Programme Area: Bioenergy

Project: Characterisation of Feedstocks

Title: D6 Final Report (Phase 1) Appendix 11

Abstract:

The primary objective of this 2015/16/17 Project was to provide an understanding of UK produced biomass properties, how these vary and what causes this variability.

This document is one of the appendices to the Final Report from the first Phase (2015/16) of the Characterisation of Feedstocks (CofF) project, Deliverable D6. D6 is provided in a number of parts consisting of the main body text plus 13 Appendices, provided in 17 files. These 13 appendices are provided in 12 pdf files plus 46 data files in Microsoft Excel format. The purpose of this report plus its related parts is to report the variability in feedstock properties of UK produced energy biomass, the causes of these variations and the relationship between the feedstock properties and the provenance data collected. Five feedstocks were studied: Miscanthus, willow short rotation coppice (SRC), poplar SRC, poplar grown as short rotation forests (SRF), and spruce SRF, with poplar and Sitka spruce selected to represent broadleaved and coniferous biomass crops respectively. Provenance data include site properties (such as general climate zone and soil chemistry), the conditions at the time of sample collection, and past management of the site and crop with soil samples also collected for analysis. The feedstock samples were analysed in UKAS accredited laboratories.

Context:

The Characterisation of Feedstocks project provides an understanding of UK produced 2nd generation energy biomass properties, how these vary and what causes this variability. In this project, several types of UK-grown biomass, produced under varying conditions, were sampled. The biomass sampled included Miscanthus, Short Rotation Forestry (SRF) and Short Rotation Coppice (SRC) Willow. The samples were tested to an agreed schedule in an accredited laboratory. The results were analysed against the planting, growing, harvesting and storage conditions (i.e. the provenance) to understand what impacts different production and storage methods have on the biomass properties. The main outcome of this project is a better understanding of the key characteristics of UK biomass feedstocks (focusing on second generation) relevant in downstream energy conversion applications, and how these characteristics vary by provenance.

Appendix 11: Null Hypothesis Tables

*Note * indicates analysis not undertaken as discussed in relevant section in D6*

Miscanthus

Variable	Planting density	Year of planting	Age of sampled stems
Moisture (ar)	*	0.083	*
Net calorific value (ar)	*	-0.083	*
Ash content (d)	*	0.518	*
Volatile matter (DAF)	*	-0.084	*
Gross calorific value (DAF)	*	0.147	*
Carbon (DAF)	*	-0.185	*
Hydrogen (DAF)	*	-0.209	*
Nitrogen (DAF)	*	-0.112	*
Sulphur (DAF)	*	0.000	*
Chlorine (DAF)	*	-0.302	*
Barium (d)	*	0.344	*
Chromium (d)	*	0.364	*
Cobalt (d)	*	0.414	*
Copper (d)	*	0.416	*
Molybdenum (d)	*	0.434	*
Nickel (d)	*	0.355	*
Vanadium (d)	*	0.323	*
Zinc (d)	*	0.197	*
Antimony (d)	*	0.921	*
Arsenic (d)	*	0.763	*
Mercury (d)	*	-0.726	*
Bromine (d)	*	0.410	*
Cadmium (d)	*	0.873	*
Lead (d)	*	-0.327	*
Al_2O_3 (na)	*	0.452	*
BaO (na)	*	0.196	*
$CaCO_3$ (na)	*	-0.498	*
Fe_2O_3 (na)	*	0.143	*
K_2O (na)	*	0.341	*
MgO (na)	*	-0.197	*
Mn_3O_4 (na)	*	0.111	*
Na_2O (na)	*	-0.231	*
P_2O_5 (na)	*	-0.280	*
SiO_2 (na)	*	0.251	*
TiO_2 (na)	*	-0.007	*
Aluminium (d)	*	0.570	*
Calcium (d)	*	-0.072	*
Iron (d)	*	0.341	*

Variable	Planting density	Year of planting	Age of sampled stems
Potassium (d)	*	0.491	*
Magnesium (d)	*	0.258	*
Manganese (d)	*	0.333	*
Sodium (d)	*	0.126	*
Phosphorous (d)	*	0.219	*
Silicon (d)	*	0.377	*
Titanium (d)	*	0.165	*
Alkali index	*	0.491	*

Willow SRC

Variable	Planting density	Year of planting	Age of sampled stems
Moisture (ar)	*	0.638	-0.265
Net calorific value (ar)	*	-0.580	0.000
Ash content (d)	*	0.353	-0.627
Volatile matter (DAF)	*	-0.145	0.677
Gross calorific value (DAF)	*	-0.290	-0.500
Carbon (DAF)	*	0.232	-0.853
Hydrogen (DAF)	*	-0.058	0.765
Nitrogen (DAF)	*	-0.087	-0.736
Sulphur (DAF)	*	0.735	-0.320
Chlorine (DAF)	*	0.364	-0.431
Barium (d)	*	-0.406	-0.324
Chromium (d)	*	0.174	-0.500
Cobalt (d)	*	-0.677	-0.493
Copper (d)	*	0.406	-0.441
Molybdenum (d)	*	0.427	-0.433
Nickel (d)	*	0.493	0.324
Vanadium (d)	*	0.348	-0.559
Zinc (d)	*	0.290	0.441
Antimony (d)	*	1.000	-0.500
Arsenic (d)	*	1.000	-0.500
Mercury (d)	*	-1.000	0.500
Bromine (d)	*	0.500	-1.000
Cadmium (d)	*	0.400	-0.462
Lead (d)	*	0.200	0.667
Al_2O_3 (na)	*	0.290	-0.441
BaO (na)	*	-0.224	-0.227
$CaCO_3$ (na)	*	-0.029	0.883
Fe_2O_3 (na)	*	-0.174	-0.647
K_2O (na)	*	0.319	-0.971
MgO (na)	*	-0.551	-0.471
Mn_3O_4 (na)	*	-0.464	-0.147
Na_2O (na)	*	-0.812	-0.177
P_2O_5 (na)	*	-0.118	-0.567

SiO$_2$ (na)	*	0.348	-0.677
TiO$_2$ (na)	*	0.370	0.375
Aluminium (d)	*	0.406	-0.441
Calcium (d)	*	0.348	-0.559
Iron (d)	*	-0.087	-0.736
Potassium (d)	*	0.058	-0.883
Magnesium (d)	*	-0.232	-0.795
Manganese (d)	*	-0.580	-0.530
Sodium (d)	*	-0.754	-0.029
Phosphorous (d)	*	0.058	-0.883
Silicon (d)	*	0.348	-0.677
Titanium (d)	*	0.551	0.029
Alkali index	*	0.058	-0.883

Poplar SRF

Variable	Trunk			Tops/branches		
	Planting density	Year of planting	Age of sampled stems	Planting density	Year of planting	Age of sampled stems
Moisture (ar)	-0.191	*	0.456	-0.069	*	0.037
Net calorific value (ar)	0.184	*	-0.457	0.103	*	-0.035
Ash content (d)	0.224	*	0.168	0.005	*	-0.179
Volatile matter (DAF)	-0.256	*	-0.263	-0.078	*	0.138
Gross calorific value (DAF)	-0.066	*	0.233	0.194	*	0.036
Carbon (DAF)	0.072	*	-0.167	0.159	*	0.095
Hydrogen (DAF)	0.048	*	-0.108	-0.006	*	-0.182
Nitrogen (DAF)	0.275	*	-0.070	0.091	*	-0.502
Sulphur (DAF)	*	*	*	0.148	*	-0.209
Chlorine (DAF)	-0.287	*	0.124	0.067	*	0.082
Barium (d)	-0.258	*	0.180	-0.418	*	0.200
Chromium (d)	-0.191	*	-0.095	-0.277	*	-0.051
Cobalt (d)	0.361	*	0.026	0.225	*	-0.023
Copper (d)	-0.100	*	-0.193	0.283	*	-0.263
Molybdenum (d)	-0.106	*	0.193	-0.199	*	-0.056
Nickel (d)	-0.016	*	-0.189	0.061	*	-0.259
Vanadium (d)	0.236	*	-0.122	-0.134	*	-0.020
Zinc (d)	0.169	*	0.022	-0.002	*	-0.005
Antimony (d)	0.484	*	0.426	-0.122	*	0.000
Arsenic (d)	0.484	*	0.426	-0.264	*	0.360
Mercury (d)	-0.021	*	0.222	-0.399	*	0.228
Bromine (d)	-0.013	*	0.337	0.341	*	0.138
Cadmium (d)	-0.193	*	-0.454	0.028	*	-0.210
Lead (d)	-0.057	*	0.054	-0.150	*	0.114
Al_2O_3 (na)	-0.184	*	-0.203	-0.055	*	0.309

BaO (na)	-0.340	*	0.207	-0.323	*	0.261
CaCO$_3$ (na)	-0.381	*	-0.073	-0.258	*	-0.107
Fe$_2$O$_3$ (na)	-0.134	*	0.201	0.153	*	0.317
K$_2$O (na)	0.302	*	0.254	-0.071	*	-0.131
MgO (na)	0.094	*	0.279	0.465	*	0.217
Mn$_3$O$_4$ (na)	0.044	*	0.330	0.043	*	0.259
Na$_2$O (na)	-0.077	*	0.357	-0.162	*	0.054
P$_2$O$_5$ (na)	-0.146	*	-0.287	0.267	*	0.019
SiO$_2$ (na)	-0.077	*	0.048	-0.122	*	0.319
TiO$_2$ (na)	-0.079	*	-0.162	-0.052	*	0.024
Aluminium (d)	-0.097	*	-0.220	-0.103	*	0.172
Calcium (d)	0.038	*	0.059	-0.198	*	-0.182
Iron (d)	-0.035	*	0.144	0.162	*	0.240
Potassium (d)	0.385	*	0.171	-0.087	*	-0.182
Magnesium (d)	0.249	*	0.196	0.337	*	0.037
Manganese (d)	0.227	*	0.206	-0.024	*	0.165
Sodium (d)	0.090	*	0.241	-0.298	*	-0.021
Phosphorous (d)	0.262	*	-0.221	0.171	*	-0.098
Silicon (d)	-0.037	*	0.059	-0.184	*	0.280
Titanium (d)	-0.174	*	-0.230	-0.090	*	-0.128
Alkali index	0.388	*	0.149	-0.095	*	-0.219

Spruce SRF

Variable	Trunk wood			Tops			Bark		
	Planting density	Year of planting	Age of sampled stems	Planting density	Year of planting	Age of sampled stems	Planting density	Year of planting	Age of sampled stems
Moisture (ar)	0.016	*	-0.003	0.620	*	0.291	0.627	*	0.290
Net calorific value (ar)	-0.010	*	0.012	-0.611	*	-0.315	-0.643	*	-0.394
Ash content (d)	-0.221	*	-0.140	0.625	*	0.803	0.663	*	0.647
Volatile matter (DAF)	0.085	*	0.062	-0.736	*	-0.631	-0.472	*	-0.455
Gross calorific value (DAF)	-0.202	*	-0.237	0.068	*	0.163	-0.413	*	-0.450
Carbon (DAF)	0.167	*	0.121	0.342	*	0.302	-0.342	*	-0.228
Hydrogen (DAF)	-0.204	*	-0.033	-0.028	*	0.072	-0.661	*	-0.545
Nitrogen (DAF)	-0.087	*	0.009	0.718	*	0.715	0.008	*	0.180
Sulphur (DAF)	*	*	*	0.476	*	0.444	0.165	*	0.101
Chlorine (DAF)	-0.044	*	0.069	0.359	*	0.378	0.283	*	0.468
Barium (d)	-0.712	*	-0.495	-0.417	*	-0.032	-0.304	*	-0.064
Chromium (d)	-0.276	*	-0.367	0.147	*	0.337	0.071	*	-0.083
Cobalt (d)	-0.348	*	-0.128	0.524	*	0.729	0.593	*	0.613
Copper (d)	-0.517	*	-0.414	0.727	*	0.581	0.525	*	0.284
Molybdenum (d)	-0.399	*	-0.285	0.611	*	0.787	0.593	*	0.613
Nickel (d)	-0.460	*	-0.347	-0.205	*	-0.065	-0.398	*	-0.327
Vanadium (d)	-0.176	*	-0.188	-0.260	*	-0.080	0.102	*	-0.125
Zinc (d)	-0.561	*	-0.554	0.624	*	0.531	0.525	*	0.436
Antimony (d)	0.000	*	-0.237	0.125	*	-0.069	0.188	*	0.529
Arsenic (d)	0.207	*	-0.248	0.382	*	0.546	0.346	*	0.751
Mercury (d)	-0.354	*	0.000	-0.120	*	0.440	0.742	*	0.351
Bromine (d)	-0.077	*	0.000	0.309	*	0.154	0.000	*	-0.463
Cadmium (d)	0.266	*	0.247	0.725	*	0.544	-0.131	*	-0.013
Lead (d)	0.045	*	-0.066	-0.065	*	-0.277	-0.180	*	-0.130
Al$_2$O$_3$ (na)	-0.234	*	0.020	-0.020	*	-0.046	0.252	*	0.147

BaO (na)	-0.338	*	-0.030	-0.576	*	-0.265	-0.305	*	-0.072
CaCO$_3$ (na)	-0.258	*	0.098	-0.452	*	-0.141	-0.020	*	0.121
Fe$_2$O$_3$ (na)	-0.003	*	-0.160	-0.213	*	-0.408	-0.276	*	-0.142
K$_2$O (na)	0.443	*	0.097	0.046	*	-0.303	0.110	*	-0.166
MgO (na)	-0.017	*	-0.130	-0.115	*	-0.424	-0.299	*	-0.300
Mn$_3$O$_4$ (na)	0.099	*	0.321	0.113	*	0.317	-0.340	*	-0.203
Na$_2$O (na)	0.327	*	0.115	0.189	*	-0.001	0.351	*	0.601
P$_2$O$_5$ (na)	-0.360	*	-0.389	-0.130	*	-0.493	-0.337	*	-0.456
SiO$_2$ (na)	0.136	*	-0.031	0.123	*	0.420	0.295	*	0.469
TiO$_2$ (na)	-0.070	*	-0.279	-0.210	*	-0.088	0.303	*	0.135
Aluminium (d)	-0.294	*	0.029	0.200	*	0.327	0.430	*	0.333
Calcium (d)	-0.292	*	-0.123	0.034	*	0.421	0.302	*	0.440
Iron (d)	-0.151	*	-0.232	-0.170	*	-0.220	-0.156	*	0.002
Potassium (d)	-0.053	*	-0.171	0.291	*	0.206	0.190	*	0.007
Magnesium (d)	-0.331	*	-0.309	0.207	*	0.147	-0.115	*	-0.062
Manganese (d)	-0.179	*	0.125	0.174	*	0.412	-0.269	*	-0.086
Sodium (d)	0.058	*	-0.089	0.484	*	0.430	0.411	*	0.587
Phosphorous (d)	-0.361	*	-0.354	0.238	*	-0.168	-0.185	*	-0.324
Silicon (d)	-0.060	*	-0.195	0.290	*	0.656	0.398	*	0.596
Titanium (d)	0.001	*	-0.164	-0.064	*	0.168	0.401	*	0.199
Alkali index	-0.065	*	-0.183	0.301	*	0.210	0.253	*	0.073