LABORATORY ANALYSIS OF FOREST-DERIVED FEEDSTOCKS

Sample Collection
A representative sample of sufficient volume, usually **18 L** (5 gal), is collected in the field and sealed in an airtight container for transport and storage. *CEN/TS 14778*

Storage
Samples are refrigerated to limit changes in feedstock properties associated with biological activity. Dry samples (MC<10%) may be stored at room temperature. *CEN/TS 14778 & 14780*

Sample Division
The sample is mixed to homogenize the sample and divided into representative subsamples. *CEN/TS 14780*

30 min

Moisture
A **300 g** (minimum) subsample is dried to constant mass at 105°C. *EN 14774*

24 hr

Low Temperature Drying
A **7-8 L** subsample is air-dried in a sheltered location to prevent contamination or oven-dried at a temperature below 40°C. *CEN/TS 14780*

7 days

Hammer Mill
Particle size is reduced in a hammer mill fitted with a 3.2 mm (1/8") screen. *CEN/TS 14780*

30 min

Mass Reduction
The milled sample is subsampled using a rotating tube divider (Retsch PK1000).

15 min

Archive
A **2.5 L** portion of the milled sample is retained in an archive.

Cutting Mill
Particle size is reduced in a cutting mill fitted with a 1 mm screen. *CEN/TS 14780*

30 min

Archive
A **236 ml** portion of the milled sample is retained in an archive.

General Analysis Sample
A **118 ml** sample of material passing the 1 mm screen is sealed in an airtight container. Subsamples of this material are used in various tests.

Bulk Density
For most feedstocks, a **6.5 L** portion of an **8 L** subsample is used to fill a 5 L cylinder which is subjected to shock, refilled, and weighed. *EN 15103*

45 min

Drying
The subsample is dried to a point below 20% moisture content (wet basis). *CEN/TS 14780 & EN 15149*

2-7 days

Particle Size
The **8 L** subsample is sieved for 15 minutes. The mass retained on each sieve and total mass are recorded. *EN 15149*

1 hr

Archive
All or part of the subsample may be archived.

Ash
The ash remaining after a 1 g subsample is heated at 575°C is weighed. 3 replicates = **3 g** total *NREL/TP-510-42622*

10 hr

CHNS
The amount of C, H, N, and S in a 2 mg subsample are determined with a CHNS analyzer. 3 replicates = **6 mg** total

8 hr

Color
Color of a 10 g sample is described (L,a,b color space). Subsample is returned to general analysis sample. 3 replicates = **30 g** total

10 min

Energy
The energy released during the combustion of a 0.65 g subsample is measured. 3 replicates = **2 g** total

45 min

Mineral
Na, Mg, Al, Si, P, K, Ca, Mn, Fe, Cu, and Zn concentrations are measured from a 0.5 g subsample. 3 replicates = **1.5 g** total

3 days

Moisture
A 2 g subsample is dried to constant mass at 105°C in a moisture analyzer. 3 replicates = **6 g** total *ASTM E 1756*

30 min

Particle Density
The solid volume of a 3 g subsample is determined with a gas pycnometer. 3 replicates = **9 g** total

45 min

TGA
A 10 mg subsample is weighed as it is heated from room temperature to above 900°C. 3 replicates = **30 mg** total

3 hr

FOREST-DERIVED FEEDSTOCKS

Forests grow over approximately one third of the land area of the United States and currently supply about 30% of the renewable energy consumed in the US, nearly three times the amount provided by wind, solar, and geothermal sources combined. Forest biomass is also used in the production of chemicals. The amount of forest biomass used for energy and chemical production will likely rise in the future due to increasing energy demand, decreasing fossil fuel availability, and environmental concerns.

Forestlands, highlighted in green, cover 750 million acres in the United States (USDA Forest Service Forest Inventory and Analysis data).

The most common forms of forest-derived feedstocks include:

- **Logs**, tree-length or near tree length wood
- **Firewood**, wood that is cut into short pieces and split to fit in fireplaces
- **Bundles**, a tightly bound collection of lengthwise oriented forest biomass
- **Bales**, cut or mulched forest biomass that is compressed and bound
- **Bark**, bark that has been removed from logs
- **Hog fuel**, forest biomass that has been comminuted in a hammermill
- **Chips**, wood that has been sliced into thin cards which are then broken into small pieces
- **Shavings**, thin layers of tissue removed from the surface of wood with a plane
- **Sawdust**, fine pieces of wood removed from the kerf by saw blades
- **Pellets**, small cylinders of compressed milled biomass

Cutting, grinding, and chipping equipment is used to prepare forest biomass for transportation and utilization as a bioenergy or chemical production feedstock. In this photograph a wheeled loader feeds loblolly pine plantation thinning residues into a horizontal grinder that conveys the ground biomass into a trailer.

Forest-derived feedstocks are either burned with minimal processing or converted to gas fuels, liquid fuels, densified solid fuels, or other chemicals not used as fuels. Pictured here are a power plant that co-fires with biomass (left), a fast pyrolysis / torrefaction system (top right), and a pellet mill that produces densified solid fuel (lower right).

Properties of forest-derived feedstocks vary based on what materials they are produced from and how they are prepared and handled. The moisture content, bulk density, particle size, ash content, color, elemental composition, energy content, and volatile chemical content of the six feedstocks shown here differ. Some of these differences are obvious and relatively easy to quantify, while others can only be detected through laboratory testing.

FEEDSTOCK PROPERTIES

The technical and economic suitability of a feedstock for a specific end use depend on feedstock properties. However, the properties of forest-derived feedstocks vary because the materials from which feedstocks are produced vary, and because feedstocks are produced and handled in different ways. The following table presents the normal ranges (dry basis unless otherwise noted) and generally preferred values for several feedstock properties:

PROPERTY	PREFERRED VALUE	RANGE		UNITS
Moisture	low	<5	>65	% (wet basis)
Bulk Density	high (dry basis)	60	700	kg/m³
Particle Size	varies, low size deviation	<1	>1000	mm
Ash	low	<0.25	>25	%
Carbon	-	45	55	%
Hydrogen	-	5	7	%
Nitrogen	low	<0.1	>1.0	%
Sulfur	low	<0.01	>0.20	%
Color	stable over time	-	-	L,a,b values
Energy	high	14	23	MJ/kg
Mineral Concentrations	low	<0.1	>1000	mg/kg
Particle Density	-	0.2	1.5	g/cm³
Volatiles	-	50	90	%
Fixed C	-	<10	>25	%

LABORATORY ANALYSIS

Feedstocks must be milled before many laboratory tests are performed. The pinyon-juniper chips shown here (left) were milled in a hammermill with a 3.2mm screen (center) and then in a cutting mill with a 1mm screen (right).

Full feedstock sample analysis can be completed in 3-4 weeks. In many cases only select tests are required and results may be available more quickly. However, during periods when personnel and equipment are obligated to other projects, results are delayed while samples are held in cold or dry storage until resources become available.

The analyses performed in the Forest Operations (USDA Forest Service) and Biosystems Engineering (Auburn University) labs conform to published standards or to methods specified by analytical equipment manufacturers.

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