Biomass gasification of candlenut shell and coconut coir with the updraft gasifier method being alternative fuel

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Abstract. Lately, the use of fossil fuels has caused many environmental problems such as global warming as a result of greenhouse gas emissions, which has led to increased fuel prices and erratic availability. These encouraged the interest of researchers to find alternative fossil fuels sourced from renewable raw materials. Candlenut shells and coconut fiber are high-potential plantation and agricultural commodities in East Nusa Tenggara. Statistical data shows that candlenut production reached 1,262.38 tons, while coconut reached 68,496 tons in 2016. The by-products of shells and coir can be used as a good raw material for the gasification process into alternative fuels. One of the established gasification processes in the industry is updraft gasifier. This research has varied the use of candlenut shells and coconut coir in the range of 0-100% to study the characteristics of its gasification products. The purpose of this study was to determine the effect of variations of candlenut shells and coconut coir in the range of 0-100% on the ignition time; the effective time of the gasification process, remaining charcoal and ash, the efficiency of the gasification process and to find out the best variation between candlenut shells and coconut fiber on gas products (syngas) updraft gasifier. The results obtained indicate that the process of gasification of candlenut shells and coconut coir using updraft gasifier was very influential at the time of ignition of syngas, and the effective time of gasification. The highest syngas ignition time was obtained in a variation of 50% candlenut and 50% coconut husk which was 43.14 minutes and the lowest was a variation of 0% shells and 100% coconut husk which was 39.75 minutes. While the highest effective time of the gasification process was obtained by variations of 100% candlenut and 0% coconut husk which was 33.13 minutes and the highest in variations of 75% shells and 25% coconut husk which was 37.40 minutes. The best gasification process was shown in a variation of 50% candlenut shells and 50% coconut husk.

1. Introduction
The use of fossil fuels is increasing causing world oil reserves to run low, so that fuel prices continue to rise. The issue of using fossil fuels also causes global warming and causes environmental damage. To minimize the worst possible impact of the use of fossil fuels, the development of renewable energy sources is an alternative to fossil fuels.

Candlenut and coconut fiber are forestry commodities that are growing rapidly in Indonesia, especially East Nusa Tenggara. In 2013 the area of candlenut plantations in East Nusa Tenggara reached 79,354 ha, and produced a total fruit production of 24,301 tons, while the production of
coconut plants in East Nusa Tenggara province in 2016 reached 68,496 tons, with candlenut production reaching 1,262.38 tons [1].

Candlenut consists of four layers which include the skin of the fruit, mesocarp, fruit flesh, shell, and seed meat. Between the shell and the flesh of the seeds is the epidermis. The percentage of each part of the whole hazelnut is 20% outer skin, middle layer 5%, and 75% shell and seeds. Comparison between shell and seed weight is 7: 3 (Dali and Ginting, 1981 in [2]) so that from 24,301 tons of candlenut in NTT has the potential to produce shells of 13,098.28 tons/year.

Coconut fruit consists of several parts, namely, epicarp (outer skin whose surface is slippery, rather hard and less than 1/7 mm thick); mesocarp (middle skin called coir which consists of hard fibers 3 - 5 cm thick); endocarp (hard shell, 3-6 mm thick, the inner part is attached to the outer shell of the seeds or endosperm); institute or endospermic pistils 8-10 mm thick [3]. Coconut fruit consists of 35% coconut fiber, 15% coconut shell, 29% fruit flesh and 21% coconut water [3]. Thus, from 68,496 tons of heads in NTT has the potential to produce coconut husk of 23,973.6 tons/year.

Today the use of candlenut shells and coconut husks is limited to smoking and making charcoal. This type of candlenut shells and coconut husk waste in very large quantities has not been utilized properly. And if the waste is not used, there will be the possibility of environmental pollution. In general, people just throw the candlenut shell and coconut coir away, although some people use it as fuel for smoking and also as ordinary charcoal or for other cooking activities. However, smoking method carried out by the community can result in environmental pollution. On the other hand, the waste or pecan shell endangers pedestrians, especially those who do not use footwear because the pecan shell is usually hard and sharp. In the utilization of biomass waste converted into heat energy, one of the ways that is often used is the combustion process with limited air (partial oxidation). The gas produced can be used for domestic purposes and can be used as a source of heat energy in the process of drying, roasting agricultural material.

The results of the proximate analysis of the candlenut shell showed that the pecan shell has a volatile value of 81.9 %, fixed carbon 12.60 %, ash 3.10 %, and moisture 2.40 %. The ultimate analysis of the candlenut shell contained carbon (C) 53.78 %, hydrogen (H) 4.37, oxygen (O) 41.50 %, nitrogen (N) 0.37 % and calorific value of 14.25 KJ kg⁻¹. While the proximate analysis of coconut fiber has a volatile value of 74.59 %, fixed carbon 21.6 %, ash 1.34 %, and moisture 2.45 %. The ultimate analysis of coconut fiber contained with carbon (C) 47.6 %, hydrogen (H) 5.7 %, Oxygen (O) 45.6 %, nitrogen (N) 0.2 % and calorific value 3942.751 cal/kg [4].

Based on the proximate and ultimate analysis, the biomass of candlenut shells and coconut fiber can be used for gas production through gasification.

Gasification is the process of converting biomass material into gas fuel and is usually carried out on a reactor called a gasifier. Gasifier is a chemical reactor where complex chemical and physical processes occur such as drying, heating, pyrolysis, oxidation, and reduction.

Based on the background, the authors are interested in conducting research with the topic "Biomass Biomass Candlenut and Coconut Fiber Biomass by Using the Updraft Gasifier Method into Alternative Fuels". The aim of the study is to find out the effect of variations in the treatment of candlenut shells and coconut coir on syngas ignition time, effective time gasification process, remaining charcoal and ash, the efficiency of the gasification process and to find out the best variation between candlenut shells and coconut coir in gas product (syngas) updraft gasifier.

2. Material and Method
This research has been carried out at the Agricultural Mechanization Engineering Laboratory, Faculty of Agricultural Technology Universitas Kristen Artha Wacana Kupang from September to October 2016. This research was used as the main tool gasifies type updraft batch capacity of 46 liters, which was equipped with a blower (combustion air supply), temperature sensor (thermocouple), stove or burner. Research support tools such as hotwire anemometer to measure airflow and flow rates, digital thermometers to record temperature performance, stopwatches, roller meters, and scales. While the
main ingredients to be used in this study are candlenut shells and coconut fiber and supporting materials include charcoal and kerosene for initial ignition.

This study used a basic design of RAL (Randomized Complete Design), 5 treatments and 3 replications to produce 15 experimental units. The treatment in this study was to examine the percentage of candlenut shell material (TK) and coconut fiber (SK) consisting of:

- Treatment A is 100% hazelnut and 0% coconut fiber
- Treatment B is 75% hazelnut and 25% coconut fiber
- Treatment C is 50% hazelnut and 50% coconut fiber
- Treatment D with 25% hazelnut and 75% coconut fiber
- Treatment E with 0% hazelnut and 100% coconut fiber

Observation Variables:
1. Syngas Ignition Time.
   Syngas ignition time is calculated based on the time interval at which syngas is turned on stably without interruption.
2. Effective time of gasification.
   The effective time of gasification is calculated based on the time needed for the conversion of all biomass in the gasifier and each kilogram of material.
3. Charcoal and Ashes Remaining
   The mass of ash and charcoal residual gasification results are collected and dried until the water content reaches 10%, then weighed.
4. Efficiency of Gasification Process
   The efficiency of the gasification process is calculated using the following formula:
   \[
   \text{Eff} = \frac{M_{bb} - M_{ab}}{M_{bb}} \times 100\% \tag{1}
   \]
   Where:
   \[
   \begin{align*}
   \text{Eff} & = \text{Efficiency of Gasification Process} \\
   M_{bb} & = \text{The Mass of Material Used} \\
   M_{ab} & = \text{The Mass of Charcoal and Ashes from Gasification}
   \end{align*}
   \]

2.1. Data retrieval
Gasifier was filled with charcoal feed (0.2 kg) and ignited evenly, candlenut shells and coconut coir were added (3 kg), ignite feeders (charcoal) with kerosene, then if the charcoal has been burned fairly evenly then data collection the temperature in the gasifier, the temperature of the ignition for the gas.
Data retrieval was carried out for 108 minutes with observation time every 3 minutes when the resulting gas was able to ignite until the gas was able to run out. After the experiment, the gasifier closes and the blower was shut down.

2.2. Data analysis
Data were analyzed using graphical analysis and analysis of variance (ANOVA) to see the effect of treatment on parameters. If it had a significant effect then we will continue the post hoc Duncan's Multiple Distance Test (GD) and to see the best treatment combination at 1% test level.

The mathematical model for the factorial RAL (complete random design) experiment with the percentage TK factor (3 levels) and the SK percentage factor (3 levels) can be written as follows [5]:

\[
Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)ij + \epsilon_{ijk} \tag{2}
\]

\[
\begin{align*}
   i & = 1,2,\ldots,a \\
   j & = 1,2,\ldots,b \\
   k & = 1,2,\ldots,n
\end{align*}
\]

For variations in the percentage of TK and SK repeated 3 times, then the mathematical equation can be written as follows:
Y_{ijk} = \mu + TK_i + SK_j + (TKSK)ij + \varepsilon_{ijk}

(3)

\begin{align*}
&i = 1, 2, 3 \\
&j = 1, 2, 3 \\
&k = 1, 2, 3
\end{align*}

Where:

- $Y_{ijk}$: The observation of TK factor level-i, SK factor level-j and on the k-replication
- $\mu$: General median value
- $TK_i$: The influence of TK factor on level-i
- $SK_j$: The influence of SK factor on level-j
- $(TKSK)ij$: the effect of the interaction of the TKSP factor on the i-level (from the TK factor), and the j-level (from the SK factor)
- $\varepsilon_{ijk}$: random influence (random error) on i level (TK factor), j-level (SK factor), TKSK interactions on i and j and in k-replications

3. Result and Discussion

3.1. Syngas ignition time

The ignition time of syngas or gas producer was calculated based on the time interval where syngas starts to burn stably without interruption in the process of gasification of the candlenut shell and coconut husk. The rate of ignition of syngas on the burner is affected by the air flow rate and material size. The longest ignition time occurred in treatment C (TK50% VS SK50%) with a material size of 1.1-3.0 cm with an effectiveness value of 43.14 minutes. The average time of ignition of syngas in each treatment can be seen in (Figure 1).

**Figure 1.** Average time to start syngas at each treatment

The duration of ignition of syngas depends on several factors, including how fast the fuel can be decomposed or decomposed into gas. If the fuel can be decomposed in a short time, the ignition time for syngas will be short. But conversely if the decomposition of fuel into gas lasts longer, then the ignition of syngas can take place in a longer time. Another factor causing fast or slow ignition time of syngas is very dependent on the temperature of the gasification reactor where if the oxidation process takes place under limited air conditions and the right material composition, the time of ignition of syngas will last longer. But on the contrary if the combustion process takes place perfectly, the syngas ignition time will take place faster [2, 6].
3.2. Effective time of the gasification process
The effective time of the gasification process is the time required to carry out thermal conversion of all biomass in the gasification reactor. The effective time of the gasification process is calculated based on the time needed for the conversion of all biomass in the updraft gasifier reactor per kilogram of material. The updraft gasifier capacity scale used in this study was 3 kg while the feeder (charcoal) was 0.2 kg so that the total material used in each treatment was 3.2 kg.

The analysis showed that the effective time of the treatment is 35.17 minutes, which is the average of all treatments. But for the treatment with the best effective time occurs in treatment A (Candlenut Shell 100% VS Coconut Fiber 0%). The average effective time of the gasification process at each treatment is shown in (Figure 2). The analysis results in the figure show that the effective time of the gasification process tends to be stable and does not experience a decrease and a significant increase in the range of 33-37 minutes.

![Effective Time of The Gasification Process](image)

**Figure 2.** Average effective time of the gasification process

3.3. Mass of charcoal and ashes remaining
Measurement of the rest of the process of gasification of the candlenut shell and coconut fiber in the form of ash and charcoal was carried out to determine the residual combustion process. Ash and charcoal measurements were carried out after drying with a moisture content <10%. From the results, it is known that the higher the percentage of candlenut shell, the remaining combustion in the form of ash and charcoal the higher as seen in Figure 3.

![Mass of Charcoal and Ashes](image)

**Figure 3.** Mass of charcoal and ashes
From the graph above shows that the greater the percentage of candelanut shell in the treatment of the gasification process, the greater the mass of ash and charcoal.

3.4. Efficiency of gasification process
The efficiency of the gasification process is the percentage of the gasification process from the Candleanut Shell and Coconut Fiber which is changed to syngas or the ratio between the syngas formed with fuel consumption. The results of the analysis show that the higher the amount of coconut fiber, the better the combustion efficiency of the gasification process, as seen in Figure 4.

![Average of Gasification Process Efficiency (%)](image)

**Figure 4.** The efficiency of gasification process

The results show that the amount of residual combustion gets smaller if the percentage of coconut coir in the treatment is higher than the percentage of the candelanut shell.

4. Conclusion
Provision of treatment in the process of gasification of the candelanut shell and coconut fiber using an updraft gasifier is very influential in the ignition of syngas, and the time of gasification effectiveness. Syngas ignition time was 43.14 minutes (C), and the gasification process time was 35.17 minutes (A). The most remaining ash and charcoal in treatment A was 985.18 grams and the lowest in treatment E was 341.73 gr, and the efficiency of the gasification process was 68.58%. The gasification process of candelanut shell and coconut fiber, the best combination occurred in the TK50% VS SK50% treatment, where the syngas flame reaches 43.14 minutes, the effective time for the gasification process is 34.17 minutes. The remaining combustion was 400.27 grams and the efficiency of the gasification process was 87.49%.

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