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Adaptation and Performance Evaluation Closed Drum Type Carbonizer for Waste Biomass

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ABSTRACT

A nation's development is frequently driven by its energy industry. It is alarming that firewood is still frequently utilized as the main source of energy for cooking in many nations, especially those that see a decline in forest cover. For the carbonization of biomass waste, a drum-type carbonizer adaptation was created. The potential for obtaining a biomass carbonization process is the subject of this research. Various agricultural waste products (such as sawdust, coffee husks, peanut shells, and millet stalks) have been heated up in a device called a carbonizer. These two residues' biomass carbonization yields were calculated and found to be 37.5% and 60.98%, respectively, for sawdust and coffee husk.

INTRODUCTION

For forestry enterprises, the development of bioenergy offers a singular chance to expand their steady revenue streams. By converting ores into metals through a process called carbonization, people were able to create charcoal, the first biofuel that helped them escape the Stone Age (Basu, P.,2006). Charcoal is utilized as a premium solid fuel worldwide for domestic cooking, metal refining, and chemical manufacture.

Additionally, the market is well defined, the technology is well known but still presents opportunities for advancements (in terms of efficiency, costs, and environmental impacts), the technology does not present a significant risk, the investment is well suited for small farmers, and the process and technology provide a great opportunity for the development of small-scale and local supply chains. Making charcoal offers favorable preconditions for effective biomass-based systems in the forestry industry [Basu, P. 2006, Reithmuller, G., and Collins, M., 2009).

By converting ores into metals through a process called carbonization, people were able to create charcoal, the first biofuel that helped them escape the Stone Age. In addition to being

Utilized as a premium solid fuel for domestic cooking, metal refining, and chemical manufacturing, charcoal has evolved with industrialization to become the most valuable reducing agent for the metallurgic industry (Borines *et al.*, 2011).

Small-scale farmers, common in Southern Europe countries, are typically not set up to deal with problems like grid connection and authorizations, emission regulation and compliance, administration, and operation of biomass power generation systems, etc. Additionally, due to their frequently limited financial resources, most of them find it difficult to invest in bioenergy plants or offer financial guarantees in order to obtain a loan, which poses a major obstacle to the widespread adoption of these systems. Last but not least, the only way that bioenergy production can be financially viable is if the State or the Region provides financial incentives. This fact breeds uncertainty among investors and increases the risk of financing because any change in the regulatory environment could have a negative impact on the entire enterprise. Investments in stationary decentralized biomass-based systems face this pertinent challenge. The current study in this context concentrated on charcoal production as a potential substitute for biopower generation for forestry farms (Borines *et al.*, 2011a, Borines *et al.*, 2011b).

There are numerous kinds of carbonization equipment that have been created, but the majority of them were made for large capacities, and some of them also had poor performance. Particularly portable metal kilns or carbonization, which is more efficient, environmentally friendly, and can be used to feed various types of biomasses or agricultural refuse (rather than just one type of biomass exclusively). A portable venture drum-type kiln with a maximum capacity of 12.45 kg of coconut shells has been developed to enhance kiln performance (Virgilio *et al.*, 2015, Nakorn *et al.*, 2018).

With the heat generated during combustion available as an additional source of energy to partly replace the currently used kerosene and firewood, the carbonizer allows waste heat extraction using exchangers or micro boilers. While population growth and current practices (such as using kerosene and firewood from unmanaged forests) are the main causes of illegal deforestation, this additional energy source from using agricultural waste in carbonizer can play a critical role in protecting the forests in rural areas. By reducing the need for firewood and preventing deforestation, the adaptation of carbonizer can increase

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carbon sequestration. Using biochar for fertilizer further reduces net emissions in the area by storing carbon in the soil (Virgilio *et al*, 2015, Gutu Birhanu and Duresa Tesfaye, 2021).The current utilization strategy of burning agricultural byproducts to recover heat is considered inefficient and bad due to the low heating value and issue with air emissions. Agricultural residues are typically made of low-density materials and have poor heating values. Apart from these, their combustion cannot be readily maintained or controlled effectively for the intended use. Therefore, turning it into a more valuable energy supply is a recurring problem.

MATERIALS AND METHODS

Materials

The materials used in the test included stopwatch, spring balance, sack, waste biomass of sawdust and coffee husk, anemometer, thermometer, Digital moisture, hygrometer, infrared thermometer, and digital multi-meter.

Assessment of Existing Carbonizer

After different carbonizer were gathered from various locations and fully analyzed regarding their technical and financial limitations. The following carbonizer designs and kinds were evaluated in order to choose the best carbonizer for waste sawdust and coffee husks: pyrolysis of wood JAERC's drum-style carbonizer and BAECR's corncob-style carbonizer.

Figure 1: a) BAECR corncob-type Carbonizer, b) JAERC Closed drum-type carbonizer

Manufacturing of Carbonizer

Based on a prepared design standard, the residual carbonizer for waste biomass was manufactured first. The part was improved, and the process proceeded as follows. As a result, a 620 mm diameter drum body was made from sheet metal that was pressed to a thickness of 1.5 mm. The exhaust chimney and coal tar box were made from sheet metal and assembled individually. The carbonizer is a cylindrically shaped reactor that was created to provide efficient carbonization in an atmosphere with little oxygen. It was constructed using the aforementioned materials, with a drum that was 620 mm in circumference and 2100 mm tall. The upper opening of the drum was covered by a suitable metal plate, which was used to fire feedstocks. Finally, the entire unit was put together to create the full waste biomass carbonization apparatus and was ready for experimental testing. Only 42 kg of raw waste biomass per lot could fit in the waste biomass carbonizing drum.

Biomass Preparation

We gathered the necessary raw coffee husk and sawdust from our center, which is considered to waste, from the fields of private investors and well-known farmers. The collected feedstocks were sorted out to guarantee a successful carbonization process and placed over the sun to reduce the moisture content of waste biomass. To provide more surfaces or contact areas for the carbonization activity, sawdust residues, in particular, were classified based on their different sizes.

Performance Evaluation of the Carbonizer

Whether a system is used for conversion or transportation, its efficiency determines how well it can carry out its duties. Additionally, it contrasts a system's real performance with the best or most ideal performance it is capable of. Calculating combustion helps determine how effective a carbonization procedure is. Before and after the procedure, various parameters were collected. The values of these parameters were then used to measure the performance of the carbonizer. Some parameters that will be obtained or measured before and after the operation are moisture content, the material's initial weight, the charcoal recovered, and weight of the container. Other values, like the weight of the volatile matter, will be obtained from computations.

These data are needed in order to compute the actual and maximum recovery of the system. Percent actual recovery, R_{actual} represents the actual weight of charcoal produced over the initial weight of the sample expressed in percentage, while percent maximum recovery, R_{max} shows the maximum weight of carbonized that can be recovered over the initial weight of the sample expressed in percentage. The weight of fixed carbon and ash present in the sample, which can be calculated by deducting the weight of water and volatile matter from the original weight of the sample, together make up the maximum weight of carbonized material that can be recovered (Virgilio *et al.*, 2015). Eqs (1), (2), and (3) show the equations for actual recovery, maximum recovery, and efficiency, respectively.

$R_{actual} = (W_{carbonized}/W_{initial}) \times 100\%$ (1)

where: R_{actual} is the actual recovery of the system (%), $W_{carbonized}$ is the weight of charcoal recovered (kg) and $W_{initial}$ is the initial weight of samples (kg)

$R_{maximum} = ((W_{initial} - W_m - W_{vm}))/W_{initial}$ 100% (2)

where: R_{max} is the maximum recovery of the system (%), $W_{initial}$ is the initial weight of wet samples (kg), W_{vm} is the weight of the volatile matter (kg) and W_m is the weight of water in the sample (kg)

$E_{system} = (R_{actual}/R_{Rmax}) * 1000$ (3)

where: E_{system} is the system efficiency (%), R_{actual} is the actual recovery of the system (%) and R_{max} is the maximum recovery of the system (%

According to Schenkel (2006), the mass yield was calculated by the ratio of the mass of carbonized product to the mass of the raw product initially introduced.

$$C_y = (\frac{m_c}{m_b}) * 100\% \quad (4)$$

Where: C_y: Mass yield (%) M_c: Mass of carbonized product (kg) and M_b: Mass of raw product (kg)

Carbonizer Capacity

The amount of material that was carbonized by the prototype carbonizer per unit time (Ricardo F. Orge, 2012), is computed as follows,

$$C = (\frac{W_t}{t}) * 100\% \quad (5)$$

Where: W_t = total weight of material loaded into the carbonizer and t= total time of operation

Total Time of Operation

This spans the period from when the carbonizer was first fired up until it was completely emptied of carbonized substance. The following practical tasks are included in this, and their time requirements are also tracked separately: (a) loading/reloading of hopper, (b) collecting the charcoal, and (c) agitating/stirring the hopper contents.

Temperature

The temperatures of the ignition compartment would be measured using thermocouple probes and a multi-thermometer data recorder with thermocouple wires. The tips of the probes, which were placed at the top and bottom of the ignition chamber, were roughly at the chamber's longitudinal line. At ten-minute intervals, temperatures were measured at each location, and the data were recorded.

Figure 2: Carbonizer prototype during performance testing

RESULTS AND DISCUSSION

Carbonizer Selection

Based on an evaluation of the various carbonizer designs already in existence, the best design of carbonizer for the carbonization of refuse sawdust and coffee husk was chosen. The carburizer's ability to contain and manage sawdust and coffee husk during operation, as well as the expense of fabrication, was the primary design consideration. The BAERC-type corncob carbonizer, which uses biomass pyrolysis, was not chosen because it can only be used for raw materials with large particulate sizes. This was considered because the JAERC drum-type carbonizer can handle refuse materials the size of sawdust and coffee husks. The JAERC drum-type carbonizer was adjusted as a result.

Performance Testing of the Drum-Type Carbonizer

The primary components of biomass materials were thermally degraded once a pyrolysis gas flame was created by heat transfer from the central tube burner, which raised the reactor chamber temperature to a high of 250–400 o C (Nakorn *et al.*, 2018). The charring procedure was seen to be finished in two to three hours. The range of charcoal yields for sawdust and coffee husk, respectively, was determined to be 36.1- 37.5 and 58.07-60.98% by dry weight. (Table1). We can determine the bulk yields using the information from sawdust and coffee husk carbonization. (table 1 and table 2). (Cocosnucifera) Wastes yielded the highest test for 8 openings in the drum-type carbonizer for Young Coconut quantity of charcoal, 8.15 kg, or 33.13% actual charcoal recovery (Virgilio *et al.*, 2015). The efficiency of a corn cob carbonizer

Table 1: Carbonization of the two residues of sawdust and coffee husk of 100% loaded

Wastes of Biomass	Time of treatment (min)	Mass of biomass (kg)	Mass of char (kg)	Loss in other forms (kg)	Mass yield (%)	Carbonizer capacity
Sawdust	130	32	12	20	37.5	15kg/hr
Coffee husk	180	41	25	16	60.98	14kg/hr

Table 2: Carbonization of the two residues of sawdust and coffee husk of 75% loaded

Wastes of Biomass	Time of treatment (min)	Mass of biomass (kg)	Mass of char (kg)	Loss in other forms (kg)	Mass yield (%)	Carbonizer capacity
Sawdust	100	24	9	15	37.5	14.4kg/hr
Coffee husk	160	31	18	13	58.07	11kg/hr

measured on a volume basis was 86.36%, and one batch charring took 90 to 110 minutes for better carbonization as opposed to 3 to 4 hours for the former (Gutu Birhanu, Duresa Tesfaye, 2021).

Temperature Variation Inside the Carbonizer

The yield of charcoal produced, the characteristics of the charcoal produced, and the reactor temperature profile have all been used to describe the performance of the carbonizer system. The graph below illustrates how the sawdust and coffee husk temperature profiles changed inside the carbonization container. We have also made an effort to monitor the homogeneity of the temperature in the carbonizer during carbonization. For this, the temperature inside the carbonizer is measured using a computerized multi-meter every ten minutes. Examples of temperature fluctuation during the carbonization of sawdust and coffee husk are shown in the figure below. These graphs demonstrate that during the carbonization procedure, the temperature inside the carbonizer is not uniform.Because the carbonization is accompanied by partial combustion processes. It is observed that there is a loss of matter at the beginning of the carbonization of the charred matter), the temperature variability can affect the mass yield. We also observed that for 130 minutes, sawdust is carbonized at a high temperature (roughly 445 °C), before cooling to temps below 209 °C. In a carbonizer, the temperature inside a corn cob quickly reached 200 °C, and heat transmission from the surrounding flue gas significantly raised that temperature to about 400°C, where the majority of the biomass residues were thermally degraded (Nakorn *et al.*, 2018). The major components of the cassava rhizome were thermally decomposed at temperatures between 250 and 300°C once a stable flame

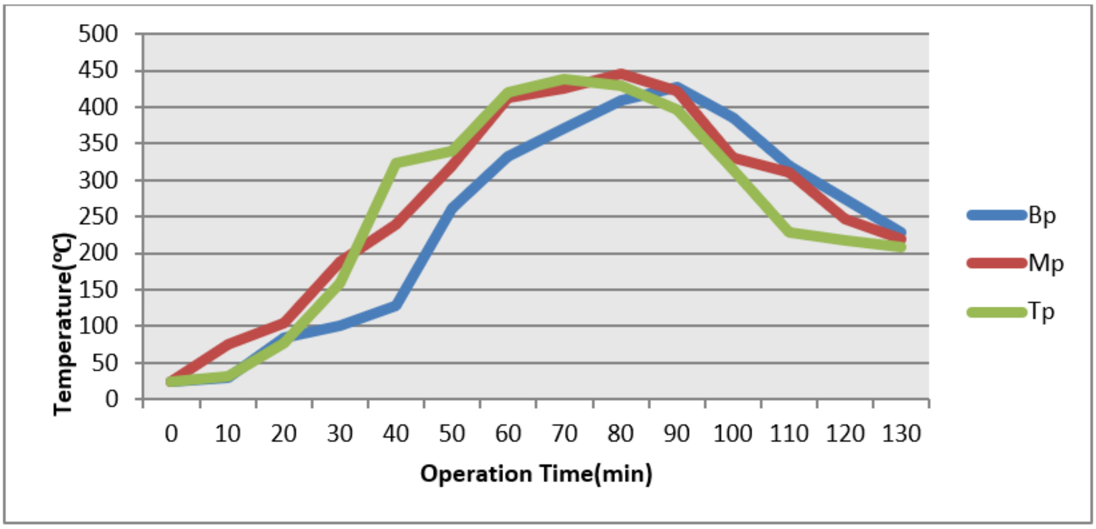

Figure 3: a) Sawdust temperature distribution around pyrolysis chamber

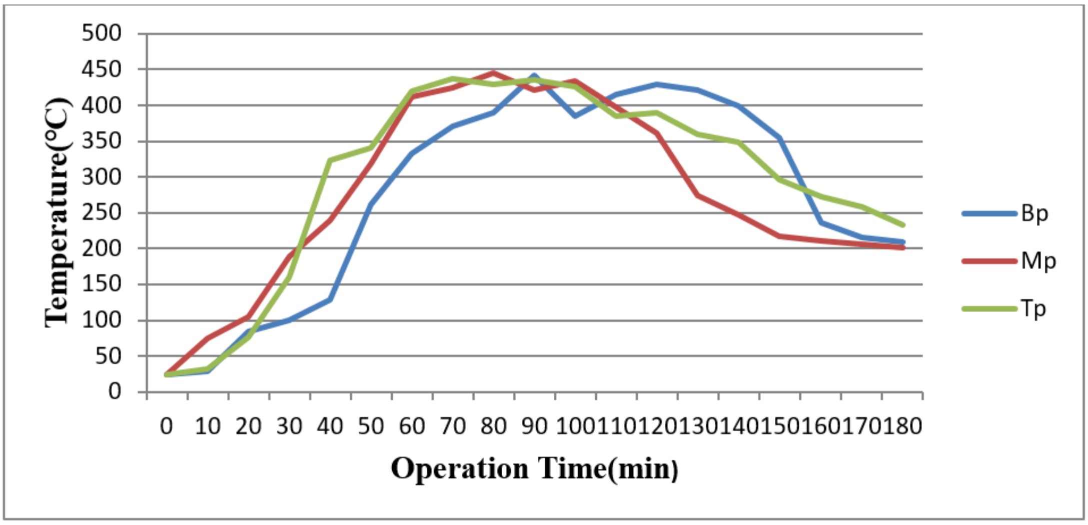

Figure 3: b) Coffee husk temperature distribution around pyrolysis chamber

from the pyrolysis gas was realized (Nakorn *et al.*, 2017). Where Bp is bottom of pyrolysis chamber, Mp is middle of pyrolysis chamber and Tp is top of pyrolysis chamber.

CONCLUSION

The efficacy of the sawdust and coffee husk pyrolysising carbonizer was measured by the reaction temperatures reached, the total processing time, and the yields of carbonized material. Reactor temperature profile, charcoal yield, and charcoal quality all affected how well the carbonizer device worked. Because partial combustion occurs alongside carbonization, which is why there is a loss of matter at the outset of the carbonization of the charred matter, temperature variability had an impact on the mass yield. Less educated rural and per urban populations will benefit from this design and process because it will enable them to create small- or medium-sized businesses with minimal resources and training. Additionally, it will benefit rural women who rely on inexpensive fuel sources, such as charcoal made from trees, to cook and who apply regular manure to farms to increase crop yields. Other than coffee husk and sawdust, other waste biomass and agricultural residues can also be carbonized using this technique. For farming residue and waste biomass to be used effectively, ultimate and proximate analyses of that biomass must be conducted.

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