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The Combustion Characteristic of Biomass Stove with Air-Preheated by Porous Medium

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A B S T R A C T

This study aims to characterize the combustion of the biomass stove filled with a porous medium for air pre-heating to enhance the biomass decomposition. An equivalence ratio, one of the important parameters for the combustion, was investigated to evaluate the completeness of the combustion process. Thermal efficiency was used as the indicator to reflect the performance of the biomass stove. Which was divided into two parts namely the pre-combustion (PCC) and the combustion chamber (CC). The CC volume was 28 liters for fuel storage, and it was insulated for reducing heat loss. The stove was made of 2 mm steel plate and the porous medium was a round-shape ceramic with a diameter of 10 mm. The boiling test was performed using corn cobs as a single solid fuel to boil water in the vessel. The temperature of the stove was measured using a thermocouple Type-K and a data recorder was used to collect the experimental data. The airflow rate was determined using an airflow meter and the fuel consumption rate was calculated using the aforementioned experimental data. Finally, the designed biomass stove will be demonstrated at the community to simultaneously enhance the community-scale energy and reduce the environmental issues.

1. INTRODUCTION

Presently, the Department of Alternative Energy Development and Efficiency, the ministry of energy of Thailand has the alternative energy development plan to use the biomass to produce heat for the thermal applications of 22,100 ktoe [1]. Moreover, in the northern part of Thailand has air pollution from the wildfire and agricultural residues (i.e. corn cob, and corn stalk among others) burning during land preparation etc. In was reported that the direct combustion of corn cob alone can produce significant amount of dust of 32.18 ton/year [2,3]. Normally, the agricultural residues are used to be burnt in the traditional stove in the rural area as the basic energy production. The traditional biomass stove such as Tao ang lo, Tao wong, and Tao cheng kran play the key role in the Thai people's lifestyle especially for the rural community. Thus, by using the air-preheating strategy can enhance the performance of the traditional biomass stove because the temperature increasing approach the combustion reaction [4,5]. The porous medium combustion, PMC, was filled to the outer chamber of the stove for enhancing the combustion efficiency when utilizing a low heating value feedstock and the combustion stability. The PMC can help to preheat the premixed air effectively [6]. The main object of this study is to investigate the effect of air-preheating by the porous medium on the combustion characteristic of biomass stove.

2. MATERIALS AND METHODS

2.1 Experimental set up

The biomass stove used in this study was made of 2.0 mm. iron plate with the combustion chamber volume of 28.0 liter The 50 mm. cement wall was used as the insulation for preventing the heat loss. For the experimental schematic is showed in Figure 1 and the specifications of the tools and equipment is presented in Table 1.

Table 1. the tools and equipment' specification

No.	**List**	**Specification**
1	Combustion chamber volume	28 liters
2	Iron plate	Thickness: 2.0 mm.
3	Insulator	Cement
4	Centrifugal blower	Model: RV40 -18/12H 12V/DC 430 mA, 5.2 W
5	Speed control	Volt input: 12V/DC Volt output: 0 – 24 V/DC
6	Thermocouples	K-type/Temp: -926 – 1,371°C
7	Data recorder	Yokogawa Model: FX1012

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2.2 Feed stock

The corn cobs collected from the sun sweet factory, Chiang Mai, Thailand were used as the sole feedstock in this study. The biomass was dried using solar dryer dome for a week before being served to the biomass stove. The biomass stove combustion testing, (BSCT was performed) to determine combustion parameters. The Thermocouples K-types equipped with the data locker were used to observe the temperature in Celsius (˚C). T-Air is the inlet air temperature T-Amb is the ambient temperature, T-wall is the cement wall temperature, T-porous top is the top layer of the filled porous medium, and T-porous bott is the temperature at the bottom part of the porous medium. The centrifugal blower was used to adjust the intake air mass flow rate of 8.77 kg/s into the combustion chamber. The data recorder collected data at the interval of 4 minute. The lighter was used to ignite the biomass fuel.

Figure 1. Experimental biomass stove diagram

2.3 Data Analysis

The combustion stoichiometry is the mass equivalence during the combustion reaction and can be calculated from the quantity of oxidizer or air by using equation (1) [7].

$$C_uH_vO_wN_xS_y + (O_2 + 3.76N_2) \rightarrow uCO_2 + vH_2O + ySO_2 + 3.76N_2 \quad (1)$$

The presented oxygen gas in the equation is the available oxygen which can help to burn and, , and y is mole of elements as C, H, O, N, and S respectively, as composition in 1 kg of fuel [7]. The corn cob characterization such as proximate and ultimate analysis were used for calculating the stoichiometric fuel-air ratio using equation (2) by following the research article of (Arun, Venkata Ramanan, & Sai Ganesh [8].

$$\phi = \frac{(FA)_{act}}{(FA)_{stoich}} \quad (2)$$

When

ϕ < 1 is fuel-lean mixture

ϕ = 1 is Stoichiometric fuel-air ratio

ϕ > 1 is fuel-rich mixture

Power Input, this is the amount of energy supplied to the stove based on the amount of fuel consumed. This is computed using the equation (3) [9].

$$P_{in} = 0.0012 \times FCR \times HVF \quad (3)$$

Where:

P_{in} is power input, (kW)

FCR is fuel consumption rate, (kg/hr)

HVF is heating value of fuel, (kcal/kg)

Power Output, this is the amount of energy released by the biomass stove for cooking or using a heat application. The power output can be computed using the following equation (4) [9].

$$P_{out} = FCR \times HVF \times TE \quad (4)$$

Where:

P_{out} is power output, (kW)

FCR is fuel consumption rate, (kg/h)

HVF is heating value of fuel, (kcal/kg)

TE is thermal efficiency, (%)

Percentage of Char Produced ,this is the ratio of the amount of char produced to the amount of rice husks used. This can be computed using the formula, weight of char in kg unit [9].

$$P_{char} = \frac{W_{char}}{W_{fuel}} \quad (5)$$

Where:

P_{char} is percentage of char produced, (%)

W_{char} is weight of char, (kg)

W_{fuel} is weight of biomass fuel used, (kg)

3. RESULT AND DISCUSSION

The biomass combustion characteristics of the biomass stove without PCM are showed Figure 2. The temperature increased during the beginning of the combustion period (i.e., 0 – 4 minutes) After that, the flame was burnt down representing the end of combustion at 8 minute because the corn cobs has a high flash point and is difficult to be burnt directly. The small amount of bamboo wood ship with the lower flash point was used to ignite. The combustion started again at 12 minutes and continued for 52 minutes. The combustion chamber had the maximum temperature the top position of porous medium chamber temperature, and the bottom position of porous mediu**m chamber temperature, were 877**°C, 201°C, and 43°C, respectively. The total mass of corn cob fuel was limited to 2.50 kg which could be burnt for 1 hour. The remaining ash was 43.0 g. The fuel consumption rate was 2.50 kg/h**,** so the percentage of produced char calculated using equation (5) was 0.017 %. From the

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equation (2), the calculated was 0.031 indicating fuel-lean mixture burning. The power input and output were 0.046 MJ/hr., 19.31 MJ/h., respectively.

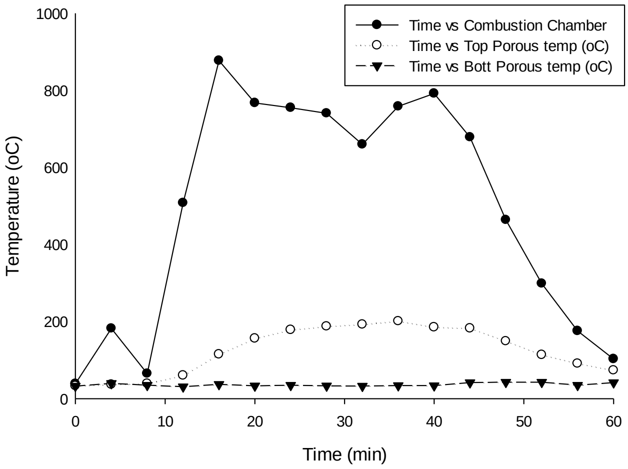

Figure 2. Temperature profiles of the combustion chamber without porous medium

The biomass combustion characteristics of the biomass stove combined with the PCM is showed in figure 3. The combustion suddenly started at the beginning of the experi**ment with the temperature of 31**°C and the corn cob biomass fuel can be ignited without bamboo chips. The combustion chamber had the maximum temperature, the top position of porous medium chamber temperature, and the bottom position of porous medium chamber temperature, of 1049°C, 485°C, 423°C, respectively. The total mass of corn cob was 16.38 kg which could be burnt in 2 hours. The generated ash was 126 g. Then the fuel consumption rate was 8.19 kg/hr., the percentage of produced char calculated using equation (5) was 7.69 % of the total corn cob weight. The percentage of char was higher than that of the non-porous stove because the corn cob has a higher moisture content. The power i**nput and output were 0.152 MJ/h,** and 63.28MJ/h., respectively.

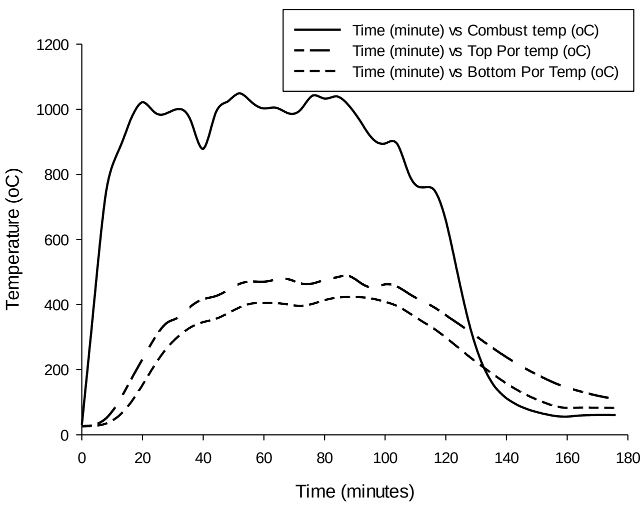

Figure 3. Temperature profiles of the combustion chamber as a porous medium.

The advantages of the PCM are performing thermal energy storage for pre-heating the inlet air resulting the higher combustion temperature.

4. CONCLUSION

The air-preheating by the PMC has a clear positive effect by increasing the combustion temperature. Moreover, the PMC can store the heat energy and discharge it to the biomass combustion chamber. The power input and power output of the stove with PMC was higher than those of the Non-PMC stove. The results from this study could be served as a preliminary information for developed the high-efficiency biomass stove.

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