Design and performance test of drum kiln for durian peel carbonization

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Abstract. Durian is one of famous fruit in several places in Indonesia. Only about 20 % of durian fruit is utilized or consumed. The huge amount of waste, especially durian peel, still unutilized and potential causing some environmental problems. Based on the composition of durian peel, carbonization is one of the best process to utilize durian peel to produce biocharcoal. The research aims to design a specific kiln for durian peel carbonization and conducting performance test of the kiln. The kiln has been designed as drum type, by using used oil drum as main raw material of the kiln, so it will be easy to find even in the village area and relatively cheaper and easier on kiln fabrication. The performance test shows that the kiln capacity is around 10 kg durian peel. The best performance was achieved in the second test, which produce yield 25% of good quality bio-charcoal in 75 minutes process at temperature range of 326 – 359 °C. The charcoal has LHV (low heating value) of 6347 kCal/kg at water content of 4.66% wet basis, which is compatible to Indonesian National Standard (SNI) quality. Based on the performance investigation, the kiln design should be improved to avoid some weakness performance such as smoke flow and duration time of carbonization.

1. Introduction
Durian (figure 1) is one of famous fruit in several places in Indonesia and some other countries such Thailand and Malaysia. Unfortunately, only about 20 % of durian fruit is utilized or consumed [7]. The huge amount of waste, especially durian peel, still un-utilized and potential to causing some environmental problems. Carbonization is one of the best simple process to utilize biomass waste which has high carbon content [1, 2, 3] to produce bio charcoal that can be used for many purposes. Due to its characteristic and composition, carbonization also the best process to utilize durian peel to produce bio-charcoal [7] which can be used for many purposes such as material in many kinds of industrial’s product or even just for land fertilizer or fuel. It means that utilization of durian peel using carbonization not only solving environmental problems, but also will be an additional income for durian producer or durian trader. The research aims to design a specific kiln for durian peel carbonization and conducting performance tests of the kiln.
2. Method

The stages of this research are described as the flow chart in figure 2. The first step was study about durian peel characteristics and inventory of problem indicator, which will be used as design parameters. The next step was calculation and design analysis, continued with technical drawing and fabrication. Final step was conducting performance test of the kiln.

In this research, problems indicator will also be used as design parameters, beside of given parameters based on the carbonization process requirement. Those parameters are kiln capacity, user capability, and the price (investment cost).

Durian usually (mostly) sold in small kiosks or even in the street side, and the consumer enjoy the durian directly in those places. Only several peoples bought durian for taking away. It means that the durian peel concentrate at each kiosk/street durian seller, and it’s not in a very huge volume. Thus, the kiln which will be designed should be portable and the capacity should be match with amount of durian peel which will be utilized. Since most of the sellers are small scale traders, so their budget capability for investment is low, and mostly come from rural area. Thus, the kiln should be cheap, easy to handle or operate, and has a simple design so it can be made by a small workshop even in the rural area. Figure 3 shows several types of portable kiln which have been designed and implemented in the field.

In this study, the kiln was design based on the used drum capacity (volume 200 lt). Parameters in the kiln performance test are capacity of kiln (kg durian peel), temperature of carbonization process (°C), total duration time of the carbonization process (minutes), yield (kg charcoal), and quality of the charcoal.

Before processing in the kiln, durian peel was chopped into smaller size (around 10cm x10cm x 5cm) in order to get maximum kiln capacity, and dried in the sun drying to reduce its water content until around 15% wet basis. Pre performance has been done to ensure all of the kiln function were well performed and to get optimum operational method. Three main tests were done based on the pre performance result, especially on kiln capacity and operational method. Energy content of charcoal determined by using bomb-calories apparatus.
3. Results and discussion

3.1. Kiln structure

Based on the design parameters above, the kiln was designed as a portable drum kiln, using used drum (from industrial/chemical agents or fuel) as main structure material. Some modifications have been done for technical aspect to achieve the carbonization process specification. They were air inlet system for combustion process in order to get slow pyrolysis temperature (300 – 500 °C), distribution of those heat energy inside the carbonization chamber, and loading and unloading systems. Result of the design is presented in figure 4. The total height of the kiln is 1670 mm, with the main part (carbonization chamber) is 890 mm length (200 lt volume). A cylinder with 700 mm length and 100 mm diameter was placed in the center of carbonization chamber, to help heating flow distribution inside the chamber.

3.2. Kiln performance test

Performance test has been done for 1 (one) investigation as pre performance test, and continue with 3 (three) main performance tests. As mentioned above, pre performance test purpose is to get optimum
operational condition of the kiln, included optimum kiln capacity, which will be used in the main performance tests. Based on the pre performance test, the optimum capacity of the kiln is around 10 kg raw material. So, about 10 kg raw material was used in each main performance test. The result of all of the tests can be seen in the table 1 and figure 5 and 6 below.

Table 1. Result of kiln performance test

| Raw material (kg) | Average temperature (°C) | Process duration (minutes) | Produced Charcoal (kg) | Yield (%) | Result of carbonization |
|------------------|--------------------------|----------------------------|------------------------|-----------|-------------------------|
| Pre test         | 10                       | 362.6                      | 70                     | 2.5       | 25                      | Fully carbonized |
| Performance 1    | 10.5                     | 328.6                      | 70                     | 2.7       | 26                      | Fully carbonized |
| Performance 2    | 10                       | 314.3                      | 72                     | 2.5       | 25                      | Fully carbonized |
| Performance 3    | 10.5                     | 359                        | 75                     | 2.6       | 25                      | Fully carbonized |

Figure 5. Temperature inside carbonization chamber during the process

Temperature is the main success factor in the slow primary pyrolysis (carbonization) process [4], which is applied as given condition in this study. The temperature during process was controlled in range of 300 °C to 500 °C. The amount and quality of charcoal produced is depend on the temperature level during the process. Each kind of material will be having specific carbonization temperature. In case of durian peel, there is no research has been done before. So, this study has no references on optimum carbonization temperature for durian peel.

Figure 6. Relationship between carbonization-rate (kg/hour) with yield of charcoal (%)
Based on the performance data as shown in table 1 and figure 5 and 6 above, the capacity of kiln is around 10 kg of durian peel. The best result was done by performance 1, which was produce highest yield (26%) in the shortest duration processing time (70 minutes) with maximum temperature of 326.9°C. Even though the process produce a homogenous fully carbonized charcoal and the yield is relatively good, the temperature inside carbonization chamber was lower than optimum temperature for carbonization process. A higher temperature can be achieved by improving air inlet system to give possibility of more combustion air flowing into the chamber. The higher temperature will also improve kiln performance as the duration time of carbonization will be shorter due to the increasing of carbonization rate. But the yield of charcoal didn’t depend on the carbonization rate as shown in the figure 6.

Quality of durian peel charcoal which was produce by using portable drum kiln which has been designed is shown in figure 7. Based on the data, durian peel charcoal quality is match with the charcoal quality standard in Indonesia (SNI) on fixed carbon based. The durian peel charcoal has energy content (LHV) of 6437 kcal/kg or 27043 kJ/kg, higher than standard charcoal energy content based on SNI (5000 kcal/kg). But durian peel charcoal has low density and high content of ash (figure 8). So, durian peel charcoal is not recommended for high rate intensive combustion system such as boiler system or power plant, but available for low rate or un-intensive combustion system such as house hold stove or small scale industries stove.

![Figure 7. Durian peel charcoal](image)

![Figure 8. Composition of durian peel charcoal](image)

Compare to other portable drum kilns (existing design), based on the charcoal yield, performance of this designed kiln is quite good as shown by data in the table 2 below. The duration time was very fast (compare to the other kilns) because durian peel has more free space when it was placed in the carbonization chamber due to its size and physical characteristic.
Table 2. Comparative among designed kiln to the other portable drum kilns (existing design) [5, 6]

| Parameter                         | Designed kiln | Drum kiln A by Isriyanto | Drum kiln A by Isriyanto | Drum kiln B by Isriyanto | Drum kiln B by Isriyanto | Drum kiln by Fonda |
|-----------------------------------|---------------|--------------------------|--------------------------|--------------------------|--------------------------|-------------------|
| Feed stock                        | Durian peel   | Coconut shell            | Rubber wood              | Coconut shell            | Rubber wood              | Saw dust mixed wood |
| Optimum capacity (kg)             | 10            | 11                       | 11                       | 11                       | 11                       | 10                |
| Duration of carbonization (minutes) | 70           | 257                      | 552                      | 107                      | 286                      | 225               |
| Temperature (°C)                  | 328.6         | 401.8                    | 397.9                    | 362.4                    | 385.4                    | 440.7             |
| Yield (%)                         | 26            | 31.97                    | 14.23                    | 26.6                     | 16.67                    | 24.1              |
| LHV (kJ/kg)                       | 27043         | 29899.8                  | 32172                    | NA                      | NA                      | 28870.6           |

4. Conclusion
Based on all of the performance data, we can conclude that:

1. The portable drum kiln which has been designed can be used for durian peel carbonization with good performance.
2. Kiln capacity is around 10 kg of durian peel of around 15% water content (wet basis)
3. Best performance done by performance test 1, which produce homogenous good quality of charcoal in 70 minutes at carbonization temperature of 326.9 °C.
4. Charcoal quality (fully carbonized) and its homogenous are representing that heat distribution inside the carbonization chamber is good.
5. The quality of durian peel charcoal produced by the kiln is match with national standard quality (SNI) of wood charcoal, based on the fixed carbon content (58%) and the energy content (LHV = 27043 kJ/kg or 6437 kcal/kg).

As a suggestion, durian peel charcoal is not recommended for biomass power plant feedstock due to the high ash content (23%), but available to use for house hold cooking stove or industrial stove fuel.

5. References
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