BIOMASS-BRIQUETTES FUEL FROM LOCAL WISDOM FOR PRODUCER GAS PRODUCTION

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ABSTRACT

This study investigates the preparation of biomass-briquettes from local wisdom for producer gas production. The biomass-briquettes fuel was prepared from agricultural biomass residues such as black rice husk, corn cop, sawdust, starch, and cow dung. The biomass-briquettes fuel of different formulas has the percentage of moisture content in the range of 2-4%, volatile content in the range of 65-69%, ash content in the range of 11-19%, and carbon content in the range of 11-18%. For the carbonized biomass-briquettes fuel of different formulas, they have moisture content in the range of 0.1-0.5%, volatile content in the range of 54-60%, ash content in the range 16-24%, and carbon content in the range of 19-30%. The high heating value properties of the biomass-briquettes fuel and the carbonized biomass-briquettes fuel were in the range of 16-18 MJ kg^{-1}. Both the biomass-briquettes fuel and the carbonized biomass-briquettes fuel produced the most CO gas, followed by H_2, CO_2 and CH_4, respectively. The producer gas which was produced by using the carbonized biomass-briquettes fuel has a slightly higher amount of CO, H_2, and CO_2, but with less CH_4 than using the biomass-briquettes fuel.

KEYWORDS: agricultural waste, biomass-briquettes, producer gas

1. Introduction

Recently in Thailand, as well as elsewhere in the world, clean energy technologies have been gaining prominence over in order to combat Green House Gas (GHG) emission. Agricultural biomass resources are widely available worldwide and provide a major share of renewable energy in most countries [1, 2]. Biomass gasification is an efficient and environmentally friendly process to prepare a gaseous fuel (producer gas) for many applications such as heat production, electrical power generation, internal combustion engine fuel, gas turbine, fuel cell, and using for chemical synthesis application including methanol methane and Fischer-Tropsch liquids [3]. Producer gas is formed by the partial oxidation at elevated temperature of a carbonaceous feedstock such as biomass or coal in a suitable furnace or producer unit by gasification process. At the sufficient temperature (500-600 °C), the primary products for the gasification of biomass are carbon monoxide (CO), hydrogen (H_2), methane (CH_4), carbon dioxide (CO_2) and contains some of particulate matter (carbon and inorganic particles) and tar (composed of higher hydrocarbon) [3, 4]. Due to variation in properties of different biomass materials, some feedstocks are more easily densified than others. Biomass material with a higher lignin, starch or protein content exhibited better compaction than those with higher cellulosic content [1, 2, 5]. In this work, the biomass-briquettes fuel were prepared from agricultural biomass residues by using cassava starch and cow dung as a binder. And some properties of the briquettes were investigated.

2. Experimental

2.1 Biomass-briquettes preparation

Biomass-briquettes were prepared by mixing biomass and fermented biomass of black rice husk, sawdust and corn cob in various weight fractions (Table 1). Tab water and binder (cassava starch or cow dung) was added in proportions of 60%wt and 15%wt to the mixture, respectively. A manual hand press generating a pressure of 4.5 MPa was developed and used. A cylindrical mold 200 mm high with a 40 mm inner diameter was used with a central rod of 10 mm outside diameter to create a hole in the middle of the briquette. The briquettes were left to dry outdoor for 7 days before testing the properties. The carbonized biomass briquettes were prepared by using homemade carbonization stove volume 7.7 L at inner temperature about 300 °C for 3 h. Then left temperature cool down to room temperature and kept all of briquette sample in desiccator until used.

Table 1 Mixing formulas in various weight fraction of different types of biomass and binders

Formulas	Mixing	Weight fraction (% wt)	Binders
A	Black rice husk: sawdust	1:1	starch
B	Black rice husk: corn cob	1:1	starch
C	Black rice husk: sawdust: corn cob	1:0.5:0.5	starch
D	Black rice husk: sawdust	1:1	Cow dung
E	Black rice husk: corn cob	1:1	Cow dung
F	Black rice husk: sawdust: corn cob	1:0.5:0.5	Cow dung
G	Black rice husk: sawdust (EM)	1:1	starch
H	Black rice husk: corn cob (EM)	1:1	starch
I	Black rice husk: sawdust: corn cob (EM)	1:0.5:0.5	starch
J	Black rice husk: sawdust (EM)	1:1	Cow dung
K	Black rice husk: corn cob (EM)	1:1	Cow dung
L	Black rice husk: sawdust: corn cob (EM)	1:0.5:0.5	Cow dung

2.2 Proximate analysis and Bulk density determination

The proximate analysis of the biomass-briquettes fuel which derived from agricultural waste was carried out according to ASTM D3173-95 (for moisture analysis), ASTM D3175-95 (for volatile matter (VM) analysis), ASTM D3174-95 (for Ash analysis), and fixed carbon, (%FC = 100 - Ash% - VM%). The bulk density of the Biomass-briquettes fuel sample was obtained by weighting of the biomass-briquettes. And the volume of the briquettes in cylinder dimension was calculated [1-2, 5]. The volume was recorded and the apparent density was calculated on the dry basis:

$$\text{Bulk density} = \frac{\text{weight of the sample (g)}}{\text{volume of the sample (cm}^3\text{)}} \quad (1)$$

All the experiments were carried out in triplicate and averages were presented.

2.3 Thermal properties of biomass-briquettes investigation

The thermal analysis of biomass-briquettes was done using two methods. The gross calorific value of the sample biomass material was determined in accordance with ASTM standard E711-87 [2]. About 0.4 g of each sample was burnt in the bomb calorimeter until complete combustion was obtained. The difference between the maximum and minimum temperatures obtained was used to compute the gross calorific values of the biomass materials as follows;

$$Q = (C_{water} + C_{cal})(T_2 - T_1) / W_f \qquad (2)$$

Where: Q = Calorific value of species (kJ kg^{-1})

W_f = Weight of the biomass material sample (kg)

C_{cal} = Heat capacity of the bomb calorimeter (kJ kg^{-1} °C^{-1})

T_2-T_1 = Rise in temperature (°C)

C_{water} = Heat capacity of water (kJ kg^{-1} °C^{-1})

Another method for estimation thermal property of the biomass-briquettes sample was carried out by using equation [6]. An approach for developing correlations by using the ratios of non-volatile, volatile, and non-organic constituents of proximate analysis from biomass materials which developed by in linear and non-linear correlations for estimating the higher heating values (HHV). The linear correlation is:

$$HHV = 19.2880 - 0.2135x\,(VM / FC) + 0.0234x\,(FC / ASH) - 1.9584x\,(ASH / VM) \qquad (3)$$

The non-linear correlation is:

$$HHV = 20.7999 - 0.3214 \times (VM / FC) + 0.0051 \times (VM / FC)^2 - 11.2277 \times (ASH / VM) + 4.4953 \times (ASH / VM)^2 - 0.7223 \times (ASH / VM)^3 + 0.0383 \times (ASH / VM)^4 + 0.0076 \times (FC / ASH) \qquad (4)$$

Where: VM = percentage of volatile mattle

FC = Percentage of fix carbon

ASH = percentage of ash

2.4 Producer gas production and composition studying

The producer gas was produced by gasification process of the briquettes samples via updraft gasifier with air flow rate of 2.1 x 10^{-3} m^3 s^{-1}. The gas compositions such as CO, CH_4, H_2, and CO_2 were analysed by using gas chromatography. The gas product was collected using gas sampling bag and then analysed in a gas chromatography-thermal conductivity detector (GC-TCD) to quantify producer gas composition using He as a carrier gas [3].

3. Results and Discussion

3.1 Bulk density and proximate analysis results

From the study, the bulk density and proximate analysis results of the biomass briquette samples with various combining formulas were shown in Table 2. And the results of the carbonized-biomass briquette samples with various combining formulas were shown in Table 3.

Table 2 Bulk density and proximate analysis results of the biomass briquettes with various combining formulas

Formulas	Bulk density (g cm^{-3})	Percent of proximate content (% wt)			
		Moisture	VM	Ash	Fix carbon
A	0.5092	2.8730	67.5963	15.5019	14.0288
B	0.5042	3.6372	65.6308	18.3125	12.4195
C	0.5132	2.2574	68.6692	15.7127	13.3607
D	0.5408	2.4572	66.0120	13.5255	18.0053
E	0.5236	2.6318	65.7966	13.8024	17.7692
F	0.5570	2.3088	67.8244	11.9458	17.9210
G	0.5023	2.2826	67.5029	18.8664	11.3481
H	0.5556	2.9842	68.4962	17.4642	11.0554
I	0.5788	3.5504	67.2164	17.9572	11.2760
J	0.5481	2.4901	67.0363	14.4288	16.0448
K	0.5773	2.3721	66.1382	16.2010	15.2887
L	0.5845	2.2908	65.0303	15.8979	16.7810

Based on the results, it shows that the briquettes have bulk density about 0.5-0.6 g cm^{-3}, the moisture content in the range of 2-4%, the volatile matter content in the range of 65-69%, the ash content in the range of 11-19%, and the fixed carbon content in the range of 11-18%. In addition, using of cow dung as a binder causes the briquettes denser and higher content of fixed carbon than the briquettes which using starch.

Table 3 Proximate analysis results of the carbonized biomass briquettes with various combining formulas

Formulas	Percent of proximate content (% wt)			
	Moisture	VM	Ash	Fix carbon
A	0.1196	54.5480	16.2128	29.1196
B	0.5279	57.6804	21.3852	20.4065
C	0.2594	58.9791	19.9422	20.8183
D	0.1395	53.8570	18.5963	27.4072
E	0.2897	57.8583	18.4207	23.4313
F	0.3193	59.8273	18.6835	21.1699
G	0.1897	56.3079	21.8609	21.6415
H	0.4417	51.6555	22.7191	25.1837
I	0.2896	57.2689	22.4701	19.9714
J	0.1175	55.2807	20.7487	23.8531
K	0.3388	54.3396	23.2749	22.0467
L	0.4898	54.7227	22.8602	21.9273

The results show that various types of carbonized have moisture content in the range of 0.1-0.5%, volatile matter in the range of 54-60%, ash in the range of 16-24% , and fixed carbon in the range of 19-30%, respectively.

3.2 Heating properties of biomass-briquettes studying.

Based on thermal properties studying of biomass-briquettes by using bomb calorimeter technique and estimation from proximate analysis data via linear and non-linear equations [6]. The results show in Table 4 and Table 5.

Table 4 The HHV of biomass briquettes with various combining formulas by using Bomb calorimeter and theoretical calculation from proximate analysis results

Formulas	Gross calorific value (MJ kg^{-1}) From Bomb calorimeter	Estimated HHV (MJ kg^{-1}) from calculation	
		Linear correlation	Non-Linear correlation
A	17.3046	18.1422	17.4277
B	16.9639	18.0603	17.0021
C	17.5963	18.0488	17.3100
D	18.0911	18.3132	17.8138
E	17.7987	18.3083	17.7746
F	18.0562	18.3464	18.0534
G	17.0530	17.8578	16.7363
H	16.8786	17.9572	17.0205
I	16.9041	18.0135	17.0155
J	17.6824	18.2220	17.6254
K	17.5778	18.1345	17.3155
L	17.9234	18.1925	17.3947

The HHV of the biomass-briquettes in various formulas determination by using bomb calorimeter exhibit the gross calorific value in the range of 16.88-18.09 MJ kg^{-1}. By using the Nhuchhen *et al.* equation, the results show that the HHV of the biomass-briquettes were in the range of 17.86-18.35 MJ kg^{-1} from the linear correlation equation. And the HHV of the biomass-briquettes are in the range of 16.73-18.05 MJ kg^{-1} from the non-linear correlation equation. Therefore the prepared biomass-briquettes have the HHV in the range of approximately 16-18 MJ kg^{-1}.

Table 5 **The HHV of carbonized biomass briquettes with various combining formulas by using Bomb calorimeter and theoretical calculation from proximate analysis results**

Formulas	Gross calorific value (MJ kg^{-1}) From Bomb calorimeter	Estimated HHV (MJ kg^{-1}) from calculation	
		Linear correlation	Non-Linear correlation
A	17.4195	18.3516	17.2755
B	17.2238	18.0117	16.3998
C	17.5754	18.0608	16.6488
D	18.1773	18.2313	16.8353
E	17.8862	18.1805	16.9231
F	18.0941	18.1181	16.8760
G	17.3342	18.0053	16.2962
H	16.5750	18.0305	16.0632
I	16.9391	17.9461	16.1948
J	17.4136	18.0901	16.4797
K	17.2309	17.9615	16.0281
L	17.6954	17.9834	16.1116

From the results it found that the carbonized biomass-briquettes in various formulas have the gross calorific value in the range of 16.58-18.18 MJ kg^{-1}. By calculation from proximate analysis results, it found that the HHV are in the range of 17.95-18.35 MJ kg^{-1} and 16.03-17.28 MJ kg^{-1} by using linear correlation equation and non-linear correlation equation, respectively.

3.3 Producer gas production and composition studying

Based on the study of the chemical composition of producer gas from biomass-briquettes and carbonized biomass-briquettes, it was found that the higher percent of gas contents are CO, H_2, CO_2 and CH_4, respectively. In addition the percent of CH_4 in the biomass-briquettes shows higher than the carbonized biomass-briquettes.

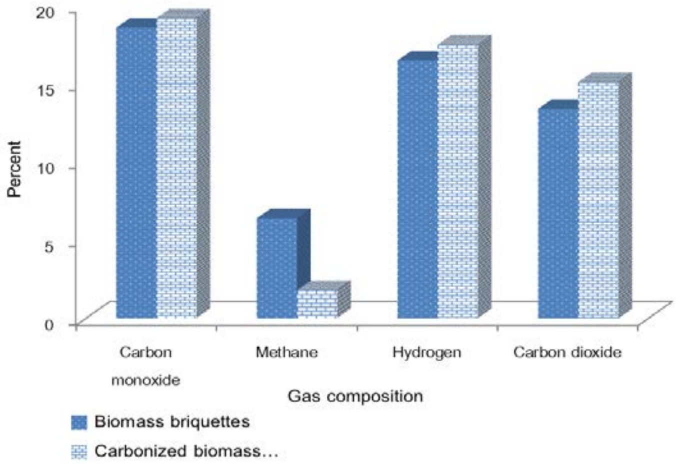

Figure 1 Gas compositions of producer gas

4. Conclusions

The agricultural residues including black rice husk, corn cop, and sawdust were used to prepared biomass-briquettes using cassava starch or cow dung as binder agent. The biomass-briquettes show higher content of moisture and volatile matter but lower content of ash and fixed carbon than the carbonized biomass-briquettes. The briquettes have the HHV in the range of 16-18 MJ kg^{-1}. These briquettes can be used to produce the producer gas which has high content of CO, H_2, CO_2 and CH_4, respectively.

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