Bioenergy feedstock characteristics

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Summary

Biomass feedstocks and fuels exhibit a wide range of physical, chemical, and agricultural/ process engineering properties. Despite their wide range of possible sources, biomass feedstocks are remarkably uniform in many of their fuel properties, compared with competing feedstocks such as coal or petroleum. For example, there are many kinds of coals whose gross heating value ranges from 20 to 30 GJ/tonne (gigajoules per metric tonne; 8600-12900 Btu/lb). However, nearly all kinds of biomass feedstocks destined for combustion fall in the range 15-19 GJ/tonne (6450-8200 Btu/lb). For most agricultural residues, the heating values are even more uniform – about 15-17 GJ/tonne (6450-7300 Btu/lb); the values for most woody materials are 18-19 GJ/tonne (7750-8200 Btu/lb). Moisture content is probably the most important determinant of heating value. Air-dried biomass typically has about 15-20% moisture, whereas the moisture content for oven-dried biomass is around 0%. Moisture content is also an important characteristic of coals, varying in the range 2-30%. However, the bulk density (and hence energy density) of most biomass feedstocks is generally low, even after densification – between about 10 and 40% of the bulk density of most fossil fuels – although liquid biofuels have comparable bulk densities.

Most biomass materials are easier to gasify than coal, because they are more reactive, with higher ignition stability. This characteristic also makes them easier to process thermochemically into higher-value fuels such as methanol or hydrogen. Ash content is typically lower than for most coals, and sulphur content is much lower than for many fossil fuels. Unlike coal ash, which may contain toxic metals and other trace contaminants, biomass ash may be used as a soil amendment to help replenish nutrients removed by harvest. A few biomass feedstocks stand out for their peculiar properties, such as high silicon or alkali metal contents – these may require special precautions for harvesting, processing and combustion equipment. Note also that mineral content can vary as a function of soil type and the timing of feedstock harvest. In contrast to their fairly uniform physical properties, biomass fuels are rather heterogeneous with respect to their chemical elemental composition.

Among the liquid biomass fuels, biodiesel (vegetable oil ester) is noteworthy for its similarity to petroleum-derived diesel fuel, apart from its negligible sulfur and ash content. Bioethanol has only about 70% the heating value of petroleum distillates such as gasoline, but its sulfur and ash contents are also very low. Both of these liquid fuels have lower vapor pressure and flammability than their petroleum-based competitors – an advantage in some cases (e.g. use in confined spaces such as mines) but a disadvantage in others (e.g. engine starting at cold temperatures).

The table overleaf shows some "typical" values, in many cases a typical range of values, for selected compositional, chemical and physical properties of biomass feedstocks and liquid biofuels. Figures for fossil fuels are provided for comparison.

Sources for further information:

US DOE Biofuels Program database: http://www.ott.doe.gov/biofuels/properties_database.html
PHYLLIS - database on composition of biomass and waste: http://www.ecn.nl/phyllis/
European Agriculture and Forestry Biomass Network: http://www.vtt.fi/virtual/afbnet/
Nordin, A. (1994) Chemical elemental characteristics of biomass fuels. *Biomass and Bioenergy* 6, 339-347.

Selected "typical" properties of certain common bioenergy feedstocks and biofuels, compared with coal and oil
N/A = not applicable

		COMPOSITION			CHEMICAL CHARACTERISTICS					PHYSICAL CHARACTERISTICS		
		cellulose (%)	hemi-cellulose (%)	lignin (%)	heating value (gross, unless specified; GJ/t)	ash (%)	sulfur (%)	potassium (%)	Ash melting temperature [some ash sintering observed] (C)	Cellulose fiber length (mm)	Chopped density at harvest (kg/m^3)	Baled density [compacted bales] (kg/m^3)
Bioenergy Feedstocks	**corn stover**	35	28	16-21	17.6	5.6				1.5		
	sweet sorghum	27	25	11	15.4	5.5						
	sugarcane bagasse	32-48	19-24	23-32	18.1	3.2-5.5	0.10-0.15	0.73-0.97		1.7	50-75	
	sugarcane leaves				17.4	7.7					25-40	
	hardwood	45	30	20	20.5	0.45	0.009	0.04	[900]	1.2		
	softwood	42	21	26	19.6	0.3	0.01					
	hybrid poplar	42-56	18-25	21-23	19.0	0.5-1.5	0.03	0.3	1350	1-1.4	150 (chips)	
	bamboo	41-49	24-28	24-26	18.5-19.4	0.8-2.5	0.03-0.05	0.15-0.50		1.5-3.2		
	switchgrass	44-51	42-50?	13-20	18.3	4.5-5.8	0.12		1016		108	105-133
	miscanthus	44	24	17	17.1-19.4	1.5-4.5	0.1	0.37-1.12	1090 [600]		70-100	130-150 [300]
	Arundo donax	31	30	21	17.1	5-6	0.07			1.2		
												(typical bulk densities or range given below)
Liquid Biofuels	**bioethanol**	N/A	N/A	N/A	28		<0.01		N/A	N/A	N/A	790
	biodiesel	N/A	N/A	N/A	40	<0.02	<0.05	<0.0001	N/A	N/A	N/A	875
Fossil Fuels	**Coal (low rank; lignite/sub-bituminous)**	N/A	N/A	N/A	15-19	5-20	1.0-3.0	0.02-0.3	~1300	N/A	N/A	700
	Coal (high rank; bituminous/ anthracite)	N/A	N/A	N/A	27-30	1-10	0.5-1.5	0.06-0.15	~1300	N/A	N/A	850
	Oil (typical distillate)	N/A	N/A	N/A	42-45	0.5-1.5	0.2-1.2		N/A	N/A	N/A	700-900