**Characteristics of Comminuted Forest Biomass**

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**ABSTRACT**

Transpirational drying and in-woods production of microchips potentially improve the economic efficiency of energy production from forest-derived feedstocks, but yield materials with moisture contents, bulk densities, and particle size distributions that differ from more conventional feedstocks. Ongoing research suggests that transpirational drying reduces the moisture content and wet-basis bulk density of forest biomass, and may affect chip size distribution. In-woods microchipping produces smaller chips and has little effect on moisture content or bulk density.

**INTRODUCTION**

Comminuted forest biomass is used in the production of solid and liquid fuels, paper, and other products. Comminution may be performed either at the harvest site or at a processing facility, and is most often accomplished using chippers that employ sharp blades to cut wood into slices that shatter into chips or using grinders that apply blunt force to break wood into pieces. The equipment used to comminute forest biomass, harvest methods, and properties of the forest biomass all affect the characteristics of the comminuted product, and the suitability of the comminuted product for specific end uses.

Costs associated with the harvest, comminution, and transport of forest biomass contribute to the cost of fuels and other products produced from forest biomass feedstocks. Fossil fuels have provided much of the energy used in the United States and other countries following the Industrial Revolution due in part to their low cost, but the increasing scarcity of fossil fuels and concerns about the environmental impacts of fossil fuel use have spurred interest in biofuels technology. Alternatives to conventional harvest and comminution methods may allow forest biomass to be delivered and utilized more efficiently, thereby improving the economic efficiency of biofuels produced from forest biomass.

In conventional harvest systems trees are cut, processed, and transported within a short time window. Water may contribute more than half of the mass of a live tree (Gibson et al. 1985), and very little of the water present in conventionally harvested trees is lost between felling and transportation. This conventional system is inefficient in two ways: energy is consumed transporting water, and some of the energy contained in the biomass is consumed evaporating water during biomass conversion processes. In an alternative system, trees are cut several weeks before processing and transportation occurs, allowing trees to lose moisture through transpiration. The effectiveness of transpirational drying varies,

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but moisture content has been shown to decrease with transpirational drying in southern pine (*Pinus* L.) species (Stokes et al. 1993). In a recent study of transpirational drying in loblolly pine (*P. taeda* L.) moisture content decreased from 53% to 39% over an eight week period (Cutshall et al. 2011).

In-woods microchip production may also improve the efficiency of biofuel production from forest biomass. In-woods comminution is currently conducted at commercial scale because densification achieved through comminution allows more efficient transportation of some materials, such as small diameter stems and logging residues. In addition, biomass piece size must be reduced to fit material handling systems and processing requirements before forest biomass can be used to produce fuels, pellets, and other products. Conventional forest chippers produce chips with a length of approximately 20 mm, but these chips are too large for some energy conversion processes and must be reprocessed. Producing microchips with a length of 10 mm or less using modified equipment at the harvest site may reduce or eliminate the time and energy costs of feedstock resizing at the receiving facility (Steiner and Robinson 2011).

Several properties of these feedstocks are commonly tested to ensure that biomass feedstocks meet delivery specifications. Implementation of near-infrared and other technologies allow some feedstock properties to be assessed quickly and monitored as feedstock moves through a process. When continuous measurement systems are not present, and for properties these systems cannot measure, samples are collected, prepared for analysis, and analyzed. Several organizations including ASTM International and the European Committee for Standardization have published biomass testing standards to facilitate repeatable, comparable feedstock characterization. Moisture content, bulk density, and particle size are among the feedstock properties commonly tested, and these tests do not require samples to be milled before analysis is performed.

The objective of this paper is to report forest-derived feedstock test results for samples collected in southern Alabama as part of a high-tonnage biomass delivery system development and demonstration project incorporating transpirational drying and in-woods microchipping (Rummer et al. 2010).

## METHODS

### Field Methods

This paper presents test results for samples of wood chips produced at harvest sites within 50 km (30 miles) of Chapman, AL beginning in 2011. Conventional pulp chips and microchips were produced from freshly cut loblolly pine, transpirationally dried loblolly pine, and a mixture of conifers and broadleaf species. Seven chip types types including whole-tree and clean chips were produced and sampled.

A Precision Husky[2] model 2366 disk chipper and a Precision Husky model 2675 disk chipper were used to produce conventional pulp chips and microchips. Both chippers were equipped with a diverter that

[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement of any product or service by the U.S. Department of Agriculture or other organizations represented here.

removed foliage and over-sized material from the chip stream. Clean chips were produced by passing whole trees through a flail before chipping. Whole tree chips (dirty chips) were produced from whole trees that had not been flail processed.

The samples of transpirationally dried pine chips analyzed for this study were produced from trees that were allowed to dry in a clearcut loblolly pine plantation. Trees were felled and placed in bunches in the first week of April, 2012. Trees were chipped seven weeks later. The average daily temperature during the sample collection period was 23°C (range 14 - 30°C) and humidity averaged 66% (range 38 – 86%; WUI 2013). Total rainfall during the 2 month period was intermittent and measured 13.6 cm (WUI 2013).

Samples representing a fully loaded chip trailer were collected during chip production by diverting chips into a collection container through a pipe intermittently inserted into the outflow stream at the chipper spout. To ensure that the entire load of chips was sampled, the sampling pipe was inserted into the outflow stream a minimum of eleven times as a chip trailer was loaded (CEN/TS 14778-1:2005). Chips captured in the collection container were mixed and sealed in an airtight sample container. Samples were stored at 2-5 °C to minimize biological activity while awaiting laboratory analysis.

**Laboratory Methods**

Subsamples needed for specific analyses were obtained from each sample through coning and quartering, as described in European Technical Specification CEN/TS 14780:2006.

Moisture content was assessed through loss on drying. As prescribed in European Standard EN 14774-2 (2009), a subsample of 300 g or more was heated at 105 °C until sample mass decreased less than 0.2% between measurements taken one hour apart. Moisture content was calculated by dividing the difference between the initial and oven-dry sample mass by the initial sample mass.

Bulk density was measured using a methodology based on European Standard EN 15103 (2009), using test cylinders with a height to diameter ratio of 1.37 and a capacity of 5 L or 20 L. A subsample with a volume 30% greater than the volume of the test cylinder was used in the tests. The test cylinder was filled to overflowing by pouring woodchips into the cylinder from a height of 15-20 cm above the cylinder. After filling, the test cylinder was dropped from a height of 15 cm onto a clean wooden board. After the cylinder was dropped the third time it was refilled to overflowing in the same manner it was originally filled and the material above the cylinder rim was removed by passing a wooden board across the cylinder rim, taking care not to apply downward pressure on the material in the cylinder. After shock treatment, refilling, and leveling off the test cylinder the mass of the material in the cylinder was recorded. This test was repeated a minimum of three times for each sample and the bulk density of the sample was calculated for each repetition by dividing the mass of the sample in the cylinder by the cylinder volume. The bulk density values of the repetitions were averaged to obtain the wet-basis bulk density estimate for the sample. The dry-basis bulk density of each sample was calculated by multiplying the wet-basis bulk density estimate by the difference between one and the decimal-form moisture content of the sample. Both sizes of test cylinders were used.

A subsample of approximately 8 L was obtained from each sample for particle size analysis. Prior to analysis, samples were dried to allow free movement of particles. Particle size was assessed using a chip classifier (TMI Chip Class™) set to shake samples for 10 minutes and equipped with 45 mm, 13 mm, 7 mm, and 3 mm round-hole screens and a bottom pan. The fraction of the subsample retained on each screen and the bottom pan was weighed, and the percent of the subsample in each fraction was calculated by dividing the mass of each fraction by the total subsample mass.

### Analysis

During the sampling period, microchip production was limited, so the sample sizes for this type of chip are also limited. The small numbers of samples collected from most types of wood chips produced in this project preclude rigorous comparative statistical analysis of test data. As additional samples are collected and analyzed, statistical testing of the effects of differing chip production methods will become possible. Descriptive statistics are presented in this paper.

## RESULTS AND DISCUSSION

Results of moisture testing are presented in Table 1. The average moisture content of loblolly pine chips produced from freshly cut trees ranged from 55% to 58%, and the average moisture content of chips made from transpirationally dried loblolly pine was approximately 39%. These results are consistent with published moisture values for pine chips, including the values reported by Cutshall et al. (2011). The average green moisture content of mixed-species chips was between 47% and 50%.

Table 1. Moisture content of wood chips produced at harvest sites in southern Alabama.

| | MOISTURE CONTENT (% Wet Basis) | | |
|---|---|---|---|
| MATERIAL | n | mean | s |
| **Pine, Freshly Cut:** | | | |
| Clean Conventional | 15 | **55.5** | *2.3* |
| Clean Microchips | 2 | **58.1** | *1.5* |
| WT[1] Microchips | 3 | **54.7** | *0.8* |
| **Pine, Transpirationally Dried:** | | | |
| TD[2] Clean Conventional | 15 | **39.3** | *3.1* |
| TD WT Microchips | 2 | **38.8** | *2.5* |
| **Mixed Species:** | | | |
| Mixed Spp WT Conventional | 4 | **46.6** | *4.9* |
| Mixed Spp WT Microchips | 7 | **49.2** | *2.2* |

[1] Whole Tree, [2] Transpirationally Dried

Results of bulk density testing are presented in Table 2. Two test cylinders were used, one with a 5 L capacity and one with a 20 L capacity, and tests conducted with the larger cylinder appear to return slightly higher bulk density values. As expected, chips produced from freshly cut trees had a higher average wet-basis bulk density than chips made from transpirationally dried trees, but the dry-basis bulk densities of chips made from fresh and transpirationally dried trees differed by less than 2%. Cutshall et al. (2011) report similar results for the bulk density of loaded chip trailers. Test results from this small sample suggest that the bulk densities of conventionally sized chips and microchips produced in this project are similar.

Table 2. Wet- and dry-basis bulk density of wood chips produced at harvest sites in southern Alabama.

| | BULK DENSITY ($kg/m^3$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 5L Wet | | 5L Dry | | | 20L Wet | | 20L Dry | |
| MATERIAL | n | mean | s | mean | s | n | mean | s | mean | s |
| **Pine, Freshly Cut:** | | | | | | | | | | |
| Clean Conventional | 5 | **377.6** | *15.2* | **164.1** | *2.6* | 7 | **404.0** | *12.7* | **175.2** | *2.6* |
| Clean Microchips | 2 | **385.9** | *4.1* | **162.0** | *4.2* | | | | | |
| WT[1] Microchips | 3 | **350.6** | *1.4* | **159.0** | *2.1* | 2 | **364.0** | *1.9* | **165.9** | *2.5* |
| **Pine, Transpirationally Dried:** | | | | | | | | | | |
| TD[2] Clean Conventional | | | | | | 15 | **283.4** | *12.7* | **171.8** | *5.8* |
| TD WT Microchips | | | | | | 2 | **267.6** | *12.9* | **163.8** | *1.3* |
| **Mixed Species:** | | | | | | | | | | |
| Mixed Spp WT Conventional | 4 | **271.7** | *23.6* | **145.8** | *24.4* | | | | | |
| Mixed Spp WT Microchips | 7 | **313.6** | *22.2* | **159.5** | *15.9* | | | | | |

[1] Whole Tree, [2] Transpirationally Dried

Results of particle size testing are presented in Table 3. The greatest fraction of conventional chips was retained on the 13 mm screen, and the greatest fraction of microchips was retained on the 7 mm screen. Transpirational drying appears to shift particle size distribution toward larger sizes in both conventional chips and microchips.

Table 3. Particle size distribution of wood chips produced at harvest sites in southern Alabama.

| | | PARTICLE SIZE (% retained on screen) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0mm | | 3mm RH[1] | | 7mm RH | | 13mm RH | | 45mm RH | |
| MATERIAL | n | mean | s | mean | s | mean | s | mean | s | mean | s |
| **Pine, Freshly Cut:** | | | | | | | | | | | |
| Clean Conventional | 7 | **1.5** | *0.2* | **7.9** | *0.7* | **27.6** | *2.2* | **62.6** | *2.8* | **0.5** | *0.4* |
| Clean Microchips | 2 | **5.2** | *1.2* | **22.0** | *0.3* | **46.4** | *0.9* | **26.6** | *0.1* | **0.0** | *0.0* |
| WT[2] Microchips | 3 | **4.3** | *2.5* | **19.3** | *2.0* | **50.0** | *5.1* | **25.9** | *1.3* | **0.5** | *0.5* |
| **Pine, Transpirationally Dried:** | | | | | | | | | | | |
| TD[3] Clean Conventional | 15 | **0.7** | *0.3* | **4.3** | *0.9* | **16.0** | *2.1* | **70.1** | *3.6* | **8.9** | *3.9* |
| TD WT Microchips | 2 | **4.2** | *0.7* | **15.7** | *0.4* | **39.0** | *3.6* | **38.1** | *0.3* | **3.1** | *2.3* |
| **Mixed Species:** | | | | | | | | | | | |
| Mixed Spp WT Conventional | 4 | **7.2** | *2.7* | **15.0** | *3.2* | **24.9** | *2.4* | **50.6** | *6.5* | **2.3** | *2.0* |
| Mixed Spp WT Microchips | 7 | **9.6** | *2.2* | **23.8** | *2.4* | **41.0** | *4.6* | **25.1** | *4.5* | **0.4** | *0.5* |

[1] Round Hole, [2] Whole Tree, [3] Transpirationally Dried

## CONCLUSION

Efforts to improve the economic efficiency of biofuels production from forest-derived feedstocks through transpirational drying and in-woods microchipping produce feedstocks that differ from conventional pulp chips with respect to moisture content, bulk density, and particle size. Ongoing sample collection and analysis is providing further data that can be used to inform policy and forest operations, but more samples are needed before statistical analysis of test results will be possible. Early findings suggest that transpirational drying reduces the moisture content and wet-basis bulk density of forest biomass, and causes a shift toward larger chip sizes while in-woods microchipping produces chips smaller than conventional chips but has little effect on moisture content or bulk density.

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