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BIOMASS SAMPLING AND ITS IMPORTANCE FOR MECHANICAL ENGINEERS

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Abstract- *Biomass conversion into heat, power and biofuels is greatly influenced by the characteristics of the biomass no matter which conversion process is the case. The characterization is very frequently based on small biomass samples for analysis of heating value, volatiles, moisture content, carbon content, ash melting behaviour, lignin, cell structure and biogas potential etc. For ultimate and proximate analysis sample size is often less than one gram. This is contradictory to the normal size of woody and herbaceous biomass plants or crops, i.e. sampling has to be planned carefully since one characteristic may vary in a stand between plants, shoots and even for different heights of a single shoot or tree. This variation may sometimes explain problems in getting statistically significant results for gasification, combustion etc. The aim of this paper is therefore to describe the variation of the characteristics and subsequently propose an appropriate sampling procedure minimising sampling uncertainty.*

Keywords: Poplar, Willow, Sampling, Moisture, Characterisation,

1. INTRODUCTION

University of Agder in Norway works with different use of bioenergy. Figure 1 shows a selection of actual topics. In all cases analysis of biomass plays a major role in explaining results, for the repeatability of the experiments, and in order to discover interaction between biomass characteristics and applications. Biomass conversion into fuels, heat and power is influenced by a lot of factors determining the fuel quality already in the growing phase like climate, species, age, soil, climate, etc. Harvesting factors have effect on the fuel too, where for example harvesting date and method, storage, handling, etc. are important. All the mentioned factors will cause differences in moisture content, ash content and ash melting behaviour, physical characteristics, emissions, and so forth during conversion to fuel, heat and power. There exist guidelines and even international standards for sampling of biomass. A search at Standards Norway www.standard.no results in 127 Norwegian and international standards related to sampling of biomass. Most of the standards are related to the analysis procedures in a laboratory, and a few on sampling in the industry. Only very seldom the sampling during experimental work in a field or a forest is treated.

The size of biomass sample in the laboratory varies at University of Agder from 7 mg, elemental or ultimate analysis via 1.5 g for heating value to several 100 grams for moisture content. This is a very small amount compared to the weight of one shoot of willow and poplar, which after three years growth accounts to up to respectively 4 kg and 6 kg dry matter in our plantation. It means you either have to rely on very homogenous characteristics or a very careful sampling. The aim of this paper is to describe the inhomogeneous nature of biomass, and discuss different appropriate sampling methods.

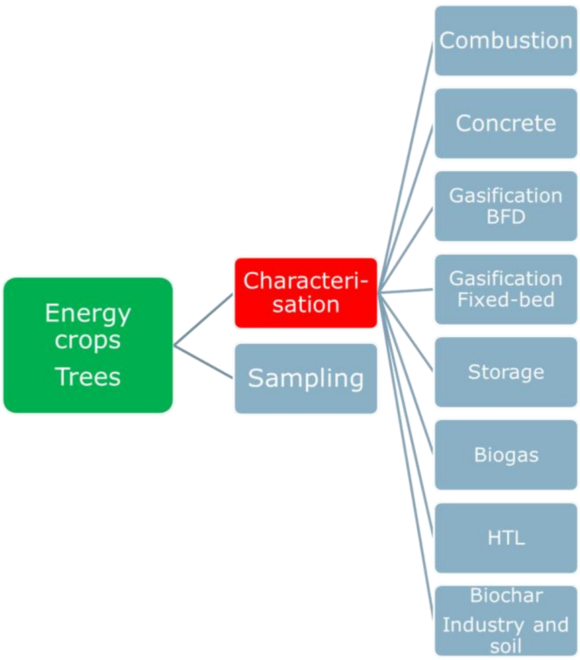

Fig.1: Characterisation of biomass is normally essential in experimental work with bioenergy.

2. MATERIALS AND METHODS

The studies were carried out in a short rotation coppice plantation of 1500 m² at sandy soil in Grimstad, southern Norway. Poplar and willow was established as cuttings in 2002 and 2005 with a planting density of 16,700 cuttings ha^{-1}. The shoots are harvested every second or third year during winter and new shoots emerge from the stump in spring, see figure 2. The actual studies are based on several harvests winter 2011-2012; see [1, 2 and 3] for more details about clones, harvest, fertilization, etc.

Fig.2: In front, new shoots in May from stumps harvested February same year. Behind, shoots in their third growing season. Clone 'Steffan'

Mapping of the variation of the characteristics was carried out by selecting several shoots from different stumps or selecting several shoots from same stump with different diameters. Subsequently harvested shoots were measured for physical size including diameter in different heights (10 cm, 100 cm, 130 cm above ground), and balancing point, which was determined by balancing a complete shoot on one finger. The complete shoot was divided in samples as described in table 1 in the field for evaluation of the variation with height. Samples were later same day transported to the laboratory. Here the samples were cut into pieces of maximum 10 cm, weighed, and dried at 105 °C to constant weight for determination of moisture content. For determination of chemical elements drying was carried out at 60 °C [2]. Finally, some shoots were selected for determination of ash content at 550 °C [4] for 20 hours and ash melting behaviour [5]. The measurement for every stem sample was not repeated, but the evenness of the curves was studied.

Table 1: Description of up to 18 samples from each individual shoot according to height in willow and poplar.

Sample	No.	Height [cm]	Length [cm]	Description
stump	-	0-10	10	Not harvested
stem	1	10-20	10	
stem	2	20-60	40	
stem	3	60-100	40	
stem	4	100-125	25	
stem	5	125-135	10	breast height
stem	6	135-185	50	
stem	7	185-235	50	
stem	8	235-285	50	
stem	9	285-335	50	
stem	10	335-385	50	
stem	11	385-435	50	
stem	12	435-485	50	
stem	13	485-535	50	
stem	14	535-585	50	
stem	15	585-top	rest	
branches	16	-	50	diameter <10 mm
branches	17	-	50	diameter >10mm
shoots	18	shoot		dead shoots

3. RESULTS

In the following figures examples of the variation of some characteristics with height are shown.

3.1 Moisture content

In figure 3 one example of moisture content variation in poplar is selected. The two shoots in figure 3 are three years old and from the same stump, but have different size. The smallest shoot is represented by the lowest and shortest curve, which indicates the lowest mean shoot moisture content. 53.8 compared to 56.1 % for the larger shoot. This difference is close to the standard error of the mean for the clone of 2.2 percentage points referred in [3]. In general, shoots from same stump have quite constant moisture content in poplar [3]. This is unlike willow, where the shoot diameter has a significant influence on the moisture content according to [1, 6].

3.2 Mean shoot ash content

The ash content curve for single shoots is more even than moisture content. Figure 4 shows one example in willow. Sample 3 60-100 cm above ground shows a global minimum for the shoot while the top has the highest concentration of ash. The last finding is expected as a willow shoot has relatively more bark with height, and bark has higher ash content than pure willow wood without bark according to Adler et *al.* [7].

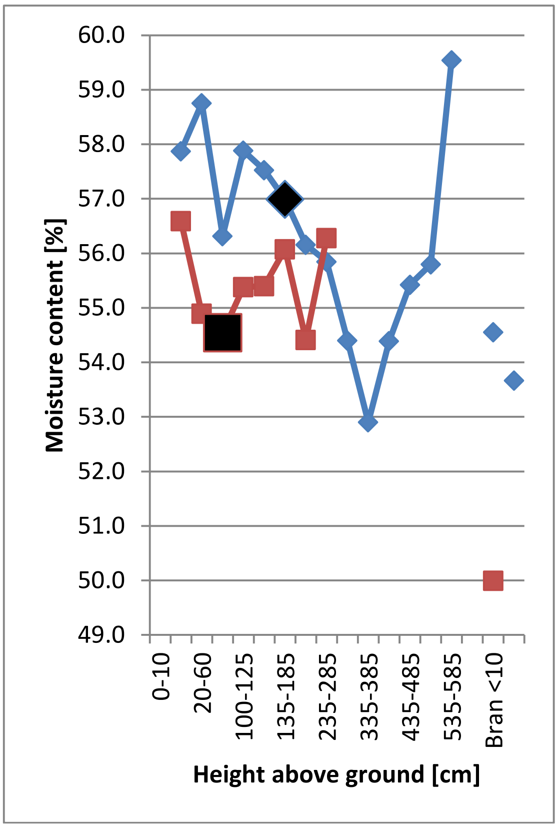

Fig.3: Moisture content variation with height for two individual shoots from one stump of poplar 'O.P.42' harvested 19 March 2012. Balancing centre has black filling. Bran <10 means branches with diameter below 10 mm while the next column (left) represents branches above 10 mm in diameter. After [3].

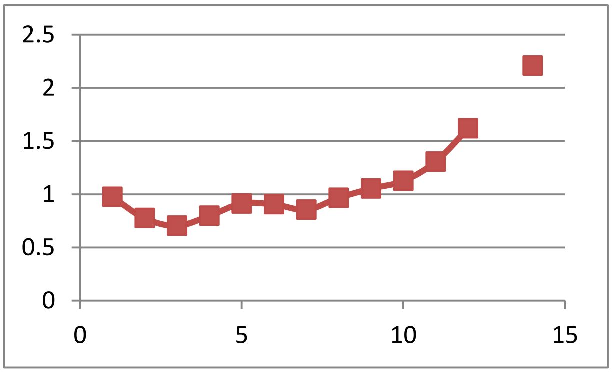

Fig.4: Ash content in [%] with height for an individual shoot of willow 'Aage' harvested 8 February 2012. The height is indicated as sample number according to table 1.

3.3 Chemical elements

Liu et *al*. [2] evaluated the distribution of twelve elements (Al, Ca, Cd, Cu, Fe, K, Mg, Mn, Na, P, Si, and Zn) with height in single shoots of willow 'Tordis' from University of Agder. Most of the elements follow the trend of the ash content in figure 4, but especially Fe and Al shows a very different pattern compared to ash. See figure 5 for aluminium, and [2] for the other elements. The shoots were harvested 12 December 2011.

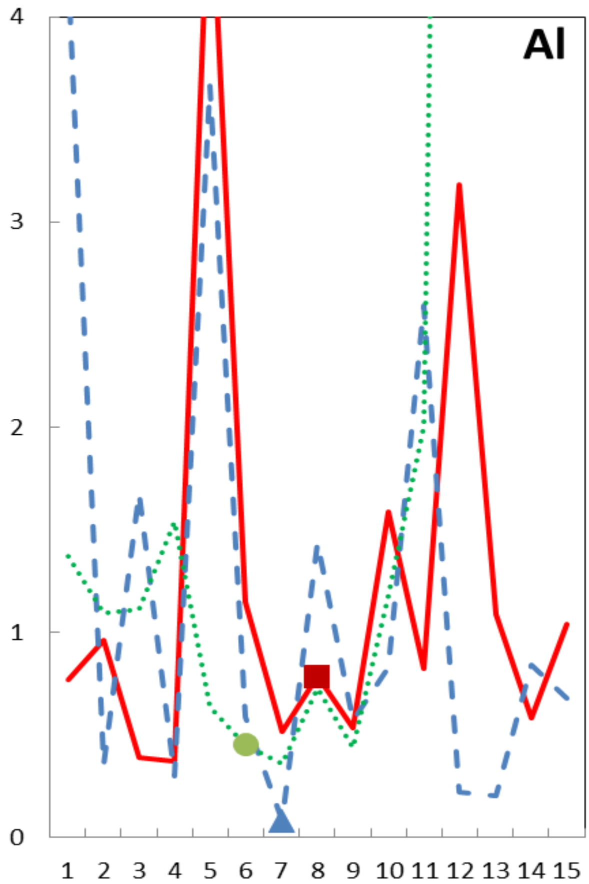

Fig.5: Distribution of aluminium in main stem of willow 'Tordis' with height as sample numbers. The different colours refer to average values for different size groups (see [2]). Value 2 at y-axis means the actual sample has two times the mean aluminium concentration for the complete stem. After [2].

3.4 Ash melting behaviour

The discovered variation for the chemical elements may influence the ash melting behaviour. One of the preliminary tests of ash from a single shoot in heating microscope resulted in the graph shown in figure 6. Other tests shows similar pattern. The relatively high flow point temperature for willow ash means it normally not will cause problems in boilers. The work will be continued.

4. DISCUSSION

Usually estimation of important biomass characteristics has to be based on sampling as it impractical to analyse complete crop yield. In the reported case study the variation with height for some characteristics is shown for selected shoots of willow and poplar. The results show some variation within single shoot and between shoots, which means sampling has to be carried out very carefully. Even a small increase in moisture content of two percentage points from 53 to 55 % means a 5.7 % decrease of lower heating value on wet basis in willow.

It is possible to select single stem samples for estimation of complete shoot mean moisture content in willow and poplar with a bias of 1.1 % [1]. The lowest bias is achieved by selecting sampling height according to clone. For chemical elements in willow 'Tordis' a 10 cm stem sample in breast height is recommended according to [2]. Preliminary results show that mean shoot ash content most likely can be estimated by a single stem sample in willow. The ash melting behaviour shows a more scattered picture, see figure 6. On the other hand, the flow point varies in the actual shoot only 60 ºC in this quite high range. This should normally not have a very critical influence on a combustion system.

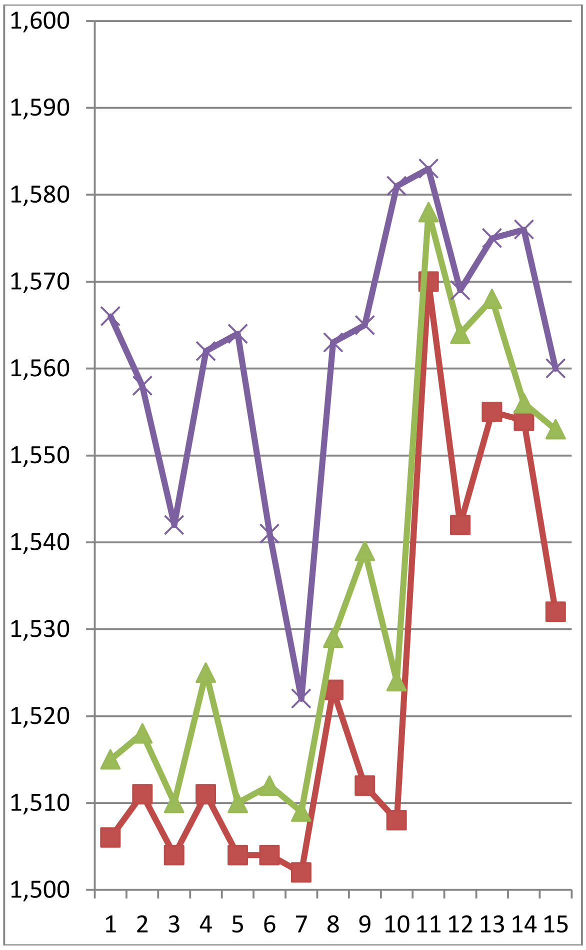

Fig.6: Ash melting behaviour [ºC] by height for one individual shoot of willow 'Tordis'. The three curves show from the top temperatures for: X Flow point, Δ Hemisphere, □ Deformation point.

A collection of several complete shoots could provide a bigger representative sample. In poplar, only one shoot per stump should be selected due to only a relatively small variation in moisture content between shoots according to [3]. This is in contrary to willow where one ought to take shoots with different diameters from several stumps according to [1]. The collection of several shoots ought to be chipped or shredded, and then carefully divided into a smaller sample for analysis.

In the industry sampling from a lorry or a transport system is described in standards like EN 14778:2011 Solid biofuels - Sampling.

Even with a representative sample mistakes may occur. One example is milling, where the mechanical handling causes increased temperature, which may change for example proximate analysis. Another case is determination of ash content. An ash sample is normally placed in a desiccator during cooling from 550 ºC to ambient temperature. Normally a desiccator contains a desiccant in the bottom. The desiccant should be removed for ash samples due to high hygroscopic ability of ash compared to desiccants, which may lead to moisture from the desiccant is transferred to the ash, see [4]. The last example comes from elemental analysis, where one should be aware that some of the elements follow the sap to the face of the cut at the end of a stem sample during drying. This changed distribution of some of the elements needs to be taken in consideration when sampling for the subsequent analysis is carried out.

5. CONCLUSION

Everyone carrying out analysis and sampling of biomass ought to be aware of the changing characteristics within shoots, between shoots, stumps, clones, etc. and the risk for changing the characteristics during pre-treatment and even analysis.

6. ACKOWLEDGEMENT

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