DETERMINATION OF HIGHER HEATING VALUES (HHVS) OF BIOMASS FUELS

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Abstract

Current issues related to fuels can be grouped under four headings. Today world is facing three critical problems: (1) high fuel prices, (2) climatic changes, (3) air pollution, and [1] heating value. Higher Heating Value (HHV) is one of the most important properties of fuels which explain the higher energy content and determine the efficient use of biomass and fossil fuels. HHV comes to design calculations or numerical simulations of thermal conversion systems for fuels. There are numerous equations proposed in the literature for calculating the HHV of fuels from the basic analysis data. The proximate and ultimate analyses of fuels are necessary for their efficient and clean utilization while the HHV of fuels determine the quantitative energy content of fuels. The proximate analysis can be applied by using the simple lab equipments. The HHVs nine biomass samples were correlated with their lignin (L%) contents. There was a highly significant correlation between the HHVs and L% of the biomass samples. The HHV (MJ/kg) of the biomass sample as a function of the L was correlated using the following Equation: HHV = 0.0979L + 16.292
for which the square of the correlation coefficient (R^2) was 0.9321. The percentage of average error which was calculated using this Equation was equal to 3.3.

Keywords: Biomass fuel; Higher heating value (HHV); Proximate analysis; Ultimate analysis

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1. Introduction

Generally, the heating value of a fuel may be explained on two bases: as higher heating value or gross calorific value and lower heating value or net calorific value. The higher heating value (HHV) refers to the heat removed from fuel combustion with the original and generated water in a condensed state, while the lower heating value is based on gaseous water as a product. The higher heating values (HHVs) contain the latent heat of the water vapor products of combustion because the water vapor is allowed to condense to liquid water. The relationship between high and low heating values (HHV): A low heating value (LHV) is the correction to HHV due to moisture in the fuel (biomass) or water vapor formed during combustion of hydrogen in the fuel [2]. On the basis of literature values for, some equations were developed for estimating the HHVs of different fuels; such as vegetable oils, diesel fuels by using their chemical analysis data. Demirbas et al. [2] have developed four formulae for estimating the higher heating values of fuels from different lignocellulosics from their ultimate analysis data.

2. Experimental

Thirty equations proposed and applied for estimating the HHV of biomass fuels were collected from the literature and are summarized in Table 2 [2,13-20]. The equations are combined in two groups according to the approaches they use, i.e. estimating the HHV based on the proximate and ultimate analysis.

$$HHV = 0.196FC + 14.119 \quad (1)$$

for which the correlation coefficient was 0.9997.

Table 1. The equations available from literature for estimation higher heating value (HHV)

Model	Equation	Units	Reference
Models based on elemental analysis			
	HHV = 0.4373C ï 1.6701	MJ/kg	[7]
	HHV = C x 7527 + (1 - C) x 11,479	Btu/lb	[7]
	(C the fraction of wood consisting of holocellulose)		
	HHV = 188.0C ï 131.5	Btu/lb	[7]
	HHV = -0.763 + 0.301C + 0:525H + 0:064O	MJ/kg	[9]
	HHV = 8561.11 + 179.72H - 63.89S - 111.17O - 91.11Cl -66.94N	kcal/kg	[8]
	HHV = 83.22C + 274.3H - 25.8O +15N + 9.4Cl + 65P	kcal/kg	[8]
	HHV = 7831C_{org} + 35,932(H 2 O/8) + 2212S - 3545C_{inorg} + 1187O+578N	kcal/kg	[8]
	HHV = 33.5 (C) + 142.3 (H) ï 15.4 (O) ï 24.5N	MJ/kg	[12]
	HHV = 30.32C + 142.3H	MJ/kg	[11]
	(C carbon content, H hydrogen content of a diesel fuel)		
	HHV = 0.3259C + 3.4597	MJ/kg	[10]

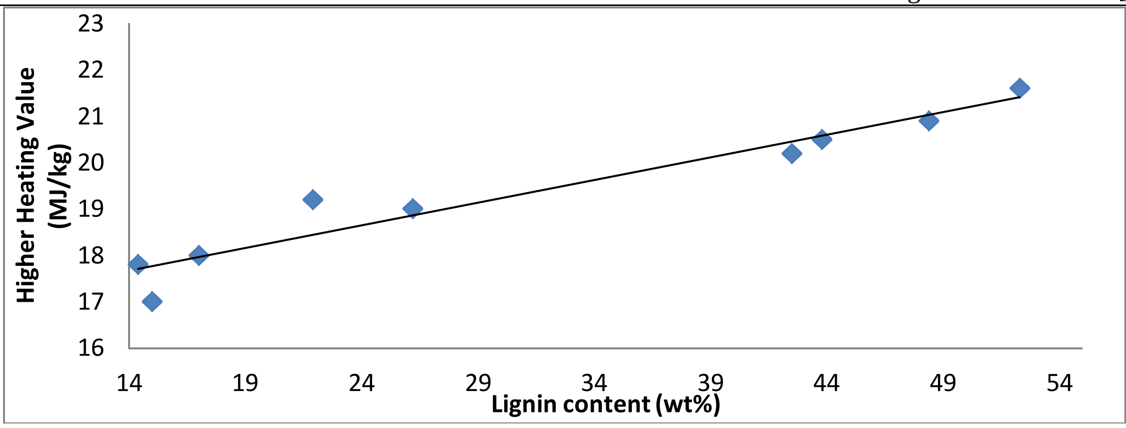

Fig. 1 Higher heating values versus lignin contents of biomass samples.

There was a highly significant correlation between the HHVs and L% of the biomass samples. The HHV (MJ/kg) of the biomass sample as a function of the L was correlated using the following Equation:

Table 2. Lignin content and higher heating values (HHVs) of biomass samples

Biomass sample	L (wt% dry basis)	HHV (MJ/kg, Measured) (wt% dry basis)	HHV (MJ/kg, Measured) (daf)	HHV (MJ/kg, Calculated)	Difference
Corn stover	14.4	17.8	18.5	17.7	-0.8
Corncob	15.0	17.0	17.2	17.8	+0.6
Sunflower shell	17.0	18.0	18.8	18.0	-0.8
Beech wood	21.9	19.2	19.5	18.4	-1.1
Ailanthus wood	26.2	19.0	19.4	18.9	-0.5
Hazelnut shell	42.5	20.2	20.5	20.1	-0.4
Wood bark	43.8	20.5	20.8	20.1	-0.7
Olive husk	48.4	20.9	21.6	21.0	-0.6
Walnut shell	52.3	21.6	22.2	21.4	-0.8

$$HHV = 0.0979L + 16.292 \qquad (5)$$

for which the square of the correlation coefficient (R^2) was 0.9321. The percentage of average error which was calculated using this Eq. (5) was equal to 3.3.

2. Conclusion

In this paper, starting from earlier pioneer works in the area of higher heating values, major contributions are summarized. Typical drawbacks of most of these equations are as follows [13-20]: (1) Analytical methods used for the determination of heating values and for elemental analyses are not fully reported, (2) the concepts of calibration errors (fit of given data) and prediction errors (application of models to new samples) are not considered, (3) the concept of latent variables is not used, nevertheless for instance; oxygen content is a variable in regression models although it is computed from the other features as the difference to 100% and (4) different writing of equations, typing errors, different rounding of coefficients and different units (kJ/kg, Btu/lb) make the comparison of models difficult.

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