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# COCONUT SHELL CARBONIZATION PROCESS USING SMOKELESS KILN

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***Abstract***. *Proper processing of coconut shell charcoal can be highly economically and environmentally valuable. The two most common uses of coconut shell charcoal are activated carbon and briquettes, obtained through carbonization. However, traditional carbonization methods involving kilns can produce excessive smoke, polluting the environment and disrupting human activities. A carbonization kiln that produces less smoke is required to address this issue. In this study, a kiln made from a steel drum with a sealer belt was fabricated to trap burning smoke inside the kiln. The results showed that adding this belt effectively reduced the smoke produced, making it more eco-friendly. Regarding charcoal production efficiency, different weigh coconut shells were burnt to produce charcoal. The result showed that burning 25 kg of coconut shell was optimal, producing a 48% charcoal content.*
***Keywords:*** smokeless kiln; coconut charcoal; carbonization

## 1. Introduction

Coconut (*Cocos nucifera*) is one of the most contributing plants to the local economy with its cultivation in approximately 92 countries across the world, covering roughly 11.8 million hectares of land (Doe *et al*., 2022). Located in the tropical region, Indonesia has emerged as one of the biggest producers of coconuts worldwide, with 3.37 million hectares of land dedicated to coconut cultivation. (Badan Pusat Statistik, 2021). However, the utilization of this plant is still being studied as researchers continue develop its various uses for optimal results. (Budi, 2011; Intara *et al*., 2021; Ahmad *et al*., 2022).

The coconut consists of coconut water, meat, a shell and a thick coir, where the weight of the coconut shell is about 15-19% of the overall weight (Suhartana, 2006). Even though the coconut shells and coir are considered waste, all parts of this coconut still have economic value, and the shell can process as activated carbon or biofuel (Arena *et al*., 2016). Across many Asian and African nations, coconuts are typically utilized as a cooking ingredient, leaving the shells as unused waste. The resulting coconut shell waste is often left in piles and can pose environmental issues. (Ikumapayi *et al*., 2020; Ningsih & Hajar, 2019; Soka & Oyekola, 2020). It is deemed crucial to enhance the value of coconut waste by transforming it into more valuable products,



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especially through proper carbonization techniques, in order to aid in addressing environmental concerns. (Ahmad *et al*., 2022; Parshiwanikar & Handa, 2022). This effort could increase the local economy and in line with the world's SDG (Sustainable Development Goals) (Susanto *et al*., 2022).

One of the most straightforward approaches towards enhancing the value of coconut waste is through the processing of coconut shells into charcoal, given its numerous advantages, such as its capacity for long-term storage, high heating value, and affordability. (Sangsuk *et al*., 2020). The processing of coconut shells into charcoal presents a viable business opportunity, as it has a diverse range of applications, including as fuel, beauty products, activated carbon, briquettes, water filters, and numerous others. (Ikumapayi *et al*., 2020).

Coconut shell charcoal (CSC) represents a highly promising source of raw materials for activated carbon (AC) production, with the potential for Indonesia alone to produce up to 66,200 tonnes annually - comprising 12% of all activated carbon raw materials sourced. (Arena *et al*., 2016; Lutfi *et al*., 2021). The significant demand for activated carbon (AC) in water purification and wastewater treatment applications can be attributed to the exceptional mechanical properties, high porosity, and surface area of AC produced from coconut shell charcoal (CSC) (Leman *et al*., 2021; Nyamful *et al*., 2021). Furthermore, the production of AC from CSC is relatively easy and can be produced by a small businesses or home industries. (Lutfi *et al*., 2021). As well as the CSC is made of natural resources then the availability of these raw materials can be planned and available locally (Sanjaya *et al*., 2016).

Briquettes, which are solid forms of alternative energy produced by compacting charcoal, is another potential application of CSC (Setyawan & Ulfa, 2019). One of the best sources of raw materials for briquet is the CSC because it has good thermal diffusion properties (Pujasakti & Widayat, 2018). Indonesia's briquettes are renowned for their exceptional quality and are highly sought after by Turkey, Brazil, as well as several European and Latin American nations. (Indonesia, 2021).

The CSC is made by using a carbonization process by gradually heating the CSC until 400°C to 600°C temperature reached (Jamilatun & Setyawan, 2014; Nurdin & Nurdiana, 2017; Parshiwanikar & Handa, 2022). The first process in this carbonization is the preparation of the coconut shell, this step is to clean up the impurity materials such as coconut fibres, sand, ashes and soil (Maryono *et al*., 2013). This cleaning process is vital because excessive impurity materials may block pores and produce low-quality CSC materials especially to make AC (Schröder *et al*., 2006).

The traditional carbonization process is using a kiln to burn the coconut shell. The kiln may be made of a brick furnace (Budi, 2011; Nurdin & Nurdiana, 2017), or a steel drum (Ekalinda, 2001; Hudaya & Hartoyo, 1990). A proper carbonization kiln could produce high yield and better quality chalcoal (Intara *et al*., 2021). The coconut shells burned out for 4 to 6 hours with the upper kiln left to be open until the smoke starts to clear. After being burnt out the shell is cooled down for 1 hour and then sorted to separate the charcoal and the half-burned shell (Hudaya & Hartoyo, 1990; Khambali *et al*., 2022; Maryono *et al*., 2013; Nurdin & Nurdiana, 2017). Not all 100% of raw coconut shells could be processed to become charcoal, most of them became ashes (Table 1). The disadvantage of this process is the smoke produced from the burning process of the coconut shell (Figure 1). In order to address the issue of smoke pollution and disturbance caused by the traditional process of carbonizing coconut shells, the development of a new design for charcoal carbonization with reduced smoke emission is necessary. This research aims to develop a carbonization kiln using a steel drum equipped with a sealer belt, which can effectively trap the smoke inside the kiln during the process and increase the yield of charcoal obtained from coconut shells. The resulting carbonization efficiency and quality will also be examined.

Table 1. Percentage of charcoal produced from coconut shell

| No | Researchers | Klin type | Char percentage |
|---|---|---|---|
| 1 | (Maryono *et al*., 2013) | Steel Drum | 30% |
| 2 | (Hudaya & Hartoyo, 1990) | Steel Drum | 37.2% |
| 3 | (Budi, 2011) | Brick Furnace | 35% |
| 4 | (Soolany, 2017) | Steel Drum | 21.4% |
| 5 | (Nurdin & Nurdiana, 2017) | Brick Furnace | 30% |
| 6 | (Manatura, 2021) | Large Scale Industrial Steel Drum | 35% -45% |

Figure 1. The carbonization process created a lot of smoke that pollutes the air

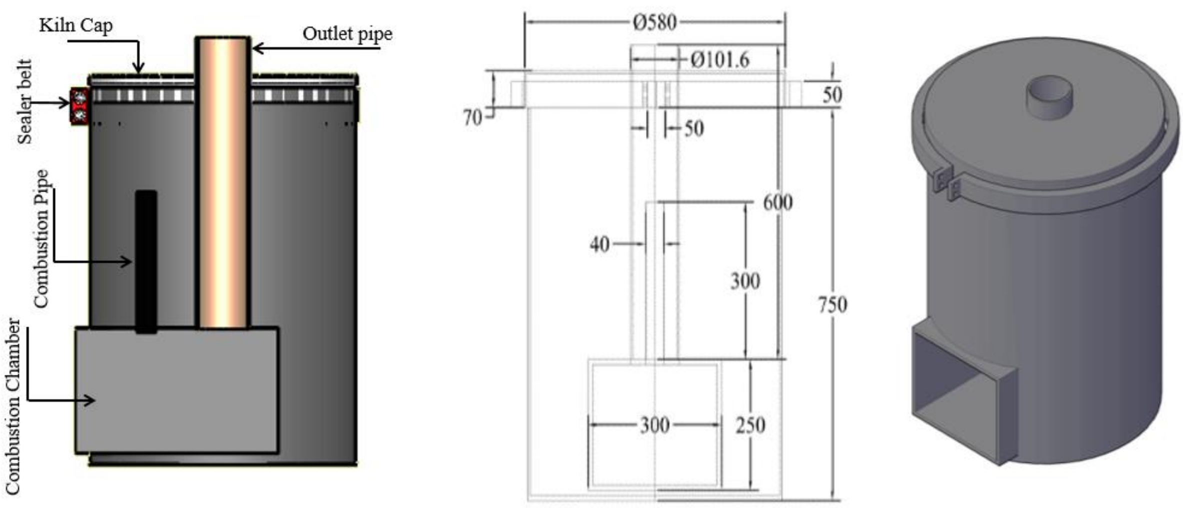
## 2. Methods

The kiln is designed based on previous research using a steel drum (Table 1) with added modifications to confine the burning smoke within the kiln, this type already developed by Manatura *et al.* However, in industrial scale that might be too costly for the home industry (Manatura, 2021).

The kiln is constructed from a recycled steel drum that has been modified to include a combustion chamber system and reactor lid. (Figure 2). The combustion chamber incorporates two channels to ensure efficient heat distribution,. The first channel is a small and short pipe used specifically for combustion, while the second channel is a larger pipe for releasing smoke from the combustion chamber. To isolate the smoke and further improve its containment, a closing lid was added, along with an additional sealer belt for even tighter smoke sealing. This sealer belt is made of steel plate coated with asbestos and tightened using 2 bolts to ensure no smoke escapes from the kiln when burned.

Table 2. Comparison of kiln specifications

| No | Configuration | Design by Manatura et. al. | Current Design |
|---|---|---|---|
| 1 | Insulator | Ceramic | No Insulation |
| 2 | Capacity | 200 liter | 200 liter |
| 3 | Kiln Material | Rolled steel sheet | Used lubricant drum |




(a) (b) (c)

Figure 2. Smokeless carbonization kiln design

The efficacy of the kiln was evaluated by arranging the coconut shells in an orderly fashion and conducting a burning process to determine the quantity of charcoal generated for 150 minutes (Figure 3). The smoke produced by the kiln during the process was also observed visually. The loss of heat was calculated by retrieving data on the initial wall temperature and the wall temperature during the burning process using equation (1) and the response data is taken every 15 minutes (Belu, 2020).

$$Q_L = U \cdot A(T_d - T_{link}) \quad (1)$$

The experiment was conducted 3 times using the capacity of 15kg, 20kg and 25kg using the coconut shells and the percentage of charcoal produced was calculated using equation (2).

$$P = \frac{\text{output}}{\text{input}} \times 100 \quad (2)$$


Figure 3. The coconut shells were arranged neatly to fill up the kiln.

## 3. Results and Discussion

### 3.1. Result

The temperatures during the process are recorded every 15 minutes during the carbonization process. The temperatures collected from the 3 experiments were then calculated to obtain the heat loss data (Table 3).

Table 3. Heat loss data

| Heating Response Time (minute) | Capacity 1 (15 kg) | Capacity 2 (20 kg) | Capacity 3 (25 kg) |
|---|---|---|---|
| **0** | 1,707.5 | 1,707.5 | 426.8 |
| **15** | 3,415.0 | 2,134.4 | 2,347.8 |
| **30** | 5,547.4 | 2,561.2 | 3,628.4 |
| **45** | 6,189.7 | 3,628.4 | 4,482.2 |
| **60** | 6,404.2 | 4,268.8 | 5,122.5 |
| **75** | 7,256.9 | 5,549.4 | 5,976.3 |
| **90** | 8,751.1 | 8,110.7 | 7,470.4 |
| **105** | 9,177.9 | 5,976.3 | 7,897.2 |
| **120** | 9,604.8 | 5,122.5 | 8,324.1 |
| **135** | 9,391.3 | 5,122.5 | 7,683.8 |
| **150** | 8,751.1 | 5,122.5 | 7,470.4 |
| **Total** | 76,196.9 | 49,304.2 | 60,829.9 |

The smoke was observed during the burning process with the kiln equipped with and without sealer. In the first experiment, the kiln without sealer still produces a large amount of smoke (Figure 4). For the second experiment, the sealer belt is installed, and very thin smoke still appears but is significantly reduced from the first attempt (Figure 5). Full kiln capacity of 25 kg yielding 48% of the charcoal (Table 4, Figure 6)


Figure 4. Thick smoke produced by kiln without sealer

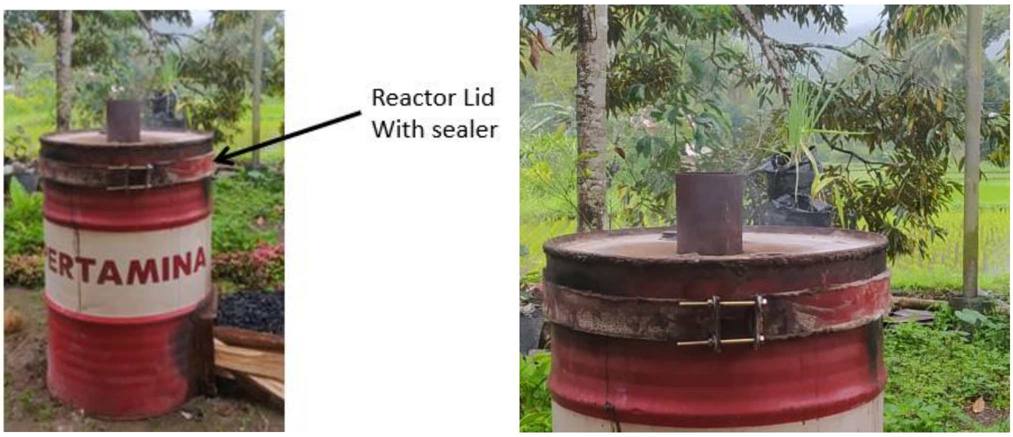



Figure 5. Very thin smoke appears at the kiln with sealer

Figure 6. Kiln capacity before and after the carbonization process

Table 4. Result of the carbonization process

| Experiment | Capacity (kg) | Result (kg) | Percentage (%) |
|---|---|---|---|
| **1** | 15 | 6 | 40 |
| **2** | 20 | 9 | 45 |
| **3** | 25 | 12 | 48 |

### 3.3. Discussion

Observation during the burning process shows that the kiln with a kiln cap to close the upper side is not enough to reduce the amount of smoke released to the environment (Figure 4). Therefore the installation of a sealer belt was necessary. Figure 5 shows that the significance of smoke reduced during the process after the sealer belt was installed. Very thin smoke still appears as the effect of the wood used as burning fuel. Compared to other methods (Figure 1, Figure 4), the kiln with a sealer belt successfully reduces the smoke that pollutes the environment. This lead assumption the design is suitable to use by the home industry that does their production in the settlement, as they no longer need to transport and burn the coconut shells far from their production sites.

Table 1 shows that the more coconut shell burned, the less loss of heat value obtained. An anomaly was found in the 2nd data where heat loss decreased after minutes of 100, this oddity was caused by the wood fuel that ran out and no stock available to add. In the 3rd experiment, everything is maintained back to normal. The full capacity of a 25 kg coconut shell yields the lowest heat loss, which means that the heat produced could be utilized effectively to burn the coconut shell inside.

During the carbonization process, a 15 kg coconut shell produces 6 kg of charcoal, a 20 kg coconut shell produces 9 kg of charcoal, and a 20 kg coconut shell produces 12 kg of charcoal in 150 minutes, with a percentage of 40%, 45% and 48% respectively. Based on the test, it was found that burning with a mass of 25 kg is the optimal result yielding 48% of charcoal content (Table 3). This result set the highest production rate among other methods (Table 1).

## 4. Conclusions

Based on the observation, the design of this kiln has shown a significant reduction in the amount of smoke produced during the coconut shell carbonization process. Although complete removal of smoke is not possible due to the effect of wood burning as fuel, using this kiln has resulted in a much higher reduction than other methods. Utilizing the kiln to its maximum capacity of 25 kg has proven to be the most efficient, with the lowest heat loss in the system and producing the most coconut charcoal after the carbonization process, with a yield of 48% from 25 kg of coconut shell. These results suggest that this kiln design is suitable for homes and small industries to improve productivity and reduce costs. Further research is needed to measure the results using air pollution measuring devices and verify how effectively the kiln promotes environmental sustainability and applicability in the settlement area.

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