Development of Candlenut Shell Carbonization Tool Using a Vertical Multi Chambers

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Abstract. Candlenut shell, a solid waste from the process of taking candlenut seeds, is potentially able to improve the quality of the life of rural community by converting it to charcoals. It seems that the local people has difficulty to produce the charcoals from the candlenut shell. The aims of the research are to produce a carbonization tool using energy derived from the candlenut shells and to determine the tool’s capacity. The tool was designed by utilizing Autodesk Inventor 2018 software. The result shows that the tool has three vertical Ø60cm x 30cm chambers that facilitate the carbonization process. The main components are a metal drum, a reservoir, two chamber barriers, and an exhaust pipe. It is also found that the best result of the tool is to process 24kg of the shell with 7.75 hours of processing time. Thus, the tool can carbonize the candlenut shell without any additional energy and the production of the charcoals is raised three times in one day.

Keywords: Carbonization tool, Candlenut shell, Charcoal, Autodesk inventor

1. Introduction

Candlenut (Aleurites moluccana) is one type of industrial plant from the family Euphorbiaceae [1,2,5]. Candlenut is classified as a medium-sized tree with a wide header that can reach height up to 20 m and has chest height diameter up to 90 cm [2]. Candlenut seeds are an economic value commodity and are the mainstay of farmers in various regions in Indonesia.

In Indonesia, candlenut plants are spread throughout the archipelago and always experience an increasing land area and production. Smallholder plantation statistics show that in 2004 candlenut production reached 94,000 tons with 206,300 Ha of land area and in 2010 increased to 100,600 tons with 215,000 Ha of area. The latest data shows that candlenut production increased significantly in 2013 to 107,200 with 215,410 Ha of land area. Based on data from the Ministry of Agriculture, Aceh Province has an average candlenut production in the last five years (2010-2014) is 11,621 tons per year. In this case, South Aceh District produced 92 tons of candlenut in 2014.

Most of the candlenut farmers in South Aceh Regency only rely on candlenut seeds as a worth selling commodity. However, the candlenut shell as a waste of the candlenut fruit [3] is not used optimally. It is approximately 60% of candlenut shell become a solid waste [4]. Since the shells are rigid waste, it remains in the environment and tend to give a negative impact on the environment. If it is utilized properly, the candlenut shell may give a significant impact toward the farmers’ livelihood. Candlenut seeds and shells can be seen in figure 1 below.
Candlenut shell has hard properties with a calorific value of 4164 cal/gram, so it can be used as fuel in drying candlenut seeds [5]. It can also be processed to produce activated charcoal that is useful for various fields, such as industry, health, environment and agriculture [6]. Activated carbon is made through a process of carbonization and activation of all carbon-containing materials [7,8]. Carbonization is a process to convert organic material to charcoal [9]. The carbonization process is an incomplete combustion process, so that the material is only carbonized and not oxidized. It is expected that the process will produce good quality charcoal.

Based on the observation, candlenut shells are not being utilized as charcoal due to the unavailability of technology to be adopted and used by candlenut farmers. The most possible technology to use is a palm shell pyrolysis drum reactor [10] and coconut shell burning air controlled drum [11], but it still uses other energy to carry out the carbonization process. Therefore, it requires efforts to help candlenut farmers to increase the economic value of candlenut seeds through the use of candlenut shells into activated charcoal. One of the efforts is to design and make a candlenut carbonization tool that is suitable for the needs of candlenut farmers, both in terms of process and cost.

2. Method
2.1. Tools and Material
The candlenut carbonization tool using a vertical multi chambers will be made using materials that are easy to find and familiar with candlenut farmers. The materials are a second-hand 200 litres metal drum which expected to be able to reduce the production costs, L-Shape angle bar, 2 mm iron plate, 1 mm aluminium plate, Ø 2 inch galvanized-pipe, 2 cm iron strip and Ø10 mm iron bar. The tool is designed by utilizing Autodesk Inventor 2018 software as an ambitious 3D parametric modeller [12]. Welding, grinding, and drilling machines and others additional tools such as hammers, chisels and scales are used in manufacturing the carbonization tool.

2.2. The Design
Considering the tool’s user, traditional farmers, the tool is designed as simply as possible in order to provide an easy operational process of carbonization. The tool utilizes human power and fully uses the energy from the candlenut itself in carrying out carbonization process. The candlenut is not only is the raw material to be proceed for charcoal, but also as fuel in the burning process. The process offered may lead to a possible low operating cost. Low operating costs will have a better impact on the candlenut farmers by increasing the value of the products they produce. Therefore, the tool is expected to be affordable by the community in terms of cost and process.

The carbonization 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. The carbonization chambers are shown in figure 2.
The three carbonization chambers mentioned above require 4 main components, namely drum as the main frame to constrain the outside and inside environment, reservoir as a reservoir for carbonization product and a place of initial burn, chamber barrier and chimney as a cover and also carries the gas out of the tool. Figure 3 below shows the detail of the 4 main components.

![Figure 3](image)

**Figure 3.** The main components of the tool. a) Drum, b) Product reservoir, c) Chamber barrier, and d) Exhaust pipe.

2.3. The Experiment Design

To determine the capacity of the tool and processing time of the carbonization process, 3 times experiment will be carried with varying the amount of candlenut shells that will be carbonized. Variations in the amount of shells in each experiment can be seen in table 1. Indicators that determine the capacity of the tool are the number of processes that can be done in 24 hours and maximum volume per process.

| Test Number | Chamber I | Chamber II | Chamber III |
|-------------|-----------|------------|-------------|
| I           | 10        | 10         | 10          |
| II          | 8         | 8          | 8           |
| III         | 6         | 6          | 6           |

**Table 1.** Variation of the amount of candlenut shells in each experiment.
2.4. Flowchart of Manufacturing and Designing Tool
The following is a flow diagram in designing and manufacturing of candlenut shell carbonization tool using a vertical multi chambers as shown in figure 4.

![Flowchart of tool design and manufacture.]

3. Results and Discussion
3.1. Candlenut Shell Carbonization Tool Using a Vertical Multi Chambers
The process of manufacturing of the tool followed the design shown in Figure 2 and 3. Through the process of manufacturing, the main parts of the tool which were produced and the complete one shown in figure 5 and 6 respectively.

The carbonization process was carried out through predetermined stages. The stages of the carbonization process by using this tool were:

i. Burning Stages. The Carbonization Chamber I (CC I) was filled with some candlenut shells that were burnt. When burnt, a chamber barrier was put to close the CC I providing a base as an area to put new shells called the CC II. This step was repeated for the CC III. Finally, an exhaust pipe was put as a lid of the tool.

ii. Cooling Stages. The burning stage completed, which was indicated by the little amount of and bluish smoke [10], then the cooling stage began. At this stage, all of the air flows, including the exhaust pipe was blocked to prevent the oxidation process taking place in the cooling process. The cooling stage completed if the chamber reaches room temperature [13].
3.2. Result of the Experiment

The carbonization process consists of 2 stages; burning and cooling. The carbonization process is counted from the combustion process begins until the cooling process is completed. The burning process starts when the first burn is carried out in the CC I and it is completed when all candlenut shell in all CCs are burnt. The burning temperature data were measured in all CCs every 15 minutes using thermocouple. The data are shown in table 2.

Table 2. Burning process’s temperature of candlenut shell.

| Time (Minutes) | Experiment I | | | | Experiment II | | | | | | Experiment III | | | |
|----------------|--------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                | CC I | CC II | CC III | Avrg. | CC I | CC II | CC III | Avrg. | CC I | CC II | CC III | Avrg. | CC I | CC II | CC III | Avrg. |
| 0              | 32   | 32    | 32     | 32.0  | 32   | 32    | 32     | 32.0  | 32   | 32    | 32     | 32.0  | 32   | 32    | 32     | 32.0  |
| 15             | 240  | 130   | 110    | 160.0 | 210  | 92    | 77     | 126.3 | 229  | 106   | 89     | 153.8 | 340  | 190   | 94     | 236.4 |
| 30             | 355  | 232   | 164    | 250.3 | 311  | 133   | 94     | 179.3 | 340  | 190   | 94     | 236.4 | 340  | 190   | 94     | 236.4 |
| 45             | 330  | 275   | 190    | 265.0 | 330  | 265   | 183    | 259.3 | 296  | 249   | 172    | 268.1 | 296  | 249   | 172    | 268.1 |
| 60             | 315  | 285   | 214    | 271.3 | 297  | 258   | 299.7  | 283   | 258  | 193   | 280.2 | 283  | 258   | 193    | 280.2 |
| 75             | 224  | 323   | 252    | 266.3 | 230  | 269   | 209    | 236.0 | 230  | 269   | 209    | 236.0 | 230  | 269   | 209    | 236.0 |
| 90             | 219  | 298   | 195    | 237.3 | 219  | 298   | 195    | 237.3 | 219  | 298   | 195    | 237.3 | 219  | 298   | 195    | 237.3 |

Figure 5. Manufacturing results of the main parts; a) exhaust pipe, b) drum, c) chamber barrier, d) product reservoir.

Figure 6. Candlenut shell carbonization tool using a vertical multi chambers after assembly.
The cooling process begins when the burning process is stopped. It is done when the temperature of the CCs outer wall is the same as the ambient temperature which is 32°C. The temperature is measured every half an hour using a thermocouple. Table 3 shows the temperature data during the cooling process.

Table 3. Cooling process’s temperature of candlenut shell.

| Time (hour) | Experiment I | Experiment II | Experiment III |
|-------------|--------------|---------------|----------------|
|             | CC I CC II CC III Avg. | CC I CC II CC III Avg. | CC I CC II CC III Avg. |
| 0.5         | 55 47 44 48.7 | 58 55 50 54.3 | 60 62 55 59.0 |
| 1           | 49 45 42 45.3 | 47 43 41 43.7 | 42 43 40 41.7 |
| 1.5         | 46 43 40 43.0 | 42 41 37 40.0 | 38 39 40 39.0 |
| 2           | 44 43 40 42.3 | 37 40 36 37.7 | 37 37 36 36.7 |
| 2.5         | 43 42 40 41.7 | 35 40 35 36.7 | 35 37 36 36.0 |
| 3           | 40 40 38 39.3 | 33 38 35 35.3 | 33 36 35 34.7 |
| 3.5         | 39 40 37 38.7 | 33 35 34 34.0 | 33 36 35 34.7 |
| 4           | 39 39 37 38.3 | 32 35 34 33.7 | 32 34 34 33.3 |
| 4.5         | 38 38 37 37.7 | 34 34 34.0 34 34.0 |
| 5           | 37 38 37 37.3 | 33 33 33.0 32 33 32.5 |
| 5.5         | 36 37 36 36.3 | 32 33 32.5 32 32.0 |
| 6           | 34 35 35 34.7 | 32 32.0 32 32.0 |
| 6.5         | 33 34 35 34.0 | 32 32.0 32 32.0 |
| 7           | 32 33 34 33.0 | 32 32.0 32 32.0 |
| 7.5         | 32 33 34 33.0 | 32 32.0 32 32.0 |
| 8           | 32 33 32.5 32.5 | 32 32.0 32 32.0 |
| 8.5         | 32 32.0 32.0 32.0 | 32 32.0 32 32.0 |

The maximum temperature in the burning process reached 355°C in experiment I in CC I, 344°C in experiment II in CC II and 340°C in experiment III in CC I. While the time needed for burning process is 1.5 hours at experiment I, 1.25 hours in experiment II and 1 hour in Experiment III. While the cooling process of experiment I took 8.5 hours, experiment II took 6.5 hours and experiment III took 6 hours.

Table 4 shows the amount of processed candlenut shells, the carbonization time and the number of repetitions of the carbonization process in one day.

Table 4. The measurement of the capacity of candlenut carbonization tool.

| Description                           | Experiment I | Experiment II | Experiment III |
|---------------------------------------|--------------|---------------|----------------|
| Σ one time processed candlenut shell (kg) | 30.00        | 24.00         | 18.00          |
| Single Processed Time (hour)         | 10.00        | 7.75          | 7.00           |
| Σ Carbonization Process in one day (time) | 2.40        | 3.10          | 3.43           |
| The amount of candlenut shell that can be processed in one day (kg) | 72.00        | 74.32         | 61.71          |
It can be concluded that experiment II has a maximum capacity in processing candlenut shell into charcoal which is 74.32 kg in one day. Hence, the candlenut carbonization tool using a vertical multi chambers maximum capacity is at 24 kg per process and able to do 3 times carbonization process in a day.

3.3. Discussion
Our results confirm that candlenut shell can be carbonized using its own energy by utilizing the candlenut carbonization tool using a vertical multi chambers. The chambers provide enough space for oxygen to be involved in the burning process. The adequate heat from the CC I will generate burning process in the last two chambers. Other tools may not applicable for candlenut shells, such as coconut and palm shell carbonization tool. Coconut shell is quiet easy to be carbonized because of its shape which provide enough space for oxygen. Palm shell has much similarity with candlenut shell in term of size. Palm shell pyrolysis reactor is still required additional energy to perform burning process. Thus the research proves that there is another way to carbonize the candlenut shell without any other additional energy.

4. Conclusion
The experiments revealed that the tool can carbonize the candlenut shell without any additional energy and the Experiment II gave the maximum production capacity. It can process 24 kg candlenut shell in 7.75 hours which indicates the process can be performed 3.1 times in a day. In consequence, Experiment II can carbonize candlenut shell 74.32kg per day, while Experiment I and III can only carbonize 72kg and 61.71 of candlenut shell.

Therefore, it can be concluded that the candlenut carbonization tool using a vertical multi chambers has 24kg in capacity with 7.75 hours in each process and able to perform carbonization process 3.1 times in a day. Thus, the tool is able to process 74.32kg candlenut shell into charcoals in a single day.

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