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A Study On The Feasibility Of Jatropha Husks And Jatopha Cake As Gasifier Feedstocks

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Abstract:

Jatropha husk and jatropha cake gasification were simulated in a downdraft gasifier whose performance was evaluated in terms of syngas heating value and gasifier efficiency at an equivalence ratio of 0.4 and gasification temperature from 800 to 1400K. H_2 composition increased from about 6% to 14%, CO_2 from about 8% to 14% while content of CH_4 decreased from about 0.6% to 0.008% while CO concentration reduced from about 21% to 15%, with gasification temperature increase. Maximum syngas heating values were 3119.1kJ/kg for jatropha cake and 2804.3kJ/kg for jatropha husks. Maximum heat conversion efficiencies of jatropha cake and jatropha husks were 70.4% and 73.4% respectively at 900K.

Introduction

Jatropha husks and cake are produced annually leaving their high energy content unexploited (Chandra et al., 2006). The husks have shown to be a successful feedstock for gasification, achieving similar results to wood (Vyas and Signh, 2007). Gasification is one of the major promising technology in which overall efficiencies can be more than 50%. Percentages of permanent gases such as CO_2, CH_4, H_2 and light hydrocarbons in the gaseous mixture depend on factors such as the gasification medium, the characteristics of the biomass, the heating rate, the temperature and the oxidizing medium amount (McKendry (2002). Syngas production from jatropha husks and jatropha cakes is studied in a downdraft air gasifier at an atmospheric pressure.

Methodology

The methodology involved a model formulation using both thermochemical equilibrium and exergy analyses of a gasifier performance. The biomass involved in the gasification is represented by Eq. (1) as:

$$CH_xO_yN_z + wH_2O + m(O_2 + 3.76N_2) \rightarrow n_{H_2}H_2 + n_{CO}CO + n_{CO_2}CO_2 + n_{H_2O}H_2O + n_{CH_4}CH_4 + (z/2 + 3.76m)N_2 \quad (1)$$

The amount of moisture per kmol of feedstock is w. The syngas mole fractions n_{CO}, n_{CO2}, n_{CH4}, n_{N2} and n_{H2} are determined by mole balancing from Eq. (1) in conjunction with methanation and water -gas shift equations. The heating value of a gas (LHV_{gas}) at 25^{o}C and 1 bar is obtained by Eq. 2 and values LHV_i are from Weber (2008):

$$LHV_{gas} = \sum \chi_i LHV_i \quad (2)$$

Exergy balance analysis yields exergy efficiency, η_{ex}, as in Eq. 3 (Kasembe et al. 2011):

$$\eta_{ex} = \frac{\varepsilon_{product}}{\varepsilon_{inputs}} = \frac{\varepsilon_{ch,gas} + \varepsilon_{ph,gas}}{\varepsilon_{ch,biomass} + \varepsilon_{ph,med}} \quad (3)$$

Results And Discussions

The Proximate And Ultimate Analysis

The physicochemical characteristics of the residues revealed that both have low moisture contents of less than 11% and their volatiles content (>50%) indicates their attractive potential for exploitation through gasification (McKendry, 2002). The jatropha husks' high heating value is 20.94 MJ/kg and that of the jatropha cake is 17.98MJ/kg.

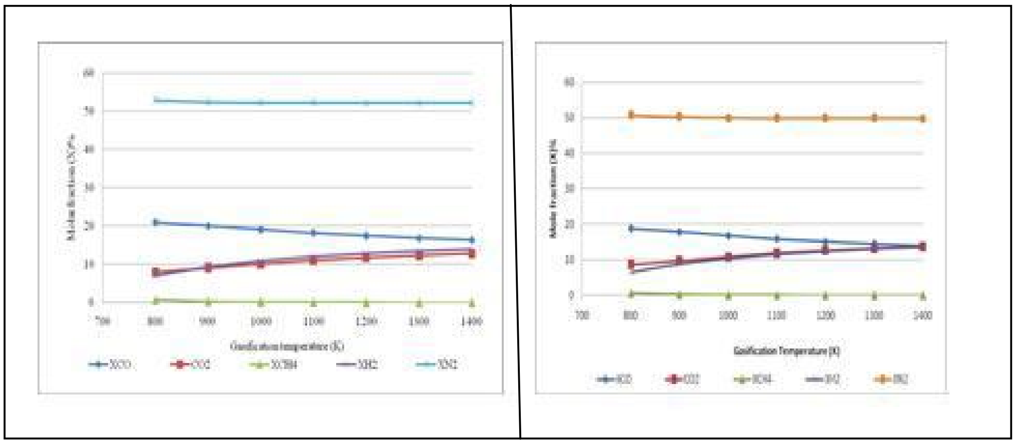
Biomass type	**Ultimate analysis (%), dry basis**				**Proximate analysis (%), dry basis**				**Biomass Formulae**
	C	**H**	**O**	**N**	**Moisture**	**Volatile matter (VM)**	**Fixed carbon (FC)**	**Ash**	$CH_xO_yN_z$
Jatropha cake	34.13	4.17	30.74	8.57	8.08	55.84	13.70	22.38	$CH_{1.06}O_{0.58}N_{0.16}$
Jatropha husks	33.75	4.12	30.36	11.21	10.73	55.07	13.65	20.55	$CH_{1.09}O_{0.59}N_{0.22}$

Table 1 : Proximate and ultimate analysis values for jatropha cake and jatropha husks

Effect Of Temperature On The Gas Products Distribution

Gasification modeling runs were performed by varying the temperature between 800K and 1400K and keeping the air equivalence ratio constant at 0.4. Gas composition from jatropha cake and jatropha husks is shown in Fig. 1. H_2 composition increases for both biomass materials from about 6% to 14% as the gasification temperature is increased due to water-gas shift reaction ($CO + H_2O \leftrightarrow CO_2 + H_2$) and the water-gas reaction ($C + H_2O \leftrightarrow CO + H_2$) where, H_2O and CO promotes H_2 via the water-gas shift reaction and water-gas reaction. The CH_4 concentration is reduced from about 0.6% to 0.008% as the temperature is increased. The CO_2 production is noted to increase from 8% to about 14% as the temperature is increased. CO concentration is reduced from about 21% to about 15%. The decrease in CO means a Bourdouard reaction shift increase CO_2.

The syngas from air gasification generally consists of a H_2/CO ratio< 1, which is suitable for combustion (Yung et al, 2009). In the present study, the produced syngas showed a ratio of H_2/CO varying between 0.3 and 0.97 which indicates that the produced gas is good for combustion.



(a) (b)

Figure 1:Temperature dependence on CO, CH_4, CO_2 and H_2 gases, ER 0.4 from (a)jatropha cake (b) jatropha husks

Effect Of Temperature On Heating Value Of Syngas And Gasification Efficiency

LHV of gas from both materials followed an increasing trend as temperature increased in the region between 800 and 900K, but above this temperature, an almost constant trend is observed. Jatropha cake and jatropha husks maximized their heating values at 900K which are 3119.1kJ/kg and 2804.3kJ/kg respectively. The thermodynamic gasifier efficiency defined according to Eq. (3). Fig. 2 depicts the gasifier efficiency of jatropha cake and jatropha husks at different against temperature. Jatropha cake maximizes their heat conversion efficiency 70.4% at 900K while efficiency of jatropha husks against temperature, at constant equivalent ratios reaches the value of 73.4% at 900K.

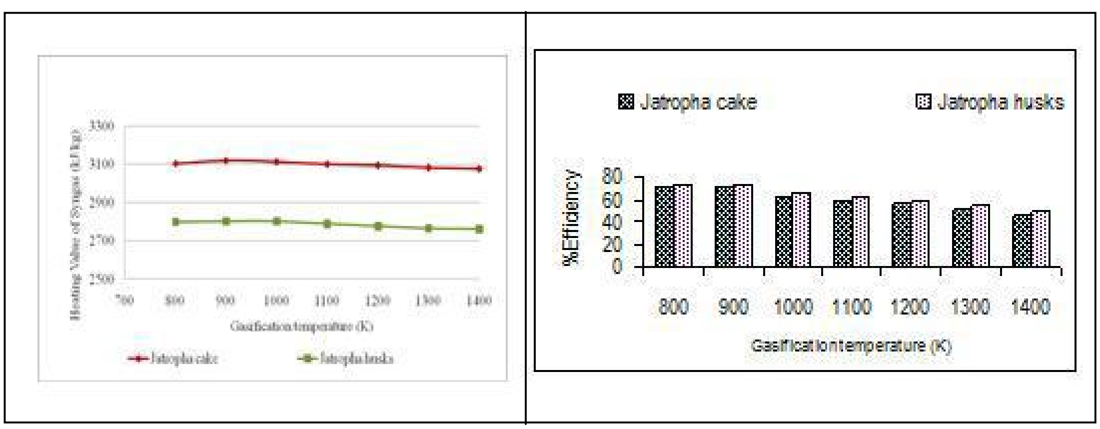


Figure 2: Effect of temperature on sygas heating values and efficiency values for jatropha cake and jatropha husks

Conclusion

- The biomass materials H_2 composition increases from about 6% to 14% with temperature while CH_4 decrease from about 0.6% to 0.008%. The CO_2 increases from 8% to about 14% with temperature, while CO reduces from about 21% to 15%.
- Maximum heating values are 3119.1kJ/kg for jatropha cake and 2804.3kJ/kg for jatropha husks which are considered to be medium heating value. Jatropha cake seemed to maximize their heat conversion efficiency at 70.4% while efficiency of jatropha husks reaches 73.4% at 900K.

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