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Candlenut Shell Charcoal Yield in Every Chamber Produced by Candlenut Shell Carbonization Tool Using a Vertical Multi Chamber

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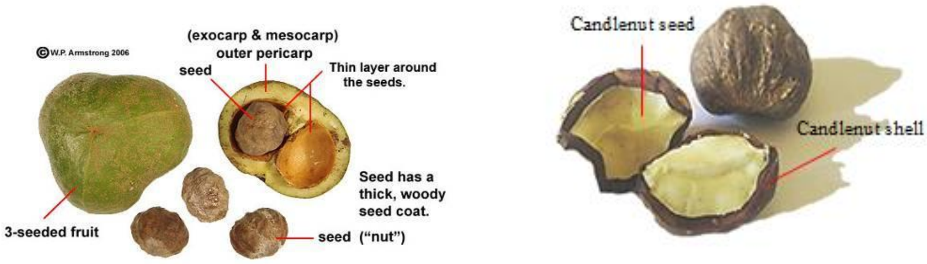
Abstract. Candlenut shell contained organic compound, such as hemicelluloses, cellulose, and lignin which can be converted to solid, liquid, and gaseous products by thermochemical methods. One of the products is charcoal. One of the tool that can carbonize the candlenut shell is candlenut shell carbonization tool using a vertical multi chamber. The tool can carbonize candlenut shell without having any additional energy. Some variables from the tool has been identify from the previous research, such as its maximum capacity and process time, while its charcoal yield remains unknown. Therefore, this research is aimed to determine the charcoal yield that can be produced by candlenut shell carbonization tool using a vertical multi chamber. Three carbonization experiments were performed with 8 kg candlenut shell filled in every carbonization chamber (CC). The carbonization process temperature was measured for each chamber by using a thermocouple in order to know the effect of temperature toward charcoal yield. As the result, the average candlenut charcoal yield that can be produced by candlenut shell carbonization tool using a vertical multi chamber is 24.99 %. Every chamber was experiencing deferent capability in producing charcoal. CC3 is the highest charcoal yield chamber with 31.38 % and then followed by CC2 with 25.04 % and CC1 with 18.79 %. Based on temperature that experiencing by every chamber, it indicates that the temperature has a significant impact on charcoal yield. When the temperature high, the charcoal yield is low and also goes the same in contrary. Therefore, candlenut shell carbonization tool using a vertical multi chamber has capability in producing candlenut shell charcoal at 24.99 % yield.

Keyword: Candlenut shell, carbonization, charcoal yield, candlenut shell carbonization tool

1. Introduction

Candlenut/Aleurites moluccana (L.) Willd which is one type of industrial plant from the family of Euphorbiaceae [1] has been planted for decades in Indonesia with both commercially and non-commercially purposes. This kind of plant has some advantages: its seed can be used as a media for a light, food and medicine, while its tree is used for timber [2]. The seeds are contained within a hard, black, rough shell ellipticalin shape and about 2.5-3.5cm (1-1.4 inches) long [3]. Hence, Candlenut consists of two main parts which are candlenut seed and candlenut shell. Candlenut and its parts are shown in Figure 1.



(a) (b)

Figure 1. Candlenut and its parts;(a) Candlenut fruit [4];(b) Candlenut seed and its shell [5].

Candlenut seeds were taken by breaking the shells as the solid waste from the candlenut fruit. Candlenut shell is 3-4 mm thick [6] containing organic compound, such as hemicelluloses, cellulose, and lignin [7] and one of biomass waste which is a renewable energy source. Its potential has to be utilized as a part of minimizing the waste and also a new option for energy by converting its form. The biomass can be converted using biochemical, chemical, and thermochemical processes. These days, thermal conversion is found widely used in the community and has received special attention since it leads to useful products and simultaneously contributes to solving pollution problems arising from biomass accumulation [8]. Biomass materials can be converted to solid, liquid, and gaseous products by thermochemical methods. One of the products is charcoal. Charcoal is produced by slow heating wood (carbonization) in airtight ovens or retorts, in chambers with various gases, or in kilns supplied with limited and controlled amounts of air [9]. Therefore, some tools were developed to produce charcoal using carbonization method.

One of biomass conversion tool that used carbonization method in converting biomass into charcoal is Candlenut Shell Carbonization Tool using a Vertical Multi Chambers. The tool can carbonize the candlenut shell without any additional energy and process 24 kg candlenut shell in 7.75 hours [10], while the amount of charcoal that produced by the tool remain unknown. Hence, this research is aimed to determine the yield of the charcoal produced by Candlenut Shell Carbonization Tool Using a Vertical Multi Chambers with temperature consideration.

2. Methodology

This section will discuss about the method in answering research objectives. They are material, research design and how to calculate charcoal yield produced by Candlenut shell carbonization tool using a vertical multi chambers.

2.1. Material

Candlenut shell is taken from candlenut collectors in South Aceh District. They get candlenut from surrounding candlenut farmers in the area. Candlenut shell is obtained from a manual process of taking candlenut seed done by collectors. This process resulted candlenut shell in irregular shape and varies in size. Crushed candlenut shell is shown in Figure 2.

Figure 2. Crushed candlenut shell.

2.2. Candlenut Shell Carbonization Tool Using a Vertical Multi Chambers

Candlenut shell carbonization tool using a vertical multi chambers is invented in 2019 as a respond of candlenut farmers need. The tool is designed using 3 vertical carbonization chambers, carbonization chamber I, II, and III, which aims to provide space for adequate air supply. It will attain a perfect burning process that generates enough heat to facilitate other chambers, carbonization chamber II and III, having carbonized. Each chamber has Ø60cm x 30cm in size. The main components are a metal drum, a reservoir, two chamber barriers, and an exhaust pipe [10]. Figure 3 will give a better understanding about the tool

The tool carbonizes the shell in every chamber after initial burning done in chamber I. It is starting from chamber I, chamber II and finally chamber III. The carbonization process was carried out through predetermined stages which are burning and cooling stage [10].

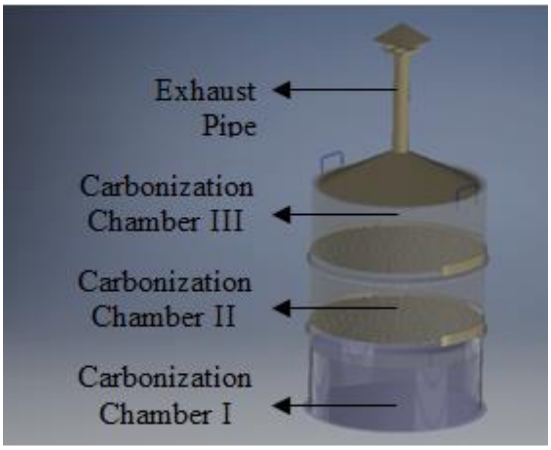


Figure 3. Candlenut shell carbonization tool using a vertical multi chamber.

2.3. Research Design

The research design is made to answer the objectives which are carbonization process temperature and charcoal yield produced by candlenut shell carbonization tool using a vertical multi chambers. The research will be performed based on the maximum capacity of the tool which is 24 kg candlenut shell in a process [10]. It is mean that every chamber will carbonized 8 kg candlenut shell. The research will be running 3 time experiments in order to have enough data to be analyzed. Table 1 lists how the experiment will be done.

Table 1. Characteristic of every experiment.

Experiment	The amount of candlenut Shell (Kg)		
	Chamber I	Chamber II	Chamber III
I	8	8	8
II	8	8	8
III	8	8	8

2.4. Charcoal Yield

After having charcoal from the carbonization process, it is weighed to identify the quantity of the charcoal gained in every carbonization chamber. Both candlenut shell and charcoal quantity are used to determine charcoal yield. Hence, the charcoal yield is determined according to the equation (1) below [11]:

$$y_{char} = \frac{m_{char}}{m_{bio}} \times 100 \tag{1}$$

where y_{char} is charcoal yield (%), m_{char} is mass of charcoal (g) and m_{bio} is the mass of biomass (g).

2.5. Research Flow

The following is a flow diagram in determining candlenut shell charcoal yield produced by candlenut shell carbonization tool using a vertical multi chambers as shown in Figure 4.

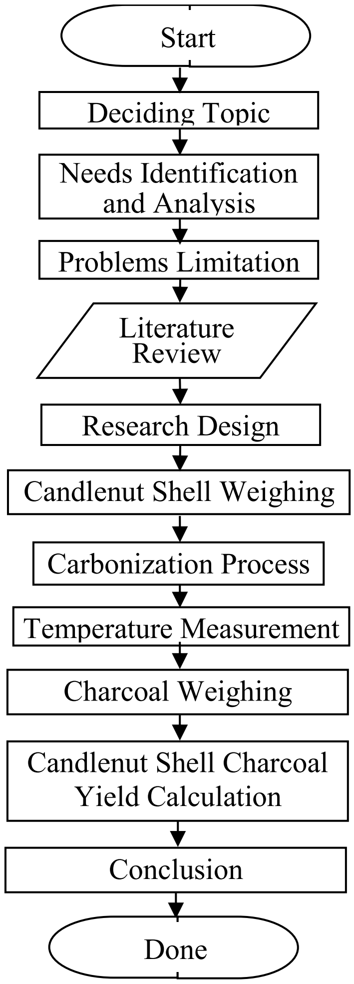


Figure 4. Candlenut shell carbonization tool using a vertical multi chamber.

3. Result and Discussion

3.1. Candlenut Shell Carbonization Temperature

As the carbonization process consisted of two predetermining stages, burning and cooling, so the temperature measured separately. In burning stage, temperature was measured gradually in every 15 minutes and the first measurement was done 15 minutes after initial burning in the carbonization chamber (CC) 1. When burning stage finished, cooling stage was started by closing all air inlet on the tool. After 30 minutes since the cooling stage started, the first temperature measurement was completed and it was frequently done for every next 30 minutes until the temperature in every chambers equal with the ambient temperature which is 32 °C. The following Table 2 shows all temperature measured for all experiments in every chambers.

Table 2. Candlenut shell carbonization temperature in Experiment I.

Time	Experiment II (8 kg/CC)									Rata-rata
	1st Run			2nd Run			3rd Run			
	CC 1	CC 2	CC 3	CC 1	CC 2	CC 3	CC 1	CC 2	CC 3	
Burning Process										
0 m	32	32	32	32	32	32	32	32	32	32.0
15 m	210	92	77	212	95	78	211	94	78	127.4
30 m	311	133	94	315	135	96	310	134	95	180.3
45 m	330	265	183	333	268	185	330	265	185	260.4
60 m	297	344	258	330	345	258	298	345	260	303.9
75 m	230	269	209	232	270	210	230	270	211	236.8
Cooling Process										
0.5 h	82	77	67	83	77	68	82	78	69	75.9
1 h	58	55	50	58	56	51	59	56	52	55.0
1.5 h	42	43	39	43	44	40	43	44	41	42.1
2 h	37	40	36	37	42	37	38	42	38	38.6
2.5 h	35	38	35	36	39	36	36	39	37	36.8
3 h	33	35	35	35	38	36	33	37	36	35.3
3.5 h	33	35	34	33	35	35	33	35	33	34.0
4 h	32	34	34	33	34	34	32	35	34	33.6
4.5 h	32	34	34	32	34	34	32	34	34	33.3
5 h	31	32	33	31	33	33	31	33	34	33.0
5.5 h		32	33		32	33		33	33	32.7
6 h		32	32		32	33		32	33	32.3
6.5 h		31	32		31	32		31	32	31.5
7 h			31			31			31	31.0

Table 2 revealed that the burning stage is able to generate its maximum temperature at 345 °C which is gain in Experiment II and III, while Experiment I was only at 344 °C. All of those highest temperature was found in CC2. It may occur because CC2 is placed in between CC1 and CC3 vertically where the heat from the CC1 and CC3 were positively contribute to the increased temperature. In addition, the tool's maximum average temperature is occurred after 60 minutes of burning process in CC2 at 303.9 °C. Figure 5 below is showing how the temperature increased in each chambers at the burning stage.

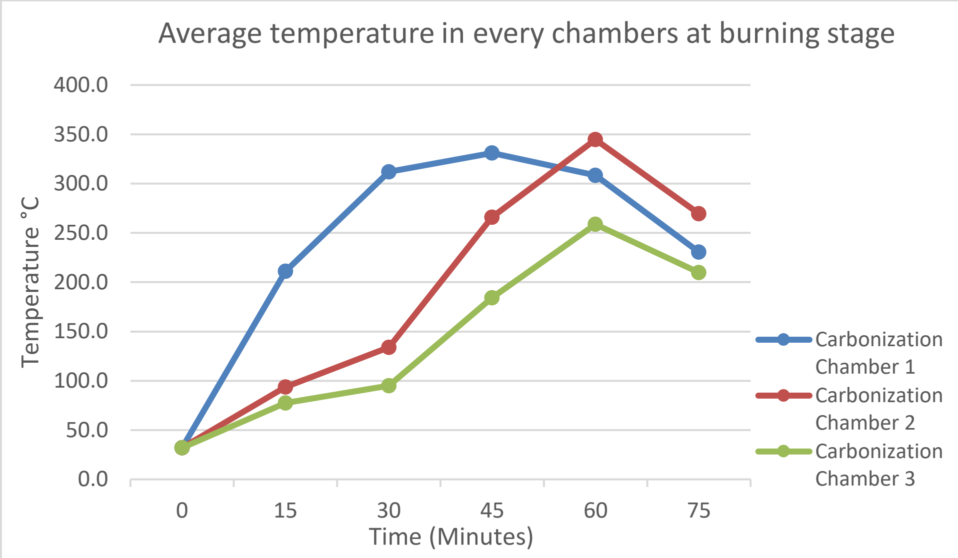


Figure 5. Temperature in every chambers at burning stage.

In the cooling stage heat gradually decrease by time. Although each experiment was experiencing identic cooling process, each chamber reached ambient temperature differently. CC1 completed the cooling process in 4.5 hours, CC2 in 6 hours and CC3 in 6.5 hours. Hence, CC1 is the first chamber that reach ambient temperature compared to other chambers. The following Figure 6 will give a better understanding how the temperature decreased.

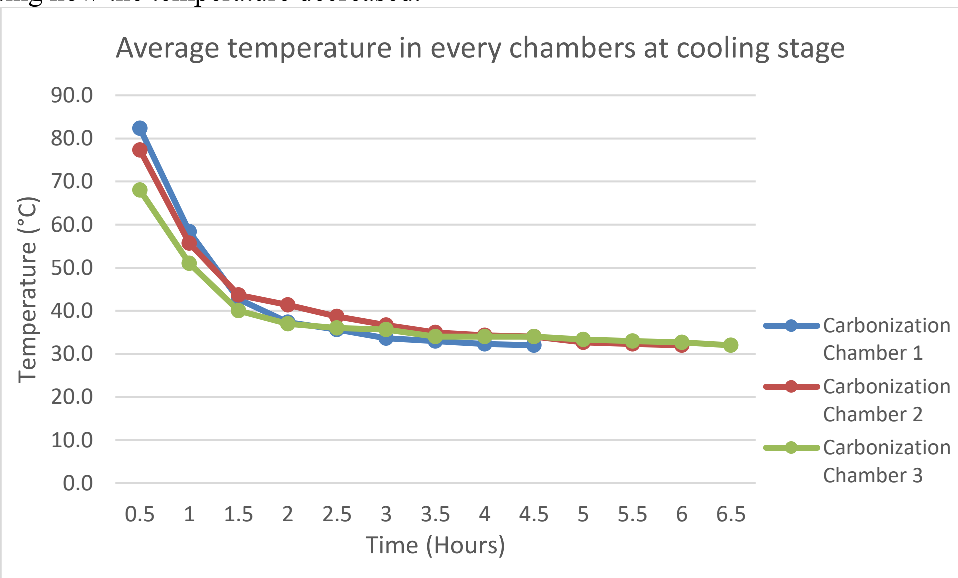


Figure 6. Temperature in every chambers at cooling stage.

The result demonstrated that the carbonization process takes 7.75 hour to carbonized 24 kg candlenut shell that distributed evenly to 3 carbonization chambers with maximum temperature 345 °C and all maximum temperature is found in CC2 with average 303.9 °C.

3.2. Candlenut Shell and Candlenut Shell Charcoal Quantity
After carbonization process, all candlenut shell charcoal in every chambers were place separately. Soon, those charcoal weighed to identify the quantity of the charcoal. Those data will be used to determine candlenut shell charcoal yield. Table 3 is listing the quantity of charcoal in every carbonization chamber.

Table 3. Candlenut shell and candlenut shell charcoal quantity.

Experiment	CC	Quantity	
		Candlenut Shell (kg)	Candelnut Shell Charcoal (kg)
I	CC1	8	1,50
	CC2	8	2,00
	CC3	8	2,50
II	CC1	8	1,49
	CC2	8	2,00
	CC3	8	2,52
III	CC1	8	1,50
	CC2	8	1.90
	CC3	8	2.51

3.3. Candlenut Shell Charcoal Yield
Candlenut shell charcoal yield produced by candlenut charcoal carbonization tool using a vertical multi chambers is calculated based on data in Table 2. The yield calculation is done by utilizing equation 1 and the results are given in Table 4.

Table 4. Candlenut shell charcoal yield.

Experiment	CC	Candlenut Shell Charcoal Yield (%)	Average Candlenut Shell Charcoal Yield (%)	Total Average Candlenut Shell Charcoal Yield (%)	Average Candlenut Shell Charcoal Yield in CC1 (%)	Average Candlenut Shell Charcoal Yield in CC2 (%)	Average Candlenut Shell Charcoal Yield in CC3 (%)
I	CC1	18.75	25.00	24.99	18.79	24.79	31.38
	CC2	25.00					
	CC3	31.25					
II	CC1	18.63	25.04				
	CC2	25.00					
	CC3	31.50					
III	CC1	19.00	24.92				
	CC2	24.38					
	CC3	31.38					

From the result listed in Table 4 it is clear that every experiment resulted in identical number of candlenut shell charcoal yield. They are 25 % in Experiment I, 25.04% in Experiment II and 24.92% in Experiment III. These results can be concluded that there is no significant yield difference from all experiments that has been done and the average candlenut shell charcoal yield produced by candlenut shell carbonization tool using a vertical multi chambers is 24.99 %.

Even though all experiments' result is identical, Table 4 revealed that the yield in every chambers are significantly different. CC1, CC2 and CC3 produced 18.79 %, 25.04 % and 31.38 % of candlenut shell charcoal yield. The range is significantly wide which is from 18.79 % to 31.38 %. As indicates in Table 2 and Figure 5, the differences among those three chambers are in temperature. It is possibly cause the yield produced differently. Figure 7 below displays a comparison between the yield and average temperature generating in every chambers.

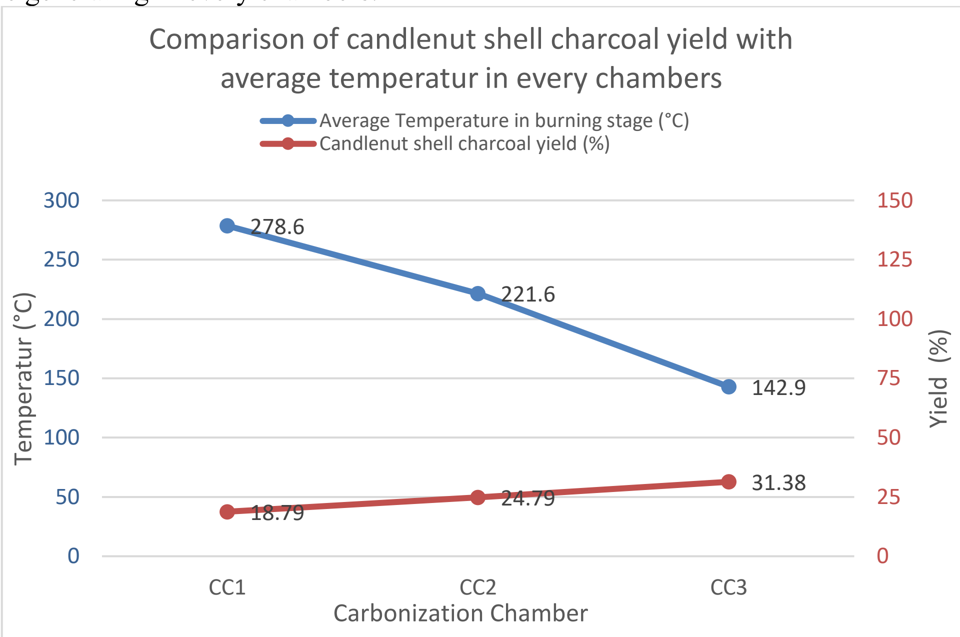


Figure 7. Comparison of candlenut charcoal yield with average temperature in every chambers.

As illustrated in Figure 6, candlenut shell charcoal yield in every carbonization chambers tends to increase when the temperature decrease. The highest average temperature was experienced by CC1 with 278.6 °C which is producing 18.79 % yield of charcoal. In the other side, CC3 was experiencing the lowest average temperature among the chambers with only 142.9 °C, but capable of producing 31.38 % yield of charcoal. It is mean that temperature affects the amount of candlenut shell charcoal yield significantly. Therefore, carbonization chamber that experiencing the lowest temperature will generate higher candlenut shell charcoal yield. In this case, the highest candlenut shell charcoal was produced by CC3 and followed by CC2 and CC1.

Since the cambers are placed vertically, where CC1 is at the bottom of the tool, followed by CC2 and CC3 at the top of the tool, chamber at the bottom of the tool will be the lowest chamber that can produce candlenut shell charcoal and chamber at the top will be in the opposite, while CC2 remains intermediately. As the result, candlenut shell charcoal yield will increase as the position of chambers increase vertically.

4. Conclusions

Candlenut shell carbonization tool using a vertical multi chamber is able to produce candlenut shell charcoal with the average yield of 24.99 %. It is 10% lower than what a process of carbonization can be generated which is 35 %. Every chambers are varying in its capability in producing candlenut shell charcoal. The main variable that has been identify is temperature. From the results, it is found that the highest candlenut shell charcoal yield is produced by the lowest temperature experienced by a chamber. The research revealed that CC1 was experiencing the lowest temperature among the chambers. Hence, CC1 is the highest chamber that can generate candlenut shell charcoal yield and followed by CC2 and CC1. In addition, the candlenut shell charcoal yield will go higher when the position of the chamber is placed higher at the tool.

Acknowledgments
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