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Short communication

Estimation of HHV of lignocellulosic biomass towards hierarchical cluster analysis by Euclidean's distance method

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ABSTRACT

A heuristic methodology to estimate higher heating values (HHV) based on a statistic tools, in particular, hierarchical cluster analysis, is disclosed in this paper. The correlation has been studied using data available in other documents, and as test samples were used biomasses from open sources or also from previously published works. The aim is to offer another fast and simple way to access the information regarding the higher heating value. The method was tuned for lignocellulosic biomass and have presented an average absolute error lower than 3% and marginal average bias error at just −0.52% indicating a good predictive capability.

1. Introduction

Presently, at a time where financial resources and when human resources are becoming scarce and time is also treasured assets, these should be spent and applied wisely and with frugality. When conducting preliminary or screening evaluations during a study, the resources should be kept as minimum as possible so that those can be applied later on the in the core of the research.

Biomass has been equated to suppress the expected depletion of fossil fuels. This feedstock benefits from while addressing the issues related to the lack of fuels to produce heat and electricity; biomass wastes can also be eliminated. Thus such sources can be envisaged as an inexpensive source of energy. The calorific value of the biomass depends on its chemical composition, moisture content, ashes amounts and its heating value [1].

This so-called heating value of biomass may be into two types, the higher heating value, and the lower heating value. The first one is defined by the heat released during combustion with the original and generated water in a condensed state. On the other hand, when water is considered a product of this particular oxidation reaction is referred as lower heating value (LHV) [2]. Such values can be determined experimentally employing an adiabatic bomb calorimeter while measuring the enthalpy change during a combustion reaction [2]. Although being a straightforward and accurate process, not all researcher have access to it [1], and outsourcing the analysis is sometimes expensive. As the elemental analysis is quite often accessed to determine the chemical composition of a sample, researchers with such information have developed empirical correlations between ultimate analysis and heating value to overcome the problem of performing the experimental measurement of heating values [2,3]. There are already many studies regarding the establishment of equations based upon the chemical composition to calculate approximately the heating values of the matter being considered. The primordial studies concerning this subject date back to the end of the 19th century, more precisely in 1880 [4], such correlation is often referred as the Dulong's formula [1]. With the resurgence interest on the use of biomass, essentially due to the biorefineries concept, a large of attention have been given to this predictive models, in particularly those applied to lignocellulosic feedstock. Most of the correlations have been widely reviewed over the years [2,4–6].

Herein we introduce a simple methodology to correlate chemical analysis with the approximated value of HHV based on a simple cluster analysis tool present in the most statistic software, by following some criteria. Like so, it can be possible to predict the HHV without spending so much time or research budget during preliminary and screening trials.

2. Materials and methods

2.1. Biomass reference database

The database used was retrieved from a previously published paper by Ahmad and Subawi [7]. Such database contains information regarding the chemical analysis and HHV from all types of biomass in particularly from the lignocellulosic one. Table 1 lists the 128 samples

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Table 1
Database used as database for correlation purposes [7]

Material	Chemical Composition (%)						HHV (MJ/kg)
	Ash	C	H	O	N	S	
Acetic acid	0.6	40	6.7	53.3	2.09	3.48	14.6
Acetone	0.6	62.1	10.3	27.6	4.28	7.38	30.9
Acetylene	0	92.3	7.8	n/a	n/a	n/a	49.6
Alabama Oakwood waste	3.3	49.5	5.7	41.3	0.2	n/a	19.23
Almond	2.17	46.6	5.85	43.9	0.83	n/a	19.03
Almond prunings	1.6	51.3	5.3	40.9	0.66	0.01	20.01
Bagasse	2.9	43.8	5.8	47.1	0.4	0	16.29
Beech	0.7	51.6	6.3	41.4	n/a	n/a	20.38
Benzene	0	92.3	7.8	n/a	n/a	n/a	41.79
Black locust	0.8	50.7	5.7	41.9	0.57	0.01	19.71
Black walnut prunings	0.8	49.8	5.8	43.4	0.22	0.01	19.83
BOM wood oil	0.7	82	8.8	9.2	0.6	n/a	36.8
Brown kelp, soquel point	42.1	27.8	3.8	23.7	4.63	1.05	10.75
Cabernet Sauvignon	0.7	48.2	6.25	43.24	1.61	n/a	19.97
Canyonlive Oak	0.36	50.6	5.98	42.88	0.05	n/a	20.72
Carbon	0	100	n/a	n/a	0	0	32.81
Carbondioxide	0	27.3	n/a	72.7	0	0	9.45
Carbonmonoxide	0	42.9	n/a	57.1	n/a	n/a	10.16
Casuarina	1.8	48.5	6	43.3	0.31	n/a	18.77
Casuarina char (950 °C)	13.2	77.5	0.9	5.6	2.67	n/a	27.12
Cellulose	16.2	44.4	6.2	49.4	0	0	17.68
Charcoal	1	92	2.5	3	0.53	1	34.39
Charcoal	7.61	89.1	0.43	0.98	0.85	1	31.12
Coal	8.4	82.6	3.02	3.66	0.92	0.73	33
Coal Pittsburgh seam	10.3	75.5	5	4.9	1.2	3.1	31.75
Coal sample	4.5	63.9	4.97	24.54	0.57	0.48	25.1
Coconut coir	0.9	47.6	5.7	45.6	0.2	0	14.67
Coconut coir	3.72	50.2	5.05	39.63	0.45	0.16	20.05
Coconut shell	0.7	50.2	5.7	43.4	n/a	0	20.5
Coconut shell char (750 °C)	2.9	89	0.7	6	1.38	n/a	31.12
Coconut shell charn (750 °C)	2.9	88.9	0.73	6.04	1.38	n/a	31.12
Coir pith	7.1	44	4.7	43.4	0.7	0	18.07
Coke oven tar	0.3	91.8	5.5	0.8	0.9	0.8	38.2
Corn cob	2.8	47.6	5	44.6	n/a	0	15.65
Corn cobs	1.4	46.6	5.9	45.5	0.47	0.01	18.77
Corn stalks	6.8	41.9	5.3	46	n/a	0	16.54
Corn stover	5.6	43.6	5.6	43.3	0.61	0.01	17.65
Corncob	1	49	5.4	44.6	0.4	n/a	17
Corncob	0.1	48.1	5.99	45.74	0.08	0.01	19.92
Cotton stalk	6.7	43.6	5.8	43.9	n/a	n/a	18.26
Cotton stalk	17.3	39.4	5.07	39.14	1.2	0.02	15.83
Cottongin trash	17.6	39.6	5.3	36.4	2.09	n/a	16.42
Cottongin trash	17.6	39.5	5.26	36.38	2.09	n/a	16.42
Cottongin waste	5.4	42.7	6	49.5	0.1	0	17.48
Cottongin waste	1.61	42.6	6.05	49.5	0.18	n/a	17.48
Cottonshells	18.1	37.2	5.34	33.38	5.95	n/a	15.53
Dallake weed	48.7	19.1	2	25.96	4.22	n/a	8.89
Dn/aglucose	0.2	40	6.7	53.3	6.7	3.72	15.6
Douglas fir	0.8	52.3	6.3	40.5	0.1	n/a	21.05
Douglas Fir	0.4	56.3	5.6	37.7	n/a	n/a	21.77
Douglass fir bark	1.2	56.2	5.9	36.7	n/a	n/a	22.1
EsC700	1.9	92.7	1.6	3.3	0.4	n/a	32.2
Ethanol	0	52.2	13	34.8	n/a	n/a	30.15
Eucalyptus	0.52	48.3	5.89	45.13	0.15	0.01	19.35
Eucalyptus camaldulensis	0.8	49	5.9	44	0.3	0.01	19.42
Eucalyptus char (950 °C)	10.5	76.1	1.3	11.1	1.02	n/a	27.6
Eucalyptus sawdust	0.2	49.3	6.4	42.01	2.02	n/a	18.5
Eucalyptusn/aGrandis	8.65	44.6	5.35	39.18	1.21	n/a	17.39
Eucatlyptus bark	1.63	51.3	5.29	40.9	0.66	0.04	20.01
Groundnut shell	5.9	48.3	5.7	39.4	0.8		18.65
Hickory	0.7	47.7	6.5	43.1	n/a	n/a	20.17
Kerosene	0	85.8	14.1	n/a	n/a	0.1	46.5
L14	1.02	92	2.45	2.96	0.53	1	34.39
LBL wood oil	0.8	72.3	8.6	17.6	0.2	0.01	33.7
Lignin (softwood)	0	63.8	6.3	29.9	0	0	26.6
Lignin(hardwood)	0	59.8	6.4	33.7	0	0	24.93
Loblolly pinebark	0.4	56.3	5.6	37.7	n/a	n/a	21.78
Low temp tar	0	83	8.2	7.4	0.6	0.8	38.75
Macadamia shell	1.13	48.8	5.91	43.41	0.56	0.01	19.26
Madrone	0.2	48.9	6	44.8	0.05	0.02	19.51
Mango wood	3	46.2	6.1	44.4	0.28	0	19.17
Maple	1.4	50.6	6	41.7	0.25	n/a	19.96
Methanol	0	37.5	12.5	50	n/a	n/a	22.69
Millet husk	18.1	42.7	6	33	0.1	0	17.48
Motor gasoline	0	85.5	14.4	n/a	n/a	0.1	46.88
Mulberry stick	2.1	44.2	6.61	46.25	0.51	n/a	18.36
N-octane	0	84.1	15.9	n/a	n/a	n/a	47.8
Northumberland No.8-Anth.	8.32	83.7	3.56	2.84	0.55	1.05	32.86
Oak char (565 °C)	17.3	64.6	2.1	15.5	0.4	0.1	23.05
Oak char-820-1185°F	14.9	67.7	2.4	14.4	0.4	0.2	24.8
Paddy straw	15.5	36	5.28	43.08	0.17	n/a	14.52
Peach pits	1	53	5.9	39.1	0.32	0.05	20.82
PeachPit	0.4	54.4	4.99	39.69	0.36	0.01	21.01
Peat S-H3	3	54.8	5.4	35.8	0.89	0.11	22
PhC300	0.6	57.8	5	36.5	0.2	n/a	22.84
Phenol	0.9	76.6	6.4	17	7.3	7.76	32.5
Pine needles	1.5	48.2	6.6	43.7	0	0	20.12
Pinewood	1.2	48.2	5.87	44.75	0.03	n/a	19.78
Pistachio shell	1.4	52.9	5.6	42.7	1.4	n/a	19.3
Plywood	2.1	48.1	5.9	42.5	1.45	n/a	18.96
Plywood	1.1	49.1	6.34	43.52	0.48	0.02	19.42
Ponderosa pine	0.3	49.2	6	44.4	0.06	0.03	20.02
Poplar	1.3	48.5	5.9	43.7	0.47	0.01	19.38
Poplar	0.7	51.6	6.3	41.5	n/a	n/a	20.75
Pressmud briquettes	2.09	46.9	6.07	43.99	0.95	n/a	18.26
QrC550	3.1	87.1	2.4	6.9	0.5	n/a	32.72
Red alder	0.4	49.6	6.1	43.8	0.13	0.07	19.3
Redwood	0.4	53.5	5.9	40.3	0.1	n/a	21.03
Redwood	1.7	52.1	6.1	41	0.2	n/a	20
Redwood char-790-1020°F	2.3	75.6	3.3	18.4	0.2	0.2	28.84
Rice hulls	20.6	38.3	4.4	35.5	0.83	0.06	14.89
Rice husk	23.5	38.9	5.1	32	0.6	0	15.29
Rice straw	19.8	36.9	5	37.9	0.4	0	16.78
Salseed husk	9.4	48.1	6.55	35.93	n/a	n/a	20.6
Sena leaves	17.3	36.2	4.72	37.49	4.29	n/a	18.13
Softwood	1.5	51.9	6.1	40.9	0.3	n/a	20.1
Spire-mint	1.36	46.6	5.87	45.46	0.47	0.01	18.77
Spruce wood	0.1	47.3	6	46.5	0.1	n/a	20.08
Subabul	1.2	56.2	5.9	36.7	n/a	n/a	22.1
Subabul wood	0.9	48.2	5.9	45.1	n/a	0	19.78
Subabul wood	3.35	46	5.82	44.49	0.3	0.01	18.64
Sudan grass	8.7	44.6	5.4	39.2	1.21	0.01	17.39
Sugarcane baggase	11.3	44.8	5.4	39.6	0.38	0.01	17.33
Sugarcane leaves	7.7	39.7	5.55	46.82	0.17	n/a	17.41
Tan Oak	0.2	48.6	6.03	44.99	0.06	0.04	18.93
Tea bush	1.7	47.6	6.13	43.16	1.33	n/a	19.84
Teawaste	1.4	48.6	5.5	39.5	0.5	n/a	17.1
Walnut shells	0.6	50	5.7	43.4	0.21	0.01	20.18
Water hyacinth	19.6	40.3	4.6	34	1.51	n/a	14.86
WesternHemcock	2.2	50.4	5.8	41.1	0.1	0.1	20.05
Wheat straw	11.2	47.5	5.4	35.8	0.1	0	17.99
Wheat straw	8.9	43.2	5	39.4	0.61	0.11	17.51
Wheat straw	13.5	45.5	5.1	34.1	1.8	n/a	17
White fir	0.3	49	6	44.8	0.05	0.01	19.95
White Fir	0.25	49	5.98	44.75	0.05	0.01	19.95
White oak	1.5	49.5	5.4	43.1	0.35	0.01	19.42
Wood Chips	0.5	47.8	5.8	45.76	0.07	0.03	18.98
Yellow pine	1.3	52.6	7	40.1	n/a	n/a	22.3

considered for this study.

2.2. Studies biomass database

The Information needed about the 100 samples of the biomass used for estimation of HHV and further comparison with the value experimentally determined, was taken from various authors or databases [1,6,8,9].