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COMPOSITION OF SYNGAS PRODUCED BY GASIFICATION OF AGRICULTURAL RESIDUE BRIQUETTES

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ABSTRACT

This paper summarizes the results of an experimental study on the gasification of briquettes made from different agricultural residues. There were investigated the effects of operating parameters such as temperature and excess air ratio both with a direct influence on the composition of syngas and the heating value. The results indicate that the concentrations of N_2, CO_2 and CH_4 increase with the increase in excess air ratio, while the concentrations of H_2 and CO decrease. The heating value of the syngas was found to decrease with the increase in excess air ratio.

KEYWORDS: gasification, agricultural residues, excess air ratio, syngas

1. Introduction

The use of biomass to provide partial substitution of fossil fuels has an additional importance as concerns global warming since biomass combustion has the potential to be CO_2 neutral. This is particularly the case with regard to agricultural residues or energy plants periodically planted and harvested. During their growth, these plants have removed CO_2 from the atmosphere for photosynthesis and released it again during combustion [1].

Agricultural residues have acquired considerable importance as biofuels for domestic cooking, industrial process heating, electrical power generation, and are used directly as well as in briquetted form for a variety of energy end uses [2].

Biomass gasification is a thermal conversion of solid biomass to gaseous fuel, into which the energy stored in the biomass is converted to calorific value of the produced gas.

The fuel gas obtained from gasification is called syngas, and has the following major components: carbon monoxide CO, hydrogen H_2, carbon dioxide CO_2, and small fractions of methane CH_4. The fraction of each component gas in syngas is known to vary with the type of biomass, the initial moisture content of the feedstock, particle size, operating temperature, and excess air ratio [3].

This paper presents the syngas composition resulted from the gasification of the briquettes made from agricultural residues. The results indicate that the concentrations of H_2 and CO decrease with the increase in excess air ratio, while the concentrations of N_2, CO_2 and CH_4 increase. The syngas composition is found to be similar to those reported by other researchers [4].

2. Experimental procedure

The gasification process consists of drying, pyrolysis or devolatilization, combustion or oxidation and gasification or reduction [5]. These processes are largely dependent on the parent biomass composition, moisture content, local stoichiometry, reactivity of biomass, and gasifier design [6].

Briquettes made of agricultural residues were used in the experiments. The elemental and proximate analyses of the fuels are listed in Table 1 where it can be seen that the sawdust briquettes have the highest carbon content and the lowest ash content, while the reed briquettes have the highest ash content. The briquettes obtained from 50% sawdust and 50% corn stalk have the highest content of oxygen.

Table 1. *Fuel properties*

Fuel sample	Reed briquettes	Sawdust briquettes	Sawdust 50% + corn stalk 50% briquettes	Sawdust 50% + wheat straw 50% briquettes
Ultimate analysis (% of dry fuel with ash)				
C	52.4	53.3	49.41	50.63
H	5.91	6.28	5.90	6.12
N	0.65	1.91	0.43	0.53
S	0.0	0.0	0.0	0.0
O	33.55	35.75	40.73	38.08
A	7.85	2.77	3.54	4.64
Proximate analysis (% of wet fuel)				
Fixed Carbon	29	24.85	22.60	20.30
Volatile matter	56.70	66.55	67.40	70.10
Ash	7.30	2.60	3.30	4.40
Moisture	7	6	6.70	5.20

3. Results and discussions

The variation in the composition of the syngas produced syngas is studied by varying the different operating conditions. The operating conditions in this study are gasification temperature and excess air ratio. The main components of the syngas are CO, H_2, N_2, CO_2, H_2O and CH_4. The molar fractions of these components were measured before the second air injection. Table 2 presents the molar composition of syngas produced through gasification of sawdust briquettes, gasification temperature and excess air ratio. The influence of temperature on syngas composition is illustrated in Figure 1. The molar fraction of the CO_2 increases with the decrease of excess air ratio.

Table 2. *Molar composition of syngas produced by gasification of sawdust briquettes*

Temperature [°C]	Excess air ratio	CO_2	CO	H_2	CH_4	N_2	NH3	H_2O	LHV
700	0.33	0.0638	0.253	0.1950	0.0049	0.4518	0.0011	0.0304	5.47
750	0.27	0.0344	0.311	0.2286	0.0039	0.4018	0.0011	0.0193	6.53
800	0.23	0.0168	0.3465	0.2511	0.0029	0.3704	0.0011	0.0112	7.18
850	0.22	0.008	0.3648	0.2641	0.002	0.3538	0.0011	0.0063	7.52
900	0.21	0.0039	0.3735	0.271	0.0014	0.3456	0.0011	0.0036	7.68

The molar fraction of CO is the most significant contribution to the heating value of the syngas, its value increasing with the gasification temperature.

The increase of the gasification temperature causes a linearly decrease of the N_2 molar fraction.

The useful energy content in the syngas can be quantified by the syngas heating value. Figure 1 shows the variation of lower heating value against temperature.

It is evident that the lower heating value increases with the increase of temperature.

The lower heating value of the syngas ranges from 5.47 MJ/Nm^3 to 7.68 MJ/Nm^3.

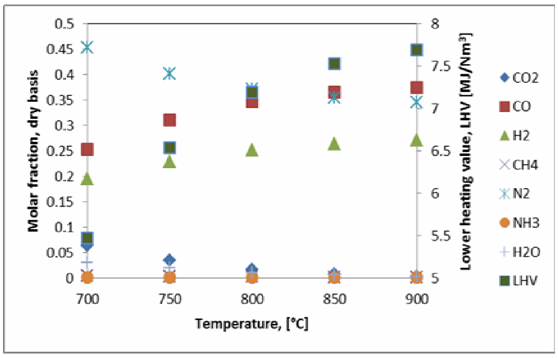

Fig. 1. *Influence of the temperature on syngas composition for sawdust briquettes*

Figure 2 presents the variation of H_2 molar fraction as a function of the gasification temperature for all briquettes made from agricultural residues. As can be seen, the increase in temperature causes an increase of the H_2 molar fraction.

The highest content of the H_2 in the syngas was obtained by gasification of briquettes made from sawdust 50% + wheat straw 50%. The minimum value of the H_2 molar fraction was obtained by gasification of sawdust briquettes.

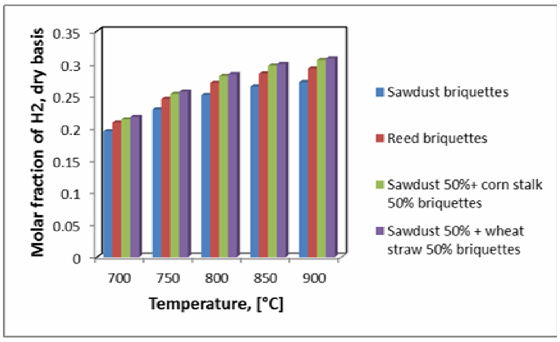

Fig. 2. *Variation of molar fractions of H_2 with temperature*

The molar fraction of H_2 has an important contribution in the calculating of syngas heating value.

Figure 3 shows the variation of the CO_2 molar fractions with temperature. It can be observed that the increase in temperature decreases the CO_2 content in the syngas.

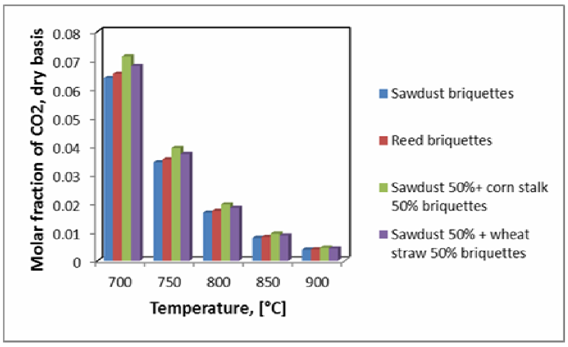

Fig. 3. *Variation of molar fractions of CO_2 with temperature*

Figure 4 shows the variation of the CO molar fractions with temperature.

The increase in temperature increases the CO content in the syngas. The highest content of the CO in the syngas was obtained by gasification of briquettes made from sawdust 50% + corn stalk 50%.

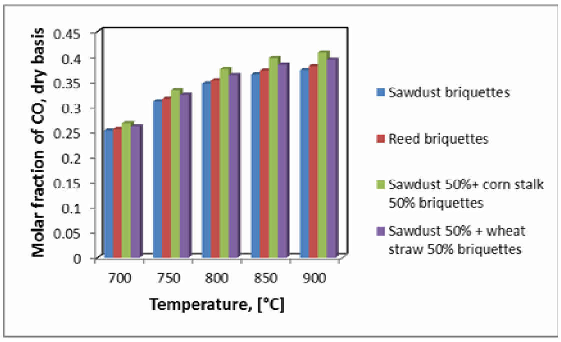

Fig. 4. *Variation of molar fractions of CO with temperature*

Figure 5 presents the variation of CH_4 with temperature. The molar fraction of CH_4 is very low and this decreases with the increase of the temperature. The highest concentration of CH_4 was obtained for gasification of sawdust 50%+wheat straw 50% briquettes.

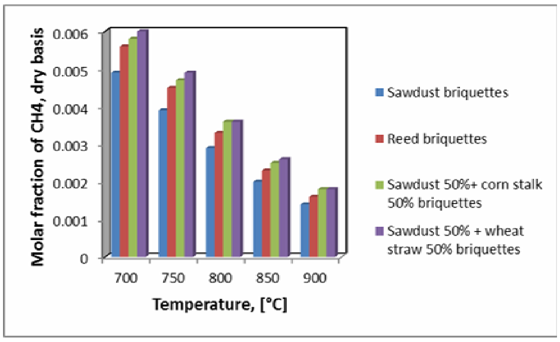

Fig. 5. *Variation of molar fractions of CH_4 with temperature*

5. Conclusions

The syngas composition is strongly influenced by temperature and excess air ratio. An increase in temperature resulted in an increase in the concentrations of H_2 and CO and a lower CO_2 production.

The highest content of the H_2 in the syngas was obtained by gasification of sawdust 50% + wheat straw 50% briquettes for an excess air ratio λ=0.18 and a temperature equivalent with 900°C. The minimum value of the H_2 molar fraction was obtained by gasification of sawdust briquettes for an excess air ratio λ=0.33 and a temperature equivalent with 700°C.

The highest contents of the CO and CO_2 in the syngas were obtained by gasification of briquettes made from sawdust 50% + corn stalk 50%.

The molar fraction of CH_4 is very low and this decreases with the increase of the temperature.

The lower heating value of the syngas was found to decrease with the increase in excess air ratio.

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