

Number	Name of author	Correlation (HHV, MJ/kg)
<i>Based on proximate analysis</i>		
(1)	Jimenez and Gonzalez [5]	$\text{HHV} = -10.81408 + 0.3133(\text{VM} + \text{FC})$
(2)	Current authors	$\text{HHV} = 19.914 - 0.2324 \text{ Ash}$
(3)	Demirbas [7]	$\text{HHV} = 0.196^* \text{FC} + 14.119$
(4)	Demirbas [7]	$\text{HHV} = 0.312^* \text{FC} + 0.1534^* \text{VM}$
(5)	Cordero et al. [6]	$\text{HHV} = 0.3543^* \text{FC} + 0.1708^* \text{VM}$
(6)	Current authors	$\text{HHV} = -3.0368 + 0.2218 \text{VM} + 0.2601 \text{FC}$
<i>Based on ultimate analysis</i>		
(7)	Tillman [8]	$\text{HHV} = 0.4373 \text{C} - 1.6701$
(8)	Current authors	$\text{HHV} = 0.3259 \text{C} + 3.4597$
(9)	Boie [11]	$\text{HHV} = 0.3516 \text{C} + 1.16225 \text{H} - 0.1109 \text{O} + 0.0628 \text{N} + 0.10465 \text{S}$
(10)	IGT [9]	$\text{HHV} = 0.341 \text{C} + 1.322 \text{H} - 0.12 \text{O} - 0.12 \text{N} + 0.0686 \text{S} - 0.0153 \text{Ash}$
(11)	Graboski and Bain [10]	$\text{HHV} = 0.328 \text{C} + 1.4306 \text{H} - 0.0237 \text{N} + 0.0929 \text{S} - (1 - \text{Ash}/100)(40.11 \text{H}/\text{C}) + 0.3466$
(12)	Channiwala and Parikh [12]	$\text{HHV} = 0.3491 \text{C} + 1.1783 \text{H} + 0.1005 \text{S} - 0.1034 \text{O} - 0.0151 \text{N} - 0.0211 \text{Ash}$
(13)	Demirbas [7]	$\text{HHV} = 0.335 \text{C} + 1.423 \text{H} - 0.154 \text{O} - 0.145 \text{N}$
(14)	Jenkins [13]	$\text{HHV} = -0.763 + 0.301 \text{C} + 0.525 \text{H} + 0.064 \text{O}$
(15)	Current authors	$\text{HHV} = -1.3675 + 0.3137 \text{C} + 0.7009 \text{H} + 0.0318 \text{O}_{*b}$

^aBiomass composition, VM, FC, Ash, C, H, O, N, S are weight percent on dry biomass basis.

^bHere O* is the sum of the contents of oxygen and other elements (including S, N, Cl, etc.) in the organic matter, i.e. $\text{O}^* = 100 - \text{C} - \text{H} - \text{Ash}$.

^cCe, L, E are weight percent of cellulose (including cellulose and hemicellulose), lignin and extractives on dry biomass basis, respectively.

^dCe' is cellulose (cellulose and hemicellulose) on dry extractable-free basis.

^eHHV and L in this equation are on dry ash free and extractable-free bases.

Table 2

Summary of recent and established correlations used for predicting the HHV of biomass.

No.	Equation ^a	Based on	Unit	References
Eq. (16)	HHV = 19.914 – 0.2324Ash	Proximate analysis	MJ/kg	Sheng and Azevedo [2]
Eq. (17)	HHV = –3.0368 + 0.2218VM + 0.2601FC	Proximate analysis	MJ/kg	Sheng and Azevedo [2]
Eq. (18)	HHV = 0.3536FC + 0.1559VM – 0.0078Ash	Proximate analysis	MJ/kg	Parikh et al. [20]
Eq. (19)	HHV = 0.3259C + 3.4597	Ultimate analysis	MJ/kg	Sheng and Azevedo [2]
Eq. (20)	HHV = –1.3675 + 0.3137C + 0.7009H + 0.0318O ^b	Ultimate analysis	MJ/kg	Sheng and Azevedo [2]
Eq. (21)	HHV = 3.55C ² – 232C – 2230H + 51.2C * H + 131 N + 20,600	Ultimate analysis	kJ/kg	Friedl et al. [3]
Eq. (22)	HHV = 0.3491C + 1.1783H + 0.1005S – 0.1034O – 0.0151N – 0.0211 * Ash	Ultimate analysis	MJ/kg	Channiwala and Parikh [4]
Eq. (23)	HHV = 354.3FC + 170.8VM	Proximate analysis	kJ/kg	Cordero et al. [8]
Eq. (24)	HHV = 35,430 – 183.5VM – 354.3Ash	Proximate analysis	kJ/kg	Cordero et al. [8]
Eq. (25)	HHV = –10.8141 + 0.3133 (VM + FC)	Proximate analysis	MJ/kg	Jimenez and Gonzales [21]
Eq. (26)	HHV = –0.763 + 0.301C + 0.525H + 0.064O	Ultimate analysis	MJ/kg	Jenkins and Ebeling [22]
Eq. (27)	HHV = 0.4373C – 1.6701	Ultimate analysis	MJ/kg	Tillman [5]

^a Dry biomass basis (wt.%).^b O* is the sum of the contents of oxygen and other elements in the organic matter (O* = 100 – C – H – Ash).**Table 3**

Developed HHV correlations and their regression statistics.

No.	Equation	Based on	Unit	R ²	Adjusted R ²	Standard error	Significance F	p-Value
Eq. (28)	HHV = 0.1905VM + 0.2521FC	Proximate analysis	MJ/kg	0.9953	0.9714	1.3507	1.24 × 10 ^{–48}	Both variables < 0.05
Eq. (29)	HHV = 0.2949C + 0.8250H	Ultimate analysis	MJ/kg	0.9976	0.9737	0.9684	1.47 × 10 ^{–54}	Both variables < 0.05