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Thermal Energy Conversion in Making Biochar from Jengkok Tobacco Waste Using Pyrolysis Extrusion Model

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ABSTRAK

Proses pirolisis mempunyai banyak model dengan karakteristik dan spesifikasi yang berbeda. Masing-masing model memberikan nilai konversi yang berbeda pada penggunaan temperatur, waktu dan bahan baku yang digunakan. Limbah Jengkok Tembakau yang berbahaya karena kandungan Arsen (As) akan dimanfaatkan menjadi produk biochar yang mempunyai nilai ekonomis dan strategis melalui proses pirolisis model *extrusion*. Tujuan dari penelitian ini adalah menentukan konversi *thermal* (% Yield) proses pirolisis bahan limbah jengkok tembakau menjadi biochar terhadap temperatur dan waktu proses yang optimal. Variabel yang ditentukan terdiri dari temperatur proses (400, 450, 500, 550, dan 600°C) dan waktu proses (30, 35, dan 40 menit). Produk hasil proses akan dilakukan analisa statistik menggunakan uji korelasi *rank spearman* dan dilanjut dengan minitab untuk menghasilkan nilai optimal. Hasil penelitian menunjukkan bahwa nilai konversi *thermal* pada proses pembuatan biochar dengan bahan baku limbah jengkok tembakau adalah sebesar 29,476% (≈30%) pada temperatur proses 500°C dan waktu proses 30 menit.

***Kata Kunci*:** biochar, extrusion, pirolisis, persen yield.

ABSTRACT

The pyrolysis process has many models with different characteristics and specifications. Each model provides a different conversion value depending on the temperature value, length of time, and the number of raw materials used. Jengkok Tobacco waste was dangerous because it contains Arsenic (As), and was used as a biochar product with economic and strategic value through the extrusion model pyrolysis process. The purpose of this study was to determine the thermal conversion value (yield percentage) of the pyrolysis process of tobacco waste material into biochar at the optimal temperature and processing time. The specified variables consist of process temperatures (400, 450, 500, 550, and 600°C) and processing times (30, 35, and 40 minutes). The product of the process will be analyzed statistically using the Spearman rank correlation test and followed by Minitab to produce the optimal value. The results showed that the thermal conversion value in making biochar was 29.476% (≈30%) at a process temperature of 500°C and a processing time of 30 minutes.

***Keywords*:** biochar, extrusion, pyrolysis, yield percentage.

1. INTRODUCTION

Waste material from the cigarette production process known as Jengkok is very abundant, estimated to reach 20 tons per day in the cigarette industry (PT. Gudang Garam Kediri). This waste is potentially harmful because of the heavy metal content of Arsenic (As) which is toxic and exceeds the pollution threshold standard. Sutapa et al. stated that waste treatment has economic value [1]. Therefore, to reduce the negative effect on waste, Bridgwater stated that it needs to be converted into biochar to have a practical value [2]. A previous study has been done to convert tobacco waste into biochar (Bio-Charcoal) using Torefication equipment [3].

Biochar is a relatively stable carbon compound, and more stable than organic compounds that are not charred [4]. Thus, it

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will not harm the environment, air, water, soil, and the social environment. A study by Widowati et al. shows that the highest increase in soil organic matter occurred after applying jengkok biochar [5]. Soil amendments using biochar and various types of organic fertilizer have been shown to improve soil properties. The experiment used three types of biochar from rice husk, corn cob, and by-products of the tobacco industry called jengkok. The results showed that each type of biochar had different effectiveness in improving the soil organic matter and its physical properties [6].

One way to produce biochar is by carbonization using pyrolysis technology. Ryu et al. [7] and Di Blasi [8] define pyrolysis as a process of thermal degradation of organic compounds in conditions without oxygen and pressure which produces solid (char), liquid (pyrolitic liquid), and gas (permanent gas) at temperatures between 400-800°C.

The percentage ratio of product produced is influenced by the operational process conditions such as temperature and retention time of material in the reactor. As also explained by Sheth and Babu, the amount of product produced during pyrolysis depends on the pyrolysis conditions [9]. The pyrolysis process can occur at temperatures above 300°C within 4-7 hours [10]. However, this condition is highly dependent on the raw materials and the method of manufacture [11,12]. Pyrolysis temperature will significantly affect the charcoal produced so that the determination of the right temperature will determine the quality of the charcoal [13].

The quality of biochar is influenced by the combustion method (reactor, temperature, and method) and the type of raw material [14]. Likewise, the conditions of the pyrolysis process can optimize biochar production [15-17].

Therefore, this study will determine the effect of technology on the biochar production process (temperature, time, and method) to produce optimal biochar products. Thus, it can be seen how much the thermal conversion value of a biomass pyrolysis process is using extrusion technology.

2. RESEARCH METHODS

2.1. Materials and Instruments

The material used was jengkok tobacco, with water content not more than 15 wt% with a temperature of 30±2°C. The weight per batch is 100-200 kg, and the machine used is an Extrusion Pyrolysis machine.

2.2. Research Methods

This research was conducted using the case study method at PT. Gudang Garam Tbk., Kediri. Analysis of the problems observed is the efficiency and effectiveness of the jengkok biochar production process using a variable temperature process (400, 450, 500, 550, and 600°C), and processing time (30, 35, and 40 minutes) on yield percentage. Observations made during the production process include the initial weight of jengkok tobacco, the weight of biochar produced, the initial temperature of biochar, and the output temperature of biochar. The data were taken directly during the production process and carried out using statistical analysis.

Raw materials (jengkok tobacco) were prepared and then weighed per batch, and the measured water content should not exceed 15 wt%. Furthermore, the material is passed through the conveyer to be inserted in the screw extruder through the hopper. The pyrolysis process with the extrusion model begins. Using the temperature and processing time according to the specified variables (400, 450, 500, 550, and 600°C / 30, 35 and 40 minutes). Observations made during the production process including the initial weight of jengkok tobacco, the weight of biochar produced, the temperature of jengkok (raw material), and the temperature of biochar produced. After the required data is complete, the yield percentage was calculated with the formula:

$$\% \, Yield \ Biochar = \frac{\text{Biochar weight}}{\text{Jengkok material weight}} \times 100 \ \% \quad (1)$$

The results obtained were then tested for correlation using Spearman rank because it was known that the data distribution was not expected based on the normality test results. After that, the optimal temperature and processing time value were determined to produce the maximum value of thermal conversion in the pyrolysis process from tobacco waste material into biochar.

Table 1. Yield percentage of biochar from Jengkok using pyrolysis extrusion model.

Set Point Temperature (°C)	Actual Temperature (°C)	Time (Minute)	Weight of Material (Kg)	Weight of Biochar (Kg)	Biochar Temperature (°C)	Material Temperature (°C)	Yield (%)
400	403.4	30	100	22.2	45.5	32	22.4
400	418.0	35	100	17.8	41	31.7	17.8
400	416.9	40	100	23.7	43.4	32.4	23.7
450	474.9	30	110	36.7	39.5	29.5	33.36
450	466.8	35	100	28.8	42.5	30.5	28.8
450	456.2	40	125	39.7	42.0	32	31.76
500	509.6	30	200	59.7	45.6	31.6	29.85
500	521.2	35	200	58.5	40	30	29.25
500	514.6	40	100	26.2	38	31	26.2
550	557.8	30	105	27.6	42	32	26.28
550	556.7	35	105	37	39	32	35.23
550	549.0	40	100	22.5	42	32.4	22.5
600	601.2	30	124	41	38	31	33.1
600	617.6	35	129	40	42	31	31
600	615.0	40	110	30.9	43	31	28.1

Table 2. Correlation factors on ETIA.

		Yield
Temperature	Correlation Coefficient	0.415
	Sig. (2-tailed)	0.0124
	N	15
Time	Correlation Coefficient	0.265
	Sig. (2-tailed)	0.0341
	N	15

*significant at the 5% significance level

3. RESULTS AND DISCUSSION

Based on the datasheet that has been collected, the yield percentage of biochar can be calculated with the formula (1). The results of the calculation of yield percentage can be seen in Table 1.

The correlation analysis was used to determine the correlation between temperature and time to percent yield. The used correlation test was the Spearman rank correlation test, because based on the results of the data normality test (in the SPSS attachment), it was known that the data distribution was not normal. The results of the correlation test were presented in Table 2.

Table 2 presented the correlation coefficient of temperature with a yield of 0.415 and a sig value of 0.0124. This indicated that an increase in temperature will be followed by an increase in yield. This sig value was smaller than 0.05 (5%), so the conclusion can be drawn that there was significant relationship between temperature and yield.

The correlation coefficient of time with a yield of 0.265 and a sig value of 0.0341, this indicated that an increase in time will not always be followed by an increase in yield. This sig value was bigger than 0.05 (5%), so the conclusion can be drawn that there was little influence or little significant relationship between time and yield.

The following statistical analysis was to analyse the effect of temperature and time variables on yield. This experiment used a factorial experimental design with two factors: temperature consisting of 5 levels, and time consisting of 3 levels.

Table 3. Analysis of temperature and time on yield percentage.

General Factorial Regression: Yield versus Temperature ; Time

Factor Information

Factor	Levels	Values
Temperature	5	400; 450; 500; 550; 600
Time	3	30; 35; 40

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	6	208,22	34,703	2,36	0,130
Linear	6	208,22	34,703	2,36	0,130
Temperature	550	190,42	47,605	3,23	0,0174
Time	35	17,80	8,898	0,60	0,570
Error	8	117,88	14,735		
Total	14	326,09			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3,83858	63,85%	36,74%	0,00%

Based on Table 3 for factorial analysis of temperature and time on yield percentage, the significance value (p-value) for the temperature variable was 0.0174 and for the time variable was 0.57. The sig value in the time variable was bigger than 0.05 (5%), so the conclusion can be drawn that there was little time effect on the yield value. In the temperature variable, the resulting sig value was 0.0174, so the conclusion drawn that the temperature affects yield. The image below (Figure 1) described the main effect plot and the interaction plot between temperature and time on yield.

Figure 1 showed that the smallest yield value was at the first temperature (400°C). Then, when the temperature was increased, there was an increase in yield. In the time variable, there was a tendency for the yield to decline with increasing time. This indicated that compounds such as hemicellulose, cellulose and lignin have been decomposed during the combustion process. The decomposition of volatile substances in biochar can increase the formation of functional groups in biochar which affected the specific surface area and pore structure in biochar [18]. The amount of volatile matter in the biochar increases with increasing pyrolysis temperature. Volatile substances are the process of losing weight (other than water) contained in biochar. The volatile matter was influenced by the pyrolysis temperature and the type of biochar raw material. The level of volatile substances in biochar was influenced by the compounds contained in the raw materials such as chemical components of extractive substances.

The graph of the interaction between time and temperature on yield was presented in Figure 2. It can be seen that there was an increase in yield from 400 to 450°C for all time variable, and tends to decrease from 450 to 550°C. This happens because jengkok is a type of raw material that is non-woody, flammable and has a lower lignin content than other raw materials. According to Demirbas [10], high lignin content will result in higher biochar formation. The yield of biochar was influenced by the conditions of making biochar (pyrolysis), especially the influence of temperature and duration of combustion. The interaction of temperature and time can affects the yield of biochar. The biochar's water content increases with increased burn time. This condition can be caused by the longer carbonization process. The more opened pores of the biochar will cause direct contact between the hydroscopic biochar and the air. So that, the biochar absorbs a lot of water vapor and the biochar yield will decrease [19].

The optimization of temperature and time on yield was presented in Figure 3. The optimal value of temperature and time to yield percentage was obtained by using Minitab Statistical Software. The optimal value was located at the 3rd temperature variable (500°C) and the 1st time variable (30 minutes) that produced a yield percentage of 29.476% (≈30%).

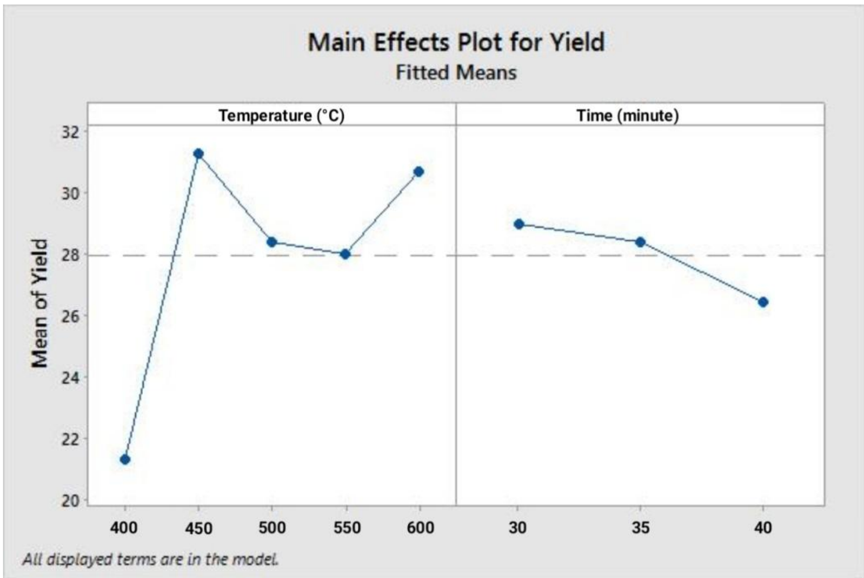

Figure 1. Main effect plot of temperature and time on yield.

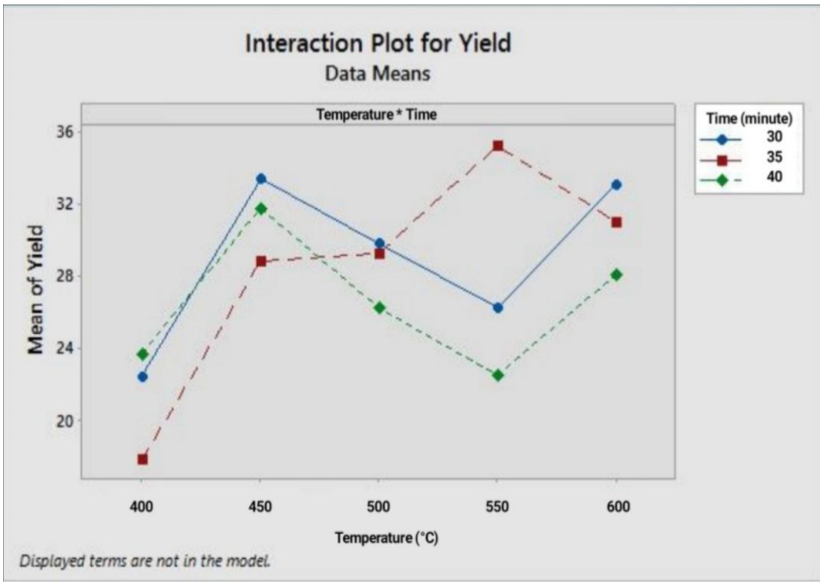

Figure 2. Interaction plot between temperature and time on yield.

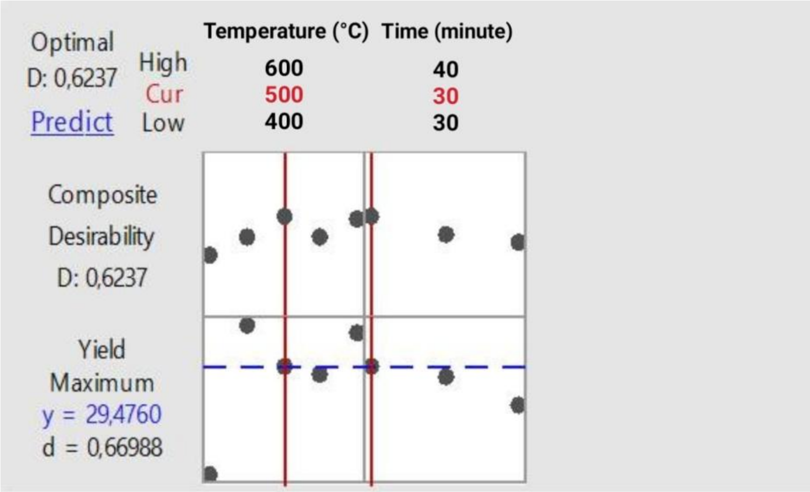

Figure 3. Plot of temperature and time optimization on yield.

4. CONCLUSION

In the biochar production process using extrusion model pyrolysis technology, there was a correlation and mutual influence between temperature and processing time on % yield. The optimal thermal conversion value was 29.476% (≈30%) at a process temperature of 500°C and a processing time of 30 minutes.

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