Basic procedures for sampling and analyzing woody biomass

Advantage report Vol. 15 No. 5 January 2015

By:

Marian Marinescu
Sylvain Volpé
Luc Desrochers
Dominik Röser

fpinnovations.ca

FPInnovations is a not-for-profit world leader that specializes in the creation of scientific solutions in support of the Canadian forest sector's global competitiveness and responds to the priority needs of its industry members and government partners. It is ideally positioned to perform research, innovate, and deliver state-of-the-art solutions for every area of the sector's value chain, from forest operations to consumer and industrial products. FPInnovations' staff numbers more than 525. Its R&D laboratories are located in Québec City, Ottawa, Montréal, Thunder Bay, Edmonton and Vancouver, and it has technology transfer offices across Canada. For more information about FPInnovations, visit: www.fpinnovations.ca.

Follow us on:

301009061: Forest Feedstocks
Advantage Report – Vol. 15 No. 5
Not Restricted to Members and Partners of FPInnovations

CONTACT

Dr. Marian Marinescu
Senior Researcher
Forest Feedstocks
604 222 5609
marian.marinescu@fpinnovations.ca

Table of contents

Keywords

Biomass, Bioenergy, Sampling, Physical properties, Moisture content, Particle size, Bulk density, Standards

BACKGROUND AND RATIONALE

Biomass sampling and analysis play decisive roles in determining the characteristics and value of the woody biomass fuel used in bioenergy systems in Canada. Sampling and analysis standards help harmonize the procedures that are used to monitor biomass quality. Because there are no Canada-wide biomass sampling standards, facilities that produce and use woody biomass have developed and implemented in-house sampling procedures of varying degrees of complexity. Given that the use of woody biomass in Canada is predicted to increase, the ability to ensure the quality of biomass will become increasingly important in order to control costs and maximize system efficiency.

A few years ago, the International Organization for Standardization (ISO) developed biomass sampling standards and it is anticipated these will be introduced in Canada in the near future. This report describes basic scientific procedures for biomass sampling and analysis that facilities could use until the ISO standards are adopted. These procedures evolved from interviews with biomass suppliers and consumers across Canada, and from expert knowledge within FPInnovations, and were guided by the intent of European and ISO standards.

During 2012 and 2013 FPInnovations interviewed many biomass supply personnel, production managers, and other key staff members at facilities across Canada that either produce or consume woody biomass fuel. The facilities included pulp and plywood mills, biomass power plants, and district heating plants in the eastern and western regions of Canada. The interviews were sometimes conducted in the course of other FPInnovations project work, either in person, by phone, or by email, using a set questionnaire. The interviewees included FPInnovations members and non-members. The purpose of obtaining the data was to learn about the biomass sampling procedures being used in these facilities in the absence of Canadian standards.

The results of the interviews were compiled, analyzed, and summarized (Table 1). The interviews revealed that many companies do not apply rigorous fuel-sampling procedures. Some facilities are sampling infrequently or not at all, and sample sizes are small. All the facilities obtain their samples manually. Usually the only critical attribute tested is moisture content, although the presence of contaminants is sometimes tested.

The interviews also revealed that fewer mills in western Canada are using biomass sampling techniques than in eastern Canada. Facilities in eastern Canada pay their biomass suppliers by the green metric tonne (GMT), while those in western Canada pay by the oven-dry tonne (ODT). Facilities in eastern Canada use sampling techniques mostly for quality-assurance purposes, while those in western Canada use them mainly for payment purposes. Both eastern and western facilities expressed interest in adopting biomass sampling techniques to improve the quality of biomass received or supplied.

Table 1. Biomass sampling procedures used in Canada: summary.[a]

Sampling variables	Biomass sector			
	Eastern Canada		Western Canada	
	Mills	Biomass energy producers	Mills	Biomass energy producers
Sampling frequency	10 to 100% of incoming truckloads.	Not formalized.	0 to 30% of incoming truckloads.	0 to 100% of incoming truckloads.
Sampling sites	Scale house or dumping site. (One pulp mill reported sampling at the conveyor belt.)	After unloading and before combustion.	Scale house.	Dumping site.
Sample size and sampling location	~500 to 1000 g, from anywhere within the load.	~1000 g, from anywhere within the load.	~0.25 m^3.	Not specified.
Sampling mode	Manual	Manual	Manual	Manual
Quality attribute tested	Moisture content and contaminants (visual assessment).	Moisture content.	Moisture content.	Moisture content.
Reasons for sampling	Quality assurance. Payment purposes.	Quality assurance.	Payment purposes.	Payment purposes.
Weight measure	GMT	GMT	ODT	ODT

[a] Based on FPInnovations survey of suppliers and consumers of woody biomass fuel.

Critical Attributes of Biomass

Recent increased demand for woody biomass in Canada has revealed a frequent mismatch between the delivered biomass and the desired feedstock attributes of various bioenergy processes. Even in traditional direct-combustion applications, such as biomass boilers and furnaces, feedstock attributes play a critical role in determining efficiency, feasibility, and environmental performance. As more bioenergy applications are being developed, the forestry companies that supply woody biomass as well as the bioenergy producers must become more cognisant of the critical attributes of woody biomass.

In terms of boiler performance, the following are the most important attributes of biomass:

- **Moisture content.** The acceptable moisture content of biomass depends on the combustion technology and capacity of the particular bioenergy system. Small-scale biomass boilers are designed to burn material with moisture contents around 30% (wet basis), but larger boilers, similar to the ones surveyed in this study, can accept a biomass moisture content of up to and sometimes exceeding 60% (wet basis). Some biomass boiler systems may use residual heat to dry the feedstock located in the loading area.

- **Particle size.** The most common particle size for biomass stoker boilers is “4-inch minus”, i.e., able to pass through a 4-inch (10-cm) grate. Fluidized bed systems are less sensitive to particle size and can accommodate particles to 6-inch (15-cm) minus size, or sometimes greater.
- **Particle size uniformity.** Particle size uniformity can increase boiler efficiency and combustion control. European standards offer guidelines regarding the percentage of fines, i.e., <3 mm (<0.1 inches), and oversize particles, i.e., >100 mm (>4 inches).
- **Degree of contamination.** Excessive soil, sand, and gravel content can cause slagging and fouling of boiler pipes. Rocks and metal can harm secondary hogging equipment, and chemical contamination of the feedstock can create harmful emissions and will increase ash content above normal levels.
- **Bulk density.** Large variations in biomass bulk density affect boiler performance and require constant adjustment of biomass feeding rates. Bulk density can also significantly influence transportation and storage costs. Consequently, biomass facilities could employ a simple procedure (described later) to monitor and control bulk density of various biomass feedstocks.

Existing Standards for Sampling Biomass

European Committee for Standardization (CEN)

The European standards for solid biofuels—CEN TC335—consist of 26 standards that were first published in 2005. They cover a wide range of subjects, including:

- Classification of wood fuel types – EN 14961
- Terminology, definitions, and descriptions – EN 14588
- Sampling – EN 14778
- Sample preparation – EN 14780
- Bulk density – EN 15103
- Particle size classification – EN 15149
- Moisture content determination – EN 14774
- Ash content determination – EN 14775
- Calorific value determination – EN 14918

International Organization for Standardization (ISO)

The ISO started the development of biomass standards—ISO TC238—in 2007. Some are published and the development of others is ongoing. ISO standards will most likely be implemented in Canada in the next few years. These ISO standards are largely based on those of CEN, but will eventually cover a somewhat wider range of topics such as wood fuel types, health and safety, etc., with the aim of reflecting the most recent practices and feedstock types. Among the topics are:

- Classification of wood fuel types – ISO 17225
- Particle size classification – ISO 17827
- Determination of ash content – ISO 18122
- Others in development

BASIC PROCEDURES FOR CONDUCTING BIOMASS SAMPLING AND ANALYSIS

FPInnovations recommends the following biomass sampling and analysis procedures for use in Canada. These procedures maintain the scientific and technical rigour of the CEN and ISO standards, yet are more straightforward and are easy to implement.

Sampling Procedures

Sampling Source

ISO and CEN standards state that biomass sampling must be performed such that samples most closely represent the source from which they were drawn. The source—which could be a truckload, pile, etc.—is known as a *lot*.

Sampling Frequency

Sampling for payment purposes: Sampling frequency depends mostly on the consistency of the quality of the delivered product. When a biomass-consuming facility has a new supplier, that facility should sample from every truckload until an acceptable quality consistency is achieved; then the frequency can be reduced to 20 to 30% (i.e., sample 1 out of every 3 to 5 truckloads).

Sampling for quality control: To maintain or increase biomass quality, the receiving facility should sample from every truckload.

To maintain or increase fuel quality in storage areas, the following are recommended:

- sample the stored material over time (e.g., every week), and
- sample the material each time the biomass supply incurs a major move (e.g., if the material is moved from receiving to storage areas, or from the reclaiming area to the boiler), in order to quickly identify the sources of variability (e.g., gravel contamination, sharp changes in moisture content).

Sample Size

The sample size extracted from the lot depends on the quality attributes being tested, as follows:

- **Moisture content:** 6 L (3 replicates of 2 L per sample[1]).
- **Particle size analysis:** 30 L (3 replicates of 10 L per sample).
- **Bulk density:** 100 L (2 replicates of 50 L per sample).
- **Ash content and calorific value:** minimum 1 g (minimum 2 replicates).

Minimum Sample Increments

To guarantee a representative sample, draw small amounts from various locations within the lot (i.e., truck, rail car, container, pile, or biomass stream). The small amounts are called *increments*, and are usually ~5 L in volume.

Draw the increments from the lot by hand (handfuls), or use a sampling tool (e.g., shovel, scoop).

Use this simple formula to calculate the *minimum* number of increments to draw:

$$n = 10 + 0.04\, W_{Lot}$$

where

n is the minimum number of increments, and

W_{Lot} is the weight of the lot in tonnes.

For example, a minimum of 11 increments (e.g., 5-L scoops) should be drawn from various locations of a 32-tonne truckload of biomass:

$$10 + (0.04 \times 32) = 11.28 = \sim 11 \text{ increments.}$$

***Tip**: Ensure that enough increments (e.g., handfuls, shovelfuls, scoops) are drawn from the lot to meet the total sample volume necessary to fulfill all biomass attribute tests. For example, 100 L is required to test for size distribution, bulk density, and moisture content. Consequently, more increments than the minimum may be required.*

Sampling Tools

The two most common sampling devices are: a sample *shovel* or *scoop* for stationary sampling (Figure 1), and a *sampling box* for sampling of biomass streams (Figure 2).

[1] The analysis is repeated (i.e., replicated) three times using 2-L replicates (3 × 2-L replicate = 6-L sample)

Figure 1. Sampling shovel (scoop) for sampling from stationary sources.

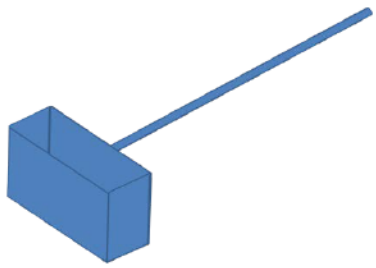

Figure 2. Sampling box for sampling from streams.

***Tip**: Ensure the sample is transferred into a clean, sealable, air-tight container or bag to preserve the moisture until the sample can be tested. If immediate testing is not possible, it is advisable to store the sample in a freezer. Bring the sample to ambient temperature when ready to proceed with sample preparation and analyses.*

Sampling from Stationary Lots

Sampling from trucks, containers, and rail cars: It is difficult to draw representative samples from trucks, containers, and rail cars because not all areas of these loads are accessible.

Some trucks and rail cars are equipped with small sampling doors, from which increments can be drawn at various locations/depths. If there is no door or other access, as much as possible, draw increments randomly from the top of the load at different locations and depths. Use a long probe to draw small increments from deeper locations within the load.

Place the increments into large, sealable, air-tight plastic bags.

Sampling from piles: Collect increments from locations within the top, middle, and bottom of the pile in proportion to the approximate volume contained in each layer (Figure 3). To avoid contamination, do not sample within 300 mm from the bottom of the pile (unless specifically testing for contamination).

For ease of carrying and safety, start sampling at the top of the pile and work down. Use a long probe to draw increments from deeper locations within the piles.

Place the increments into large, sealable, air-tight plastic bags.

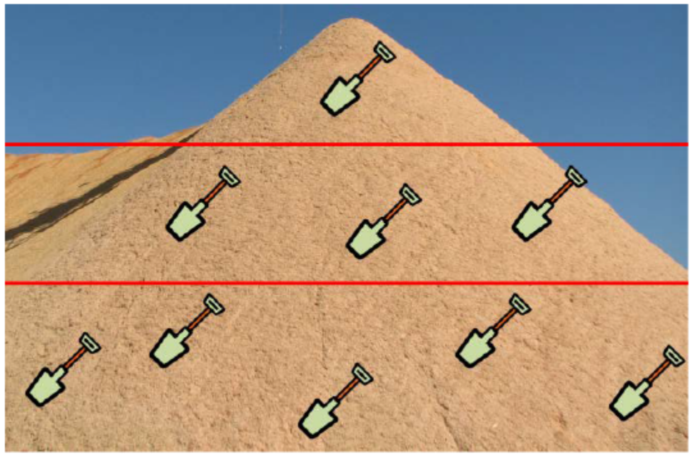

Figure 3. Collect increments from locations within the top, middle, and bottom of the pile.

Sampling from Biomass Streams

As far as safety is concerned and in terms of the consistency of the material in the sample, sampling from stationary lots is preferable over sampling from moving biomass streams. However, sometimes it is necessary to sample from moving streams, such as from a conveyor belt.

Sampling from conveyor belts: It is unsafe to collect increments from biomass streams by hand. To ensure that samples are representative of the complete cross-section, the best sampling locations are transfer points between conveyors or at the conveyor end.

Use a sample box to collect the increments, or install sampling collection systems at transfer points.

Sample Storage

For moisture content determination, the packaged samples should be weighed immediately after sampling to prevent the moisture from accidentally getting out of the package or condensate on the package walls. The packages should be protected from direct sunlight. To minimize biological activity, samples should be submitted for testing within 24 hours. Alternatively, samples can be stored for a maximum of seven days in a refrigerator at 5°C. If longer-term storage is required, samples may be kept in a freezer.

Separation and Analysis of Biomass Samples

Tip: *Photocopy the procedures on the following pages, and then laminate and keep them handy in the work areas where the separation and/or analyses are performed.*

Separating Biomass Samples: *Coning and Quartering*

Objective: to separate the original sample into representative subsamples that are the appropriate size for the attribute being tested (e.g., moisture content analysis, bulk density analysis).

Work space: Perform the procedure indoors if possible, on a hard, smooth, and clean surface. If performed outdoors, do not undertake this procedure in rainy or windy conditions. Ensure lots of room exists to manoeuvre around the sample

Materials and equipment:

- ☐ Clean concrete pad or tarp
- ☐ Clean shovel(s) or scoop(s)
- ☐ One long piece of lumber (optional)
- ☐ Large, clean, sealable, air-tight plastic bags
- ☐ Digital or analog scale

Procedures:

Step 1
Mix the sample thoroughly to ensure uniformity.
Mixing can be done with shovels or scoops by shifting the material from one place to another a few times. Ensure the material at the top of the pile (oversize) and the material at the bottom of the pile (fines) are mixed uniformly in the sample.

Step 2
Arrange the material into a conical pile in the center of the concrete pad or tarp.

Step 3
Flatten the pile with the piece of lumber, or use the shovel handle. Two people may be needed for this task.

Step 4
Use the piece of lumber or the shovel handle to separate the sample into four quadrants.

Step 5
With scoops or shovels, take two diagonally opposite quadrants and mix the material into one pile. Load the material into sealable, air-tight plastic bags.

Step 6
Weigh the material. If the material meets the required weight of a subsample (e.g., 1 kg for moisture content analysis), go to Step 7. Otherwise, continue to separate this pile starting with Step 1, until a satisfactory subsample size is achieved and a sufficient number of subsamples are obtained.
Label the bags with the date, time, location, supplier, weight at the time of sampling, and name/ID# of the person who conducted the sampling and/or separation.

Step 7
You may separate any remaining material into subsamples for other tests. Otherwise, store or discard the remaining material.

Analyzing the Moisture Content of Biomass Samples

Objective: to find the moisture content percentage *mc* (%) (% by weight, wet basis) of a biomass sample.

Work space: This procedure should be performed in laboratory conditions.

Materials and equipment:

- ☐ Digital scale with a capacity of at least 2000 g and accuracy of 0.1g
- ☐ Drying oven
- ☐ Clean sample weighing tray, able to hold at least 300 g of biomass
- ☐ 6 L (>1 kg) of biomass sample (3 replicates of at least 300 g each)

Procedures:

Step 1

Follow the procedures for *Separating Biomass Samples* to separate 3 replicates of at least 300 g each from one sample of at least 1 kg of biomass.

Step 2

Weigh the empty sample tray and record its weight (*tare*) m_t.

Step 3

Load the material of a replicate into a weighing tray. Weigh the loaded tray and record the weight m_{wet}.

Step 4

Load the tray into the oven and set to 105°C.
Keep the tray in the oven until constant mass is obtained[2].

Step 5

Weigh the loaded tray and record the weight of the dry material m_{dry}.

Step 6

Calculate moisture content *mc* (%) according to the following formula:

$$mc\ (\%) = [(m_{wet} - m_{dry}) / (m_{wet} - m_t)] \times 100$$

Step 7

Analyze the 3 replicates and report the average.

[2] Mass constancy is obtained when the mass lost between two weights taken 60 minutes apart is not exceeding 0.2% of the total lost in mass (EN-TS 14774-1:2009). The drying time will depend on the particle size and the thickness of the sample in the tray, and may vary between 5 and 24 hours (overnight).

Analyzing Biomass Particle Size Distribution

Objective: to find the percentage by weight of each particle size class m_{SC} (%) in the biomass sample. The test can be performed on either dried or “as received” biomass. Typically, the test is performed with oven-dry biomass.

Work space: This procedure should be performed in laboratory conditions.

Materials and equipment:

- ☐ Vibrating or oscillating, round-hole, chip-size classifier machine
- ☐ Digital scale with a capacity of at least 10 kg and accuracy of 1 g
- ☐ Clean sample weighing trays, one for each sieve and one for the fine particle collection tray
- ☐ 30 L of biomass (3 replicates of 10 L each)

Procedures:

Step 1
Follow the procedures for *Separating Biomass Samples* to separate 3 replicates of 10 L each from a sample of 30 L of biomass.

Step 2
Determine which sieve sizes are needed, and then stack the sieves in the machine in descending order (largest holes at the top). Ensure a fine particle collection tray is placed at the bottom.

Step 3
Weigh the biomass sample and record its weight m_s in grams.

Step 4
Place the biomass on the top sieve (largest hole size) and turn on the machine.

Step 5
Let the machine shake the sieves for 15 minutes.

Step 6
Weigh each empty sample tray and record its weight m_t.

Step 7
Starting with the top sieve, one at a time, gently remove each sieve from the machine and unload the contents into a weighing tray—one tray for each sieve. Ensure all particles in each sieve are emptied into the tray. Label each sample weighing tray with the sieve size from which the material originated.

Step 8
Weigh each loaded tray and record its weight m_{SC}, where *SC* is the size class/sieve size of the material collected in each tray.

Step 9
Calculate the particle size class percentages m_{SC} (%) according to the following formula:

$$m_{SC}\,(\%) = [(m_{SC} - m_t) / m_s] \times 100$$

Step 10
Analyze the 3 replicates and report the average.

Analyzing Bulk Density of Biomass Samples

Objective: to find the bulk density (kg/m^3) of biomass. The test can be performed on either dried or “as received” biomass. Typically, the oven-dry mass and the “as received” volume are used to calculate bulk density.

Work Space: Perform the procedure indoors if possible, on a hard, smooth, and clean surface. If performed outdoors, do not undertake this procedure in rainy or windy conditions. Ensure lots of room exists to manoeuvre around the sample.

Materials and equipment:

- ☐ Digital scale with a capacity of at least 30 kg and accuracy of 10 g
- ☐ Biomass scoop or shovel
- ☐ Sturdy cylindrical container of known volume V (e.g., 50 L = 0.05 m^3)
- ☐ 100 L of biomass (2 replicates of 50 L each)
- ☐ One long piece of lumber (optional)

Procedures:

Step 1
Follow the procedures for *Separating Biomass Samples* to separate 2 replicates of 50 L each from 100 L of biomass.

Step 2
Weigh the empty container and record its weight m_c.

Step 3
Fill the container with biomass until a 20-cm-deep mound, as measured from the lip of the container, is created on top.

Step 4
Control-drop the container three times on the ground or on a wood block from ~15-cm height. Some biomass will spill onto the floor.

Step 5
Use the biomass that fell on the floor to top up the container. Use a long piece of lumber or the shovel handle to level off the material and to remove any larger pieces sticking out of the container.

Step 6
Weigh the loaded container and record the weight m_s.
Calculate the bulk density (BD) (kg/m^3) according to the following formula:

$$BD = (m_s - m_c) / V$$

Step 7
Analyze the 2 replicates and report the average.

Biomass Analyses Performed at Specialized Laboratories

These are analyses that require specialized equipment and procedures; bagged samples are normally sent to specialized labs.

Ash Content Analysis

This is a mandatory analysis for wood pellets, but is not always required for wood chips or hog fuel. However, high ash content in a sample is a good indication of increased biomass contamination (i.e., rocks, metal, sand, etc.). Therefore, this analysis is crucial to increasing the quality of the biomass fuel and, ultimately, boiler efficiency.

The ash content (dry basis) is determined as the mass of inorganic residue remaining after ignition of a fuel under specified conditions, expressed as a percentage of the mass of the dry matter in the fuel. The sample is typically dried and ground to a <1-mm particle size and is then heated in a controlled environment at a temperature of 550°C. The temperature is first raised to 250°C to drive off volatiles and then increased to 550°C.

Calorific Value Analysis

This is a mandatory analysis for wood pellets, but not always required for wood chips or hog fuel.

Gross calorific value (or higher heating value) of a biomass sample, as received, is measured by burning it in the presence of oxygen in a bomb calorimeter. Accounting for moisture, the gross calorific value is presented in MJ/kg on a dry basis.

INFORMATION SOURCES

Standards

European Committee for Standardization. *CEN TC335 – Solid biofuels.*
http://www.cen.eu/

International Organization for Standardization. *ISO TC238 – Solid biofuels.*
http://www.iso.org/

Literature

Marinescu, M.V. 2013. *Critical biomass attributes of the most common bioenergy and biofuel applications*. Advantage Report Vol. 13, No. 10. FPInnovations, Vancouver, British Columbia.

Nader, J. 2001. *Sampling a truckload of chips: how to ensure representative samples.* Advantage Report Vol. 2, No. 16. FERIC, Pointe-Claire, Québec.

Head Office

Pointe-Claire
570, Saint-Jean Blvd
Pointe-Claire, QC
Canada H9R 3J9
T 514 630-4100

Vancouver
2665 East Mall
Vancouver, BC.
Canada V6T 1Z4
T 604 224-3221

Québec
319, rue Franquet
Québec, QC
Canada G1P 4R4
T 418 659-2647

OUR NAME IS INNOVATION