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# Carbon Conversion and Energy Consumption Analysis Carbonization of Coconut Shell at High Temperature

Diana Silvia Rahma Wardhani[1], Kirana Aurelia Salshabila[1], Ardika Nurmawati[1], Wiliandi Saputro[2], Erwan Adi Saputro[1,3]*

[1]Departement of Chemical Engineering, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya 60294, Indonesia
[2]Departement of Mechanical Engineering, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya 60294, Indonesia
[3]Departement of Environmental Science, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya 60294, Indonesia

*Corresponding author:
E-mail:
erwanadi.tk@upnjatim.ac.id

ABSTRACT

Carbon/charcoal is a chemical element with the symbol C. Coconut shell can be changed to carbon using a carbonization process. The carbonization process is the process of changing the original law material into black carbon through combustion in a closed space with limited air. Temperature and time carbonization are very influential in the carbonization process. This experiment aims to observe the effect of the duration of the carbonization process on the amount (yield) of coconut shell charcoal obtained by using mass balance analysis. In this experiment, the coconut shell was made into carbon with a carbonization process using a muffle furnace with a temperature of 400℃ for 1 hour and 2 hours. The result showed that 200 grams of dry coconut shell carbonized with 1 hour produced 49.45 grams of coconut shell, while carbonized with 2 hours produced 48.69 grams of carbon.

*Keywords: Carbon, carbonization, coconut shell*

## Introduction

Carbon comes from burned materials, carbon is a solid material that has pores (Saputro et al., 2020). Carbon is a material that has various morphologies. There are several morphologies of carbon, including colloidal carbon, nanotubes, fullerenes, graphite, graphene, colloidal sphere, nanofiber, porous carbon, nanowire, and activated carbon. The many morphologies of carbon result in a very wide range of carbon applications, such as catalyst supports, adsorbents, gas storage, separation technology, battery electrodes, porous material templates, fuel cells, and biological cells. Carbon has several advantages, including, that it is not dangerous, cheap, has a high volumetric capacity, high reproducible capacity, is easy to compose, is abundant in quantity, and is cheap. Carbon sources can be obtained from glucose compounds, cyclodextrins, fructose, cellulose, sucrose, amylopectin, flour, organic molecules, and biomass waste (monosaccharides, hexose, and pentose) (Rahman et al., 2015).

Carbon is made using combustion or carbonization. The carbonization process is the process of burning raw materials using air limited in temperature 300℃ until 900℃. This process's purpose is to convert raw materials into black carbon through a combustion process with limited air. The carbonization process can be influenced by the carbonization time and temperature carbonization (Patmawati, 2022). If the carbonization time is too long, the yield will be higher, the water content will be less, and the ash content will increase. But the carbonization process time to longer, the combustion

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will be more complete (Turmuzi & Syaputra, 2015). Meanwhile, the carbonization temperature influences the charcoal/carbon result obtained. The higher the temperature, the less charcoal/carbon obtained will be because some of the charcoal/carbon turns into ash. This causes more and more substances to decompose and evaporate (Kurniati, 2008).

One material that can be used to make carbon is coconut shell. Coconut shells have several chemical contents including, cellulose (26.60%), lignin (29.40%), hemicellulose (27.70%), extractive solvent (4.20%), uronic anhydride (3.50%), ash (0.62%), nitrogen (0.11%), water dam (8.01%) (Cheremisinoff & Ellerbusch, 1978). Coconut shell contains a carbon compound (C) of 49.62%. The carbon content of the coconut shell will increase to 64.87% after the carbonization process (Suryadi et al., 2022). Cellulose is an organic compound found in cell walls that functions to strengthen the structure of the coconut shell. Hemicellulose is in the space between cellulose fibers in plant cell walls, hemicellulose can be said to be a filler for cellulose fibers. Meanwhile, lignin is a chemical compound that has an amorphous structure and is very complex. It functions as a binder for other cells and provides strength (Winata et al., 2020). The very high carbon content in coconut shells means that coconut shells can be used as carbon raw materials. Carbon is a porous solid that contains 85-95% carbon, produced from materials containing carbon through heating at high temperatures. Apart from being used as fuel, carbon can also be used as an adsorbent. Carbon has better properties than firewood. The economic value of a coconut shell can be increased by making the coconut shell into carbon (Ramadhani et al., 2020).

The number of coconut shells in Indonesia is very large, this is because coconut production in Indonesia has increased from year to year. In 2019 Indonesia produced 2.84 million tons of coconut per year, in 2020 Indonesia produced 2.81 million tons of coconut per year and in 2021 Indonesia produced 2.85 million tons per year. The province in Indonesia that produces the most coconuts is Riau with a production figure of 395.00 thousand tons in 2021 followed by North Sulawesi with a coconut production of 271.10 thousand tons and East Java with a production figure of 244.50 thousand tons (Badan Pusat Statistik, 2023). One of the wastes produced from coconut production is coconut shells. Coconut shells are waste from processing coconuts whose meat is taken. Coconut shells are hard and covered with coconut husks. In general, coconut shell waste is used for fuel, and household purposes, or can also be used as handicrafts (Nustini & Allwar, 2019).

In previous research on carbonization using polyethylene terephthalate (PET), carbon conversion was obtained at 55.17% (Nabil et al., 2022). There have been several studies on carbon production by the carbonization process including research conducted by (Idrus et al., 2013), where the carbonization process at 400℃ for 2 hours produced 1.2 kg of charcoal from 6.5 kg of coconut shell raw material. Where to research conducted by Nurdin and Nurdiana (2017), 3 kg of coconut shell charcoal was produced from the initial raw material, about 15 kg through a carbonization process using a furnace with a temperature of 400℃ for 1 hour. This study aims to observe the effect of the duration of the carbonization process on the amount (yield) of coconut shell charcoal obtained by using mass balance analysis.

## Material and Methods

The material in this study was coconut shells obtained from a coconut mill shop in Gresik City, East Java, and the main tools in this study are a muffle furnace, mortar, pestle, sieve, and analytical balance.

### *Experimental steps in this study*

The coconut shell is cleaned of the fibers that are still attached and crushed into smaller pieces. Then the coconut shell is dried in the sun. A total of 200 grams of dried coconut shells were put into the furnace for the carbonization process at 400℃ with variations in the length of the carbonization process for 1 hour and 2 hours. After the carbonization process is complete the coconut shell is cooled for ± 24 hours. After that, the coconut shell carbon is crushed and sieved uniform size.

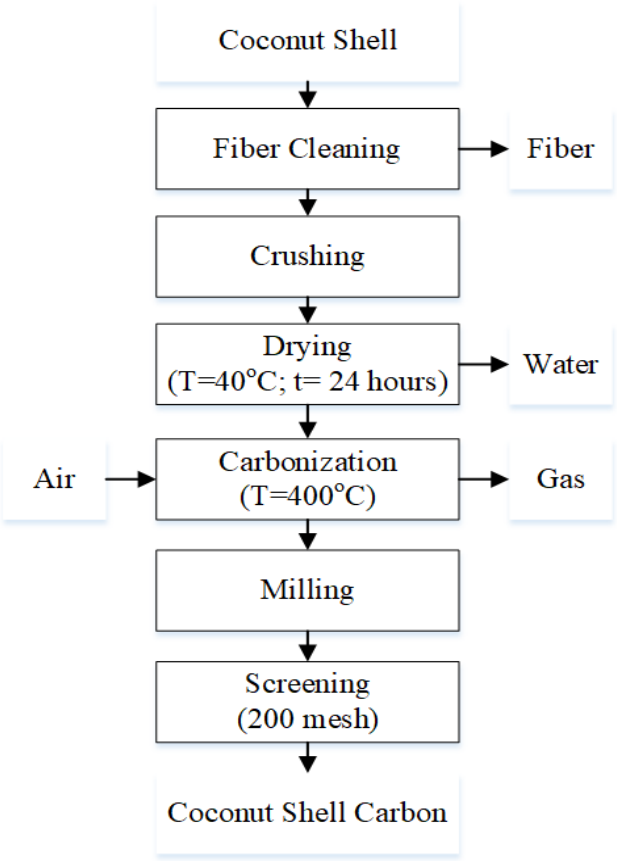



Figure 1. Flowchart for the production of coconut shell carbon

**Results and Discussion**

***Process for making coconut shell carbon***

The process of making carbon black consists of several stages. The initial stage of making coconut shell carbon is the process of cleaning the coconut shell from dirt and coconut fiber that is still attached followed by a size reduction process to facilitate the next process. Then, the coconut shell is dried in the sun for about 1 day until completely dry. The dried coconut shell is ready for further processing.

(a) (b)

Figure. 2(a) Coconut shell before cleaned and dried, Fig. 2(b) Coconut shell that has been cleaned and dried

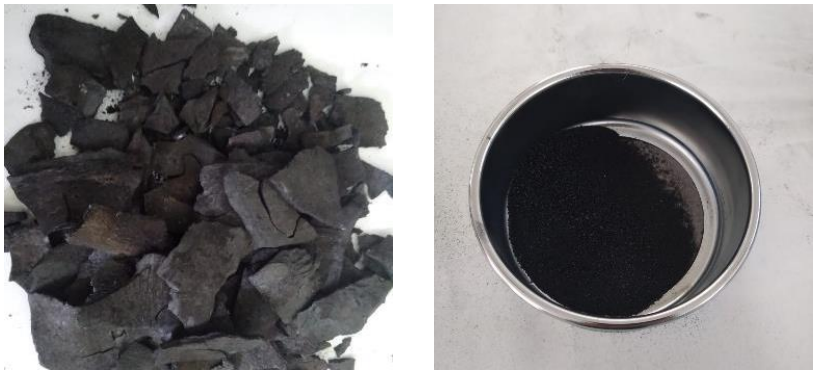
The coconut shell carbonization process was carried out using a muffle furnace at a temperature of 400℃ with variations in the carbonization time of 1 hour and 2 hours. The purpose of varying the

length of carbonization time is to see the best carbon yield which is affected by the carbonization time factor. The carbonization process is carried out by placing the raw material in the form of coconut shells into a container (cross porcelain) and putting it into a heating device (furnace).


(a) (b)

Figure 3. (a) Put coconut shell in the muffle furnace, Fig. 3(b) Carbonization process using muffle furnace

Based on physical observations, the carbonization stage produces black, slightly gray carbon. The size of the carbon obtained is still in various sizes so a grinding process is needed so that the size is uniform. The grinding stage is carried out using a mortar and pestle. Then the carbon size was uniformized using a 200 mesh sieve to obtain coconut shell carbon in the form of powder.



(a) (b)

Figure 4. (a) Coconut shell carbon before crushing, Fig. 4(b) Coconut shell carbon after crushing

***Coconut shell carbon production mass balance***

The mass balance is a quantitative calculation of all incoming, outgoing, accumulated, and wasted materials in the production process. However, in this process, it is considered that there is no buildup on the equipment being processed. Therefore, the mass entering the system must equal the mass leaving the system. In other words, the flow when the material enters is equal to the flow when the material leaves. In any system, the amount of matter will remain the same regardless of changes, whether physical or chemical (Saputro et al., 2021). In this study, the mass balance of carbon production from coconut shells with variations in carbonization time was calculated as shown in Table 1.

Table 1. Mass balance of carbon production from coconut shells with variations in carbonization time

| No | Process | Component | Carbonization Time | | | |
|---|---|---|---|---|---|---|
| | | | **1 hour** | | **2 hours** | |
| | | | **Input (gr)** | **Output (gr)** | **Input (gr)** | **Output (gr)** |
| 1 | Fiber Cleaning | Coconut Shell | 300 | 220 | 300 | 220 |
| | | Coconut Fiber | 0 | 80 | 0 | 80 |
| | **Total** | | **300** | **300** | **300** | **300** |
| 2 | Crushing | Coconut Shell | 220 | 220 | 220 | 220 |
| | **Total** | | **220** | **220** | **220** | **220** |
| 3 | Drying | Coconut Shell | 220 | 200 | 220 | 200 |
| | | H2O | 0 | 20 | 0 | 20 |
| | **Total** | | **220** | **220** | **220** | **220** |
| 4 | Carbonization | Cellulose | 200.00 | 9.24 | 200.00 | 14.00 |
| | | Carbon | 0.00 | 51.26 | 0.00 | 49.45 |
| | | Ash | 0.00 | 5.26 | 0.00 | 5.66 |
| | | H2O | 0.00 | 105.98 | 0.00 | 103.33 |
| | | O2 | 47.41 | 9.73 | 47.41 | 10.67 |
| | | CO | 0.00 | 65.94 | 0.00 | 64.30 |
| | | N2 | 156.05 | 156.05 | 156.05 | 156.05 |
| | **Total** | | **403.46** | **403.46** | **403.46** | **403.46** |
| 5 | Milling | Carbon | 51.26 | 51.26 | 49.45 | 49.45 |
| | **Total** | | **51.26** | **51.26** | **49.45** | **49.45** |
| 6 | Screening | Carbon | 51.26 | 48.69 | 49.45 | 46.98 |
| | | Carbon (over-size) | 0.00 | 2.56 | 0.00 | 2.47 |
| | **Total** | | **51.26** | **51.26** | **49.45** | **49.45** |

The first step in this experiment is fiber cleaning. Before the cleaning process, the weight of the source is 300 grams, while after the cleaning is 220 grams. The second process is crushing the coconut shell, the purpose of this crushing is to make it easier for the coconut shell to enter the furnace because its size is smaller. In crushing there is no change in mass. The third process is drying, in this process $H_2O$

evaporates. Before the drying process, the weight of the source is 220 grams, while after the cleaning is 200 grams. The fourth step is carbonization, in this process, a reaction occurs $C_6H_{10}O_5 + O_2 + N_2 \rightarrow 6C + 5H_2O + O_2 + ash + N_2$. The carbonization process in this experiment uses a temperature of 400℃ with time variations of 1 hour and 2 hours. Before the carbonization process, the weight coconut shell was 200 grams, while after this process coconut shell turned to carbon as much as 51.26 grams in an experiment with time variations of 1 hour and 49.45 grams in an experiment with time variations of 2 hours. The fifth process is milling, in this process carbon milling becomes powder. In this process, there is no change in mass. The last process is screening, carbon was sieved using a 200 mesh sieve. Before the screening process, the weight of carbon was as much as 51.26 grams in an experiment with time variations 1 hour and 49.45 grams in an experiment with time variations 2 hours, while after the screening carbon was as much as 48.69 grams in an experiment with time variations of 1 hour and 46.98 gram in an experiment with time variations 2 hours.

The result of the conference for carbon from coconut shell with time variations 1-hour carbonization process is 24.725%, while for carbon from coconut shell with time variations 2 hours carbonization process is 24.345%. Meanwhile, research conducted by (Nurdin & Nurdiana, 2017) carbon conversion from coconut shell obtained is 60% with a carbonization process operating time of 1 hour and a temperature of 400℃. In research conducted by (Tirono & Sabit, 2012) carbon conversion from coconut shell obtained is 37.9% with a carbonization process operating time of 1.5 hours and a temperature of 400℃. In research conducted by Nurisman et al. (2017) carbon conversion from coconut shell obtained is 59.17% with a carbonization process operating time of 2 hours and a temperature of 450℃ using a pyrolysis process. The factor affecting the carbonization process is temperature and time carbonization process. Too high a temperature can cause a change in some materials to ash and the longer the carbonization process, the better but if time is too long it can cause a change in some materials to ash (Nurisman et al., (2017). The higher temperature carbonization process results in lower volatile matter in coconut shell. High-temperature carbonization causes the inorganic salt content of coconut shell will be lower (Iloabachie et al., 2018). The weight of coconut shell loss of each process indicates the extent of the chemical reaction involved, which in turn affects the property of the carbon product. The weight loss of character is based on the weight of the raw materials coconut shell (Katesa et al., 2013).

***Energy consumption***

In this research, furnace 47900 was used for the carbonization process. Furnace 47900 has a power of 1000 watts, to calculate the energy consumption the following equation is used:

$$W(E) = P \times t \tag{1}$$

Annotation
P = Power (watt)
T = Time (hour)
W (E) = Energy in watt-hour

(Huda, 2021)

From the equation above, the energy consumption is obtained at 1 kWh for the carbonization process with an operating time of 1 hour and 2 kWh for the carbonization process with an operating time of 2 hours. Energy consumption in the carbonization process with an operating time of 1 hour less than carbonization process with an operating time of 2 hours. The resulting carbon yield is also not too far off in comparison. The cost incurred carbonization process with operating time 2 hours more than carbonization process with an operating time 1 hour. So, the carbonization process of coconut shell is economically better using an operating time carbonization of 1 hour.

## Conclusion

The conversion of carbon with operating time carbonization process 1 hour is 24.725% and 24.345% in 2 hours. The best result is the carbonization coconut shell using an operating time of 1 hour because conversions obtained more than using an operating time of 2 hours. The carbonization process to a longer time causing a change in some materials to ash. And energy consumption is less than the operating time carbonization process 2 hours. Economically more recommended to use 1 one-hour carbonization process because more affordable.

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