding resistance of 150kV overhead line at Menes Baru - Tanjung Lesung, Banten.

The grounding resistance of transmission towers, both the high and extra high voltage overhead lines (SUTT / SUTET), reaches a maximum of 10Ω for 66kV, 150kV, 275kV and 500kV systems. There are 5 high voltage overhead lines, which capacities are close to 66kV and 150kV, with a maximum grounding resistance of 3Ω. Another 5 extra high voltage overhead lines, which capacities are close to 275kV and 500kV, have a maximum grounding resistance of 1Ω.

These low grounding resistances are required to ensure the safety of personnel from touch voltage and step voltage on the tower, and drain lightning impulses to the earth effectively [5]. Therefore, it is necessary to conduct research on the preparation of activated charcoal from bagasse waste for the application of grounding resistance reduction by giving additives to the soil with varying concentrations of activated charcoal and salt.

2. Material and Methods

The tools used in this research are glassware such as measuring flask, stirring rod, dropper, cup, volume pipette, weighing bottle, erlenmeyer, test tube, and other equipment such as balance, oven/microwave, furnace, pyrolysis, earth tester, 100mesh sieve 100, mortar and pestle.

The materials used in this research are bagasse waste from Oude Pangkah Suikerfabriek Sugar Factory Tegal, Central Java. Amylum, 15% KOH solution, 0.1N I_2 solution, KI solution, 0.1N sodium thiosulfate, starch and distilled water.

2.1 Preparation of Bagasse Waste

Bagasse was washed using clean running water in order to remove impurities such as soil and other dirts. Afterwards, it was dried in the sun for 3 days to remove moisture.

2.2 Preparation of Bagasse Activated Charcoal

The dried bagasse was dehydrated in an oven at 105^{o}C for 6 hours until a constant weight. Bagasse powder of 100 grams was then carbonized by burning in pyrolysis for 90 minutes at 600, 700, 800, 900, and 1000^{o}C, and at 800^{o}C for 30, 60, 90, 120, and 150 minutes. Bagasse charcoal samples were cooled afterwards for 1 day at 30^oC, prior to sieving with 100mesh sieve.

2.3 Activation of Bagasse Activated Charcoal

Bagasse charcoal was activated by soaking in 15% KOH activating agent for 24 hours prior to filtration using filter paper. The charcoal samples were then washed using distilled water until pH 7 and then dried in an oven for 24 hours at 150^{o}C until constant weight. Activated charcoal was then characterized to measure yield, moisture content, ash content, volatile matter, fixed carbon, iodine adsorption, and RSM (Response Surface Methodology) analysis.

2.4 Application of Bagasse Waste

Bagasse activated charcoal was mixed with NaCl with a concentration ratio of 0:1, 0.25:0.75, 0.5:0.5, 0.75:0.25 and 1:0. Each sample was inserted into a 4inch dia. pipe along with a 100cm long L50x50x4 elbow ground stick and compacted with a starch mixture. Afterwards, the ground apparatus were planted in the ground near the transmission tower base at 1.5m deep, and then connected with ground steel wire and tower stub material. The grounding resistance tests were then performed employing an earth tester.

3. Results and Discussions

3.1 Yield

Table 1. Yield of activated charcoal

Sample Code	T (°C)	T (minute)	Yield
A1	600	90	36,71%
A2	700	90	34,09%
A3	800	90	32,68%
A4	900	90	28,98%
A5	1000	90	25,29%
B1	800	30	44,57%
B2	800	60	38,89%
B3	800	90	32,68%
B4	800	120	24,22%
B5	800	150	20,79%

Table 1 shows the results of activated charcoal yields for various temperature and time of samples carbonization. The yields of bagasse activated charcoal in this study range between a minimum of 20.79% for sample B5 and a maximum of 44.57% for sample B1

Figure 1 shows the plot and regression curves of activated charcoal yield vs. pyrolysis time at 90minute. The longer carbonization time, the lower the yield of activated charcoal produced. By linear regression, the value of R^2 = 0.9747 is obtained. If the value of R^2 is close to 1, then the two variables have a strong relationship [6].

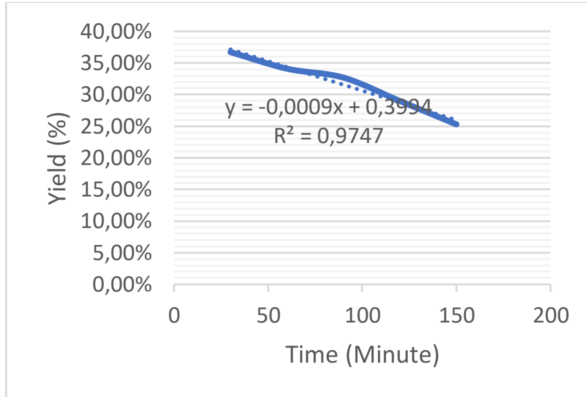

Figure 1. Effect of time on the yield of activated charcoal.

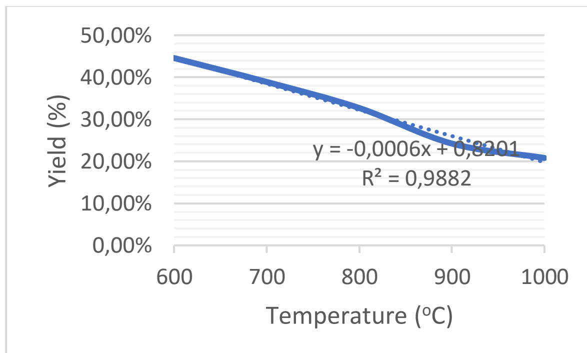

Figure 2. Effect of temperature on the yield of activated charcoal.

Figure 2 shows the plot and regression curves of activated charcoal yield produced after 800°C of pyrolisis vs. temperature. The higher the carbonization temperature, the lower the yield. By linear regression, the value of R^2 = 0.9882 is obtained. High carbonization temperature tends to reduce the yield of activated charcoal [6]. In fact, the high temperature results in increased degradation of the charcoal. The lower charcoal yield at higher pyrolysis temperature is due to the chemical reactions that occur between the charcoal and water vapor [7].

3.2 Moisture content

Table 2 shows the measurement results of moisture content of samples in this study which range between a minimum of 1.21% for sample B5 and a maximum of 2.21% for sample A2. All samples have moisture content less than 15% so they all meet the Indonesian national standard (SNI).

Table 2. Moisture content of activated charcoal

Sample Code	Moisture content	SNI 06-3730-1995
A1	2,06%	Maximum 15%
A2	2,21%	
A3	1,81%	
A4	1,89%	
A5	2,08%	
B1	1,91%	
B2	1,86%	
B3	1,81%	
B4	1,24%	
B5	1,21%	

Figure 3 shows the plot and regression curves of moisture content vs pyrolisis time of bagasse charcoal at 800°C. Minimum moisture content of 1.79% was measured for sample pyrolised for 120 minutes. Regression for 2nd order polynomial equation obtains the R^2 value = 0.8564. The longer the carbonization process, the larger number and size of pores opening or surface area of the charcoal [8], so that more moisture can be released. However, the moisture content is slightly increased for sample pyrolised for 150 minutes. Larger surface area may also adsorb more moisture during the process of transferring charcoal from the oven to the weighing device when there is direct contact between charcoal and air containing water vapor.

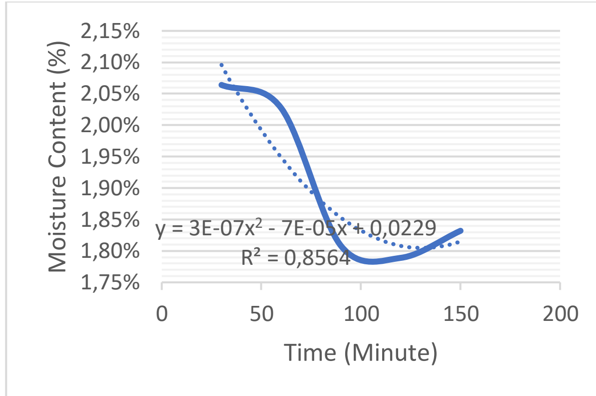

Figure 3. Effect of carbonization time on the moisture content of bagasse activated charcoal

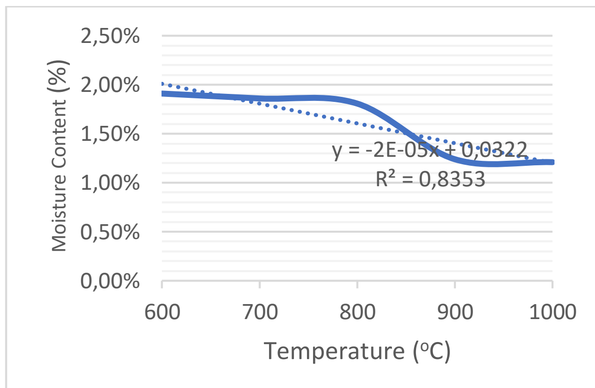

Figure 4. Effect of carbonization temperature on the moisture content of bagasse activated charcoal

The plot and regression curves showing the effect of temperature on the moisture content of activated charcoal produced over ninety minutes of pyrolysis is shown in Figure 4. The higher the carbonization temperature, the less moisture content is contained in samples. A value of R^2 = 0.8353 is obtained with a linear regression. As the increased carbonization temperature causes dehydration, the water contained in activated charcoal will evaporate quicker into the air. The highest moisture content is therefore observed for samples carbonized at the lowest temperature. The hygroscopic nature of charcoal as caused by water vapor molecules trapped in its hexagonal lattice during the cooling process can lead to an increased moisture content.

3.3 Ash content

The samples ash content is shown in Table 3 which ranges between a minimum of 14% for sample B5 and a maximum of 34% for sample B1. All samples have ash content higher than 10% so they do not meet the SNI

Table 3. Ash content of bagasse activated charcoal

Sample Code	Ash Content	SNI 06-3730-1995
A1	27%	Maximum 10%
A2	22%	
A3	21%	
A4	23%	
A5	27%	
B1	34%	
B2	26%	
B3	21%	
B4	17%	
B5	14%	

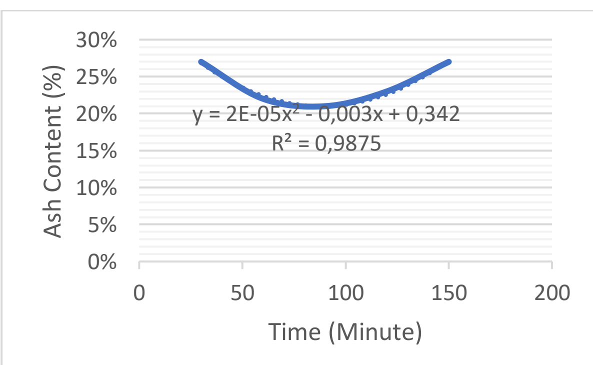

Figure 5. Effect of carbonization time on the ash content of bagasse activated charcoal

Figure 5 shows the plot and regression curves for the ash content of activated charcoal prepared at 800°C vs time. The ash content drops to a minimum of 21% for samples carbonized for 90 minutes. Using 2nd order polynomial regression, we obtain a value of $R^2 = 0.9875$, which indicates that there is significant relationship between the carbonization time and the ash content of activated charcoal.

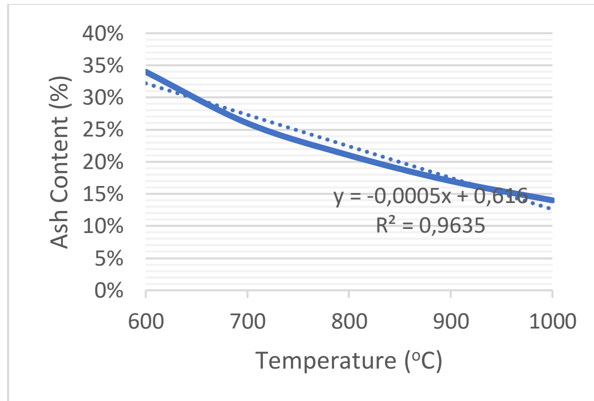

Figure 6. Effect of carbonization temperature on the ash content of bagasse activated charcoal

Plot and linear regression curves showing the temperature effect on the ash content of activated charcoal produced over ninety minutes of carbonization is shown in Figure 6. The higher the carbonization temperature, the less ash is produced. A value of $R^2 = 0.9635$ is obtained with a linear regression. The ash content will increase with carbonization temperature [10]. High carbonization temperatures cause inorganic elements to oxidize and produce ash compounds that cause high ash content. High ash content reduces adsorption capacities, thus interfering with the performance of the activated charcoal [11].

3.4 Volatile matter

Table 4 shows the volatile matter content of activated charcoal, which ranges between a minimum of 1.91% for sample B5 and a maximum of 2.74% for sample B1. The maximum volatile matter content of activated charcoal is 25% according to the SNI, and all samples meet this standard

Table 4 Volatile matter content of activated bagasse activated charcoal

Sample Code	Volatile Matter	SNI 06-3730-1995
A1	2,37%	Maximum 25%
A2	2,21%	
A3	2,06%	
A4	2,25%	
A5	2,45%	
B1	2,74%	
B2	2,40%	
B3	2,06%	
B4	1,97%	
B5	1,91%	

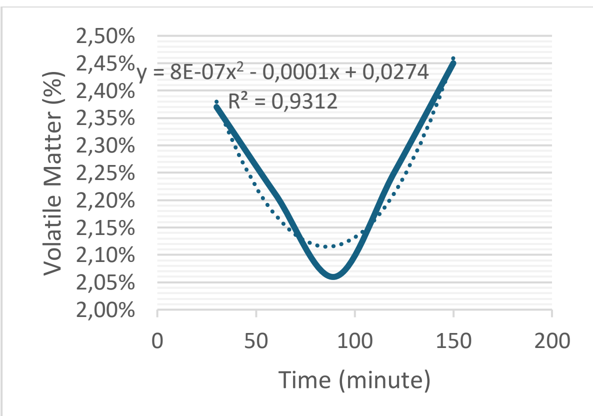

Figure 7. Effect of carbonization time on volatile matter content of bagasse activated charcoal

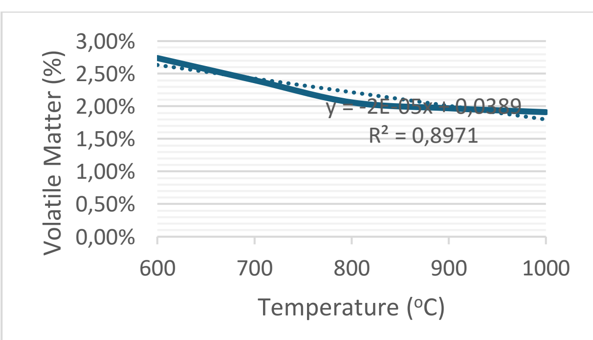

Figure 8. Effect of carbonization temperature on volatile matter content of bagasse activated charcoal

Figure 7 shows the plot and regression curves of volatile matter content against carbonization time. For samples prepared over 90 minutes, the volatile matter content decreased to a minimum of 2.06%. The value of R^2 = 0.9312 is obtained by 2nd order polynomial regression, which means that the volatile matter content is significantly correlated to the carbonization time

The plot and regression curves of volatile matter content of activated charcoal prepared over ninety minutes against carbonization temperature is shown in Figure 8. A value of R^2 = 0.8971 was obtained with a linear regression. The higher the carbonization temperature, the less volatile matter is remained in the samples. [10]. A complete decomposition of noncarbon compounds occurs at high temperature. A tool to measure the amount of volatile matter evaporated during the carbonization process is volatile matter, which is a product of the decomposition of compounds still present in charcoal other than water. This parameter has the ability to measure the level of active charcoal adsorption. As the volatile matter content in activated charcoal increases, its adsorbing capacity for solutions and gases decreases.

3.5 Fixed carbon

Table 5 shows the fixed carbon content measurement results of bagasse activated charcoal which range between a minimum of 63.26% for sample B5 and a maximum of 84.09% for sample B5. All samples except B5 meet the SNI, in which the minimum fixed carbon content is 65%.

Table 5. Fixed carbon content of

bagasse activated charcoal

Sample Code	Fixed Carbon	SNI 06-3730-1995
A1	70,63%	Minimum 65%`
A2	75,79%	
A3	76,94%	
A4	74,75%	
A5	70,55%	
B1	63,26%	
B2	71,60%	
B3	76,94%	
B4	81,03%	
B5	84,09%	

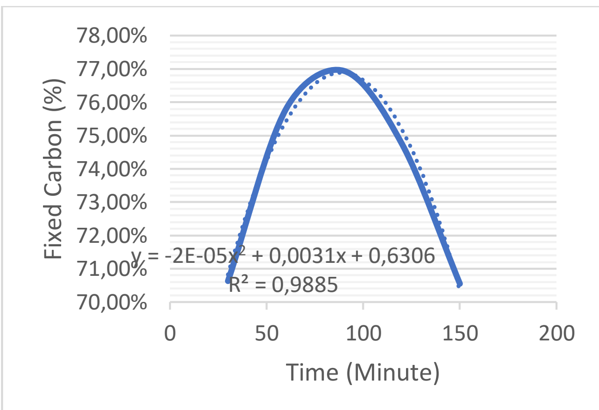

Figure 9. Effect of time on fixed carbon of activated charcoal

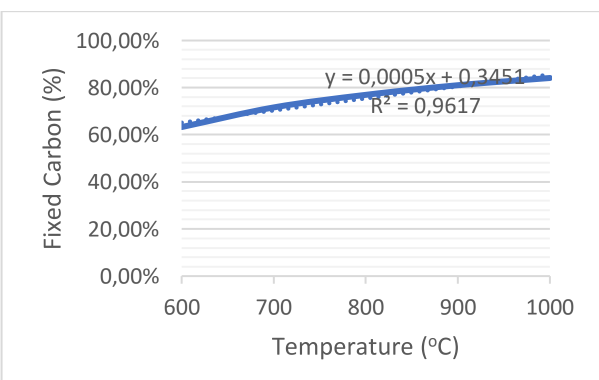

Figure 10 Effect of carbonization temperature on fixed carbon content of bagasse activated charcoal

Figure 9 shows the plot and regression curves of the fixed carbon content of activated charcoal produced at 800°C against carbonization time. The highest fixed carbon content of 76.94% is observed for sample

carbonized for 90 minutes. By using 2nd order polynomial regression, the value of R^2 = 0.9885 is obtained. This result means that carbonization time has a strong relationship with fixed carbon content. Samples carbonized for 120 and 150 minutes have moisture content, volatile matter and ash content increase, which cause the fixed carbon content to decrease [13].

Figure 10 shows the plot and regression curves of fixed carbon content of activated charcoal produced over 90 minutes against carbonization temperature. The higher the carbonization temperature, the higher the fixed carbon content remained in the sample. By using linear regression, the value of R^2 = 0.9635 is obtained. Fixed carbon content is influenced by ash and volatile matter content in activated charcoal [14]. Apart from volatile matter and ash content, fixed carbon content can also be influenced by lignin and cellulose content.

3.6 Iodine Absorption

Table 6 shows the results of iodine adsorption measurement of bagasse activated charcoal which range between a minimum of 1,142.10mg/g for sample B5 and maximum of 1,725.84mg/g for sample B1. All samples meet the SNI, in which the minimum iodine adsorption capacity of activated charcoal is at least 750mg/g.

Table 6. Iodine absorption capacity of bagasse activated charcoal

Sample Code	Iodine Absorption	SNI 06-3730-1995
A1	1167,48	Minimum 750 mg/g
A2	1294,38	
A3	1370,52	
A4	1395,90	
A5	1497,42	
B1	1725,84	
B2	1573,20	
B3	1370,52	
B4	1294,68	
B5	1142,10	

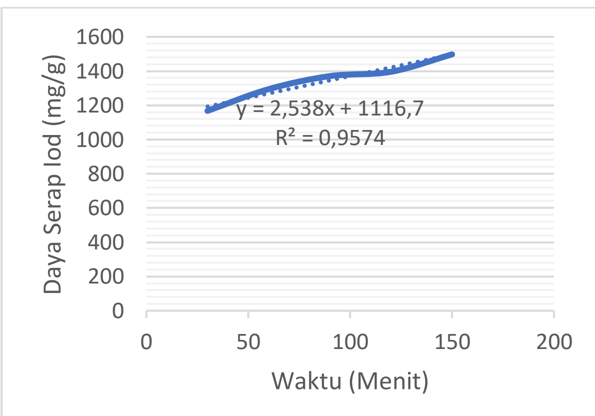

Figure 11. Effect of carbonization time on iodine absorption of bagasse activated charcoal

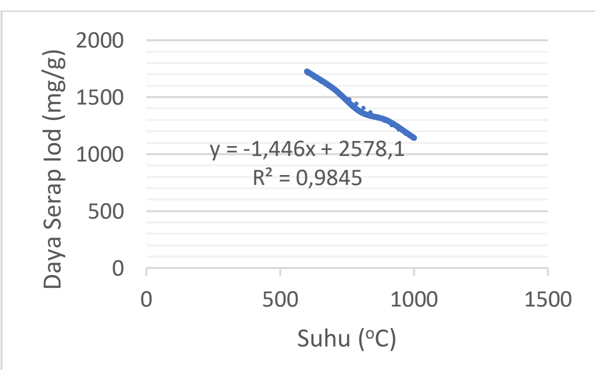

Figure 12. Effect of carbonization temperature on iodine absorption of bagasse activated charcoal

Figure 11 shows the plot and regression curves of the iodine absorption capacity against carbonization time of activated charcoal prepared at 800°C. The longer the carbonization time, the higher the iodine adsorption capacity [15]. By employing linear regression, the value of R^2 = 0.9574 is obtained.

The increasing time of carbonization provides higher surface area of the pores within the activated charcoal that can adsorb more iodine.

The plot and regression curves of the iodine adsorption of activated charcoal against carbonization temperature for ninety minutes is shown in Figure 12. The higher the carbonization temperature, the lower the iodine adsorption capacity. The value of R^2 = 0.9845 is obtained with a linear regression.

3.7 Response Surface Methodology (*RSM*) Analysis

Figure 13 shows the contour plot of fixed carbon content within the experimental ranges of carbonization temperature and time. This contour plot can explain how the combination of carbonization time and temperature affects the fixed carbon content of activated charcoal samples, which intensities are represented through the gradation of colors [16]. A darker green colored area indicates a higher percentage of fixed carbon content in the related samples. Therefore, the area with the darkest green color indicates the samples with fixed carbon content of more than 80%. These samples were prepared at 900 – 1000°C for 50 – 130 minutes.

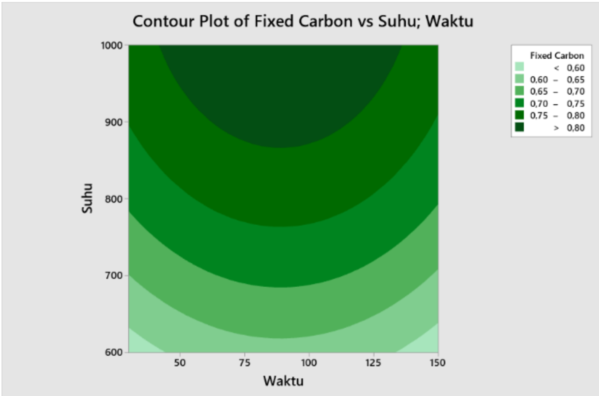

Figure 13. Contour plot of fixed carbon content against carbonization time and temperature of bagasse activated charcoal

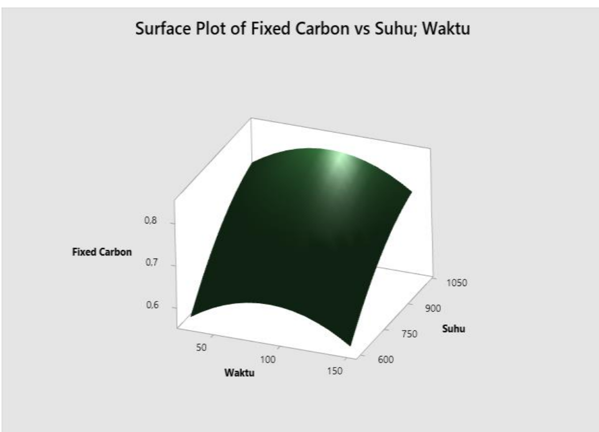

Figure 14. Surface plot of fixed carbon content of bagasse activated charcoal as optimized for carbonization temperature and time

Figure 14 is the surface plot which shows that the maximum fixed carbon content will be reached within 90 to 120 minutes of carbonization at 1000°C. This result indicates that a high fixed carbon content is resulted by a high carbonization temperature and optimum carbonization time, which results in more effective removal of impurities. The higher carbon content provides a larger surface area in the pores of activated charcoal, which makes it easier to adsorb hygroscopic water [9].

Figure 15 shows the analysis process carried out using the MINITAB 19 program to obtain RSM optimization. The optimum time of 149.8 minutes and optimum temperature of 992.05°C are required to obtain optimum yield of 20.79%, ash content of 14.2%, moisture content of 1.70%, fixed carbon of 83.71%, volatile matter of 2.09%, and iodine adsorption of 1,142.1mg/g with a desirability value of 0.99. The ability to produce the desired product almost perfectly is indicated by the desirability value getting closer to one [17].

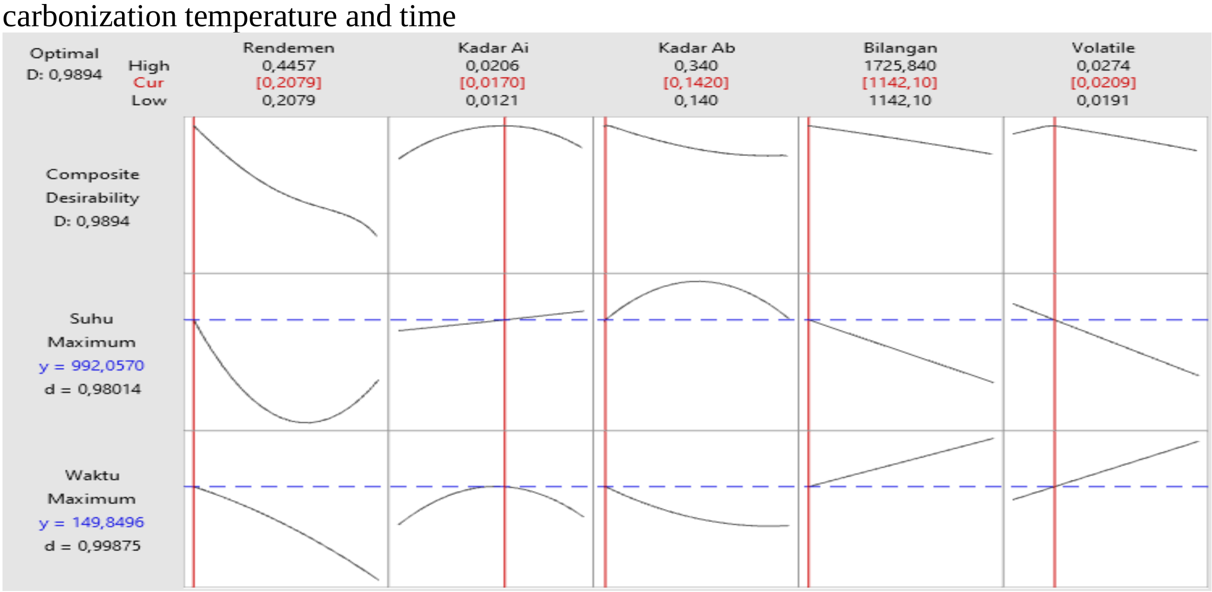

Figure 15. Optimum yield plots of activated charcoal

Table 7. Results of Yield Validation

Temperature (°C)	Time (Min)	Yield (Replication)		
		#1	#2	#3
992,05	149,84	20,69	21,01	20,83

Table 7 shows yields of carbonization as performed three times at optimum condition, which are not significantly different from the RSM prediction (rounded into 21%). This result validates the RSM analysis for optimization. Accuracy calculations were then performed, in which the RSM model has an acceptable value of 99.74%.

3.8 Application of bagasse activated charcoal for the reduction of grounding resistance

Table 8 shows the value of grounding resistance as measured for various concentration ratios of bagasse activated charcoal to NaCl. The value of grounding resistance without the mixture is 9.65Ω. The grounding resistance value is decreasing as the portion of activated charcoal increases while the portion of NaCl decreases. The grounding resistance is reduced by 8.91%, 36.3%, 54.1%, 71.1%, and 76.3% from the original value consecutively, with incremental increases of activated charcoal portion by 0.25.

Table 8. Grounding resistance for various concentration ratio of bagasse activated charcoal to NaCl

Sample Code	Concentration Ratio	Grounding Resistance (Ω)
n/a	0:0	9,65
1	0:1	8,79
2	0.25:0.75	6,15
3	0.5:0.5	4,43
4	0.75:0.25	2,79
5	1:0	2,29

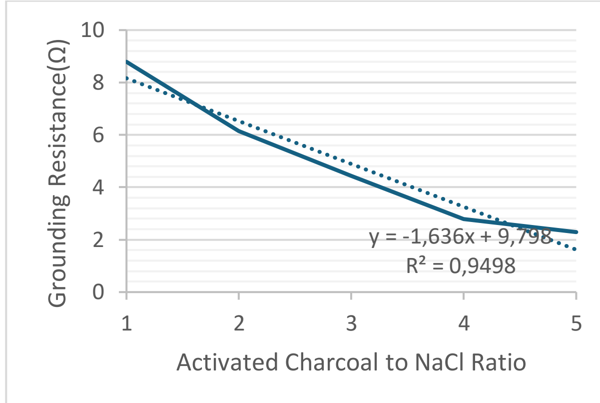

Figure 16. Effect of bagasse activated charcoal to NaCl concentration ratio on grounding resistance

Plot and regression curves showing the effect of bagasse activated charcoal to sodium chloride concentration ratio on the resulting grounding resistance value can be seen in Figure 16. The grounding resistance is negatively correlated with the concentration ratio of activated charcoal to NaCl. A value of R2 = 0.9498 is obtained through linear regression. This result confirms the fact that the addition of activated charcoal and sodium chloride in different concentrations ratio, most effectively 1:0, showed an impact on decreasing the grounding resistance value in paddy fields or clay soil, due to the mineral content of the mixture [18].

4. Conclusion

The preparation of bagasse activated charcoal by carbonization at temperatures of 600, 700, 800, 900 and 1000°C for 30, 60, 90, 120 and 150 minutes obtained optimum conditions as analyzed using RSM at carbonization time of 149.8 minutes and temperature of 992.05°C. The optimum characteristic values obtained are yield of 20.79%, ash content of 14.2%, moisture content of 1.71%, fixed carbon of 83.71%, volatile matter of 2.09%, and iodine adsorption of 1,142.1 mg/g. All these characteristics meet SNI 06-3730-1995, the

Indonesian national standard for activated carbon.

The values of grounding resistance were measured for the applied mixtures of activated charcoal to NaCl at concentration ratios of 0:1, 0.25:0.75, 05:05, 0.75:0.25, 1:0. The highest resistance reduction was 76.3% at concentration ratio of 1:0. The value of grounding resistance from 150kV SUTT in Menes Baru - Tanjung Lesung is 2.29 Ω, which meets the standard of SPLN T5.012-2020.

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