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Energy Values for Whole Trees and Crowns of Selected Species

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Abstract

Energy values, Btu's (British thermal units) per ovendry pound, were determined for whole-tree and crown materials from western hemlock {*Tsuga heterophylla* (Raf.) Sarg.), coast Douglas-fir {*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii),* and western redcedar *(Thuja plicata* Donn ex D. Don). Samples were collected from small-diameter stands in northwest Washington where whole-tree harvesting is underway. Samples of crown material representing each diameter class were composited into a single sample for each species. The whole-tree sample, collected from a van being loaded with hog fuel from the whole-tree chipping operation, was a mix of species and diameters. Crowns had a higher Btu value than did whole-tree material. With the exception of redcedar, energy values for crown material is higher than commonly used values for wood alone. Results of this study indicate that use of wood energy values may underestimate the product potential of hog fuel created from whole-tree chipping.

Keywords: Energy; whole-tree harvesting; hog fuel, wood energy; western Washington; western hemlock; Douglas-fir; western redcedar.

Background

The Quilcene Ranger District, Olympic National Forest, has about 20,000 acres of overstocked, stagnant stands comprised primarily of western hemlock {*Tsuga heterophylla (Rat.)* Sarg.), coast Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco, var. *menziesii),* and western redcedar *(Thuja plicata* Donn ex D. Don). The term "doghair"' is used to describe these stands, which have as many as 40,000 trees per acre averaging less than 8 inches in diameter (Pong and Waddell 1985, 1986). Many attempts were made to convert these stands to a more productive status. These actions were stymied by inefficient harvest equipment and lack of adequate markets for the woody biomass generated from the thousands of small-diameter trees. This situation began to change in the early 1980's when innovative harvesting and in-woods-processing equipment were developed by Hermann Brothers Logging and Construction Company. In the past 2 years, Hermann Brothers has purchased and constructed specialized equipment capable of harvesting these stands in a cost-effective manner (Lambert and Howard 1987). As important as the development of equipment to handle small trees, however, is the marketing of biomass products.

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[1] Terms used in this report are defined in "Definition of Terms."

Multiproduct marketing is a major factor in the profitability of harvesting stands-of small-diameter trees. The ability to sell all woody biomass products not only enhances the economics of stand conversion but also effectively eliminates the costs of dealing with logging residue. The current technology used to harvest doghair stands results in nearly 100-percent utilization. Biomass remaining after harvest is comprised primarily of small standing dead trees that fall apart during felling, some branches that break off during handling, and down and dead materials existing at the time of harvest.

The current processing equipment is designed to produce three products: small saw logs, pulp chips, and hog fuel. The designation of particular trees or components of trees to these products is based on diameter and existing markets. As broad market changes occur or local contracts need to be met, trees are diverted to the appropriate product. Sales of hog fuel are as important to the economics of the operation as are sales of the higher value chips and saw logs. Without a market for hog fuel, important income is lost and dispersion or treatment costs of this material become prohibitive. These costs are borne by the land manager as well as by the timber operator because the resulting logging residue might require treatment in preparation for the next crop of trees.

Pricing of hog fuel, usually sold on a dry-ton basis, is based on its net energy value to the buyer. Hog fuel from doghair stands is comprised primarily of bark, branches, foliage, and some of the smaller diameter trees not having significant value for other products. To properly value this product, the purchaser and the seller need to know the energy content. Some information exists for energy content of wood and bark for selected species (Arola 1977). Energy values for whole trees and crown materials, however, do not exist for the species being harvested from the doghair stands. This lack of information is significant in that bark and foliage have higher Btu values than does wood. The proportion in which these components occur in the hog fuel thus affects the final energy value and income derived from the harvest operation. The study was conducted to provide information on the energy content of hog fuel derived from whole-tree harvesting of small-diameter trees.

Objective

The objective of the study was to determine the higher heating value of samples of whole-tree chips and crown materials from trees being harvested in the doghair stands on the Quilcene Ranger District. Energy values (Btu's per ovendry pound) were derived for the three major species in these stands: western hemlock, Douglas-fir, and western redcedar. Hog fuel derived from these stands comes from whole-tree chips and crown materials created during the delimbing-debarking process. Because hog fuel may be created separately from these two sources, it is important that energy values from each source be known. Species were not separated during whole-tree chipping operations, which resulted in a composite value for hog fuel from this source.

Methodology

Woody biomass samples-were collected from the two sources noted above. For whole-tree chips, samples were taken from the ongoing doghair processing operation at a time when entire trees were being chipped for hog fuel. Processing was halted and samples were collected from a van that was being loaded. The samples were scooped up from various locations and depths in the van. This resulting sample, about 5 gallons, was then thoroughly mixed and a smaller sample extracted. The smaller sample was dried and ground in a Wiley mill.[2] Samples of this fine material were then taken and placed in a plastic bag. The size of the final sample was large enough to provide adequate material for at least eight Btu tests. The exact species composition of this sample was not known. The distribution of species being chipped on the day the sample was taken is assumed to be representative of the average doghair whole-tree chipping operation. Variance calculated from this sample is for the material collected and does not provide information on the variability of energy content for all doghair stands.

The samples of crown material were collected during the biomass sampling procedure described by Pong and Waddell (1986). During their biomass sampling procedure, the entire crown of sample trees was chipped. Samples were extracted for Btu testing after the chipped material was thoroughly mixed. This was done for each diameter class (1-12 inches) for the three species involved in the study. Once the crown samples for each species were collected, they were mixed again and a composite sample was taken for Btu testing. As for the whole-tree chips, this material was dried, ground in a Wiley mill, and an adequate sample was placed in a plastic bag. The bags were identified by number only, to obscure the species' identity.

Heat-content analyses were conducted by the University of Washington College of Forest Resources. Higher heating values were determined by use of a bomb calorimeter, following standard laboratory practices. All results are expressed in Btu's per ovendry pound; some samples evaluated at air-dry moisture content were corrected to ovendry conditions. Eight tests were run for each of the four samples (whole-tree; and crowns for hemlock, Douglas-fir, and western redcedar). Statistical analysis of the tests was provided by the University of Washington staff.

Results

Table 1 gives the mean Btu values for whole-tree chips and crown material, by species. Also included is information for evaluating the statistical precision of the results.

The precision of the estimates in table 1 is high, as is indicated by the low standard error of the mean for each source. As noted above, these values do not necessarily represent true mean values for all doghair stands. Mean energy content for the population could be estimated, by testing-samples collected throughout the range of doghair stands.

[2/]Ihe use of trade, firm, or corporation names in this publication is for the information; and convenience of the reader. Such use does not constitute.an.official endorsements approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Table 1—Heating values and statistical data for 8 tests of whole-tree chips and crowns for western hemlock, Doualas-fir. and western redcedar

Source	Higher heating values per ovendry pound[a]	Coefficient of variation	Standard error of the mean
	Btu's	-------- *Percent* --------	
Whole-tree chips	8,773	1.17	0.41
Crown material:			
Western hemlock	9,132	.71	.25
Douglas-fir	9,173	.86	.30
Western redcedar	9,397	.92	.33

[a] Heat released by burning a known quantity of fuel in laboratory conditions, where the heat of condensation is captured, resulting in the maximum energy potential; used as a basis for comparing fuels.

The following higher heating values (Btu per bone-dry pound) are reported by Arola (1977) and Corder (1973):

	Wood	Bark
	(Btu's per ovendry pound)	
Western hemlock	8,000-8,620	8,900- 9,400
Douglas-fir	8,438-9,050	9,800-10,100
Western redcedar	9,700	8,700

Resins have a higher heating value than wood does, about 17,000 Btu per pound (Corder 1973). Because of this, resinous woods such as cedar and Douglas-fir have higher Btu values than does less resinous wood such as hemlock. Bark, having a higher amount of resinous compounds, generally has higher Btu values than wood does. An exception to this is western redcedar (see above tabulation). In general, softwoods are more resinous than hardwoods and thus have higher heating values.

As noted earlier, the biomass sources evaluated in this study were expected to have higher energy values than did values for wood only. A comparison of table 1 values with those shown in the tabulation above show that this is generally true. The basis for this assumption was the inclusion of a high proportion of bark and foliage in both whole-tree chips and crowns. Pong and Waddell (1986) reported an average of 18-, 21-, and 24-percent crown plus bark for western hemlock, Douglas-fir, and western redcedar, respectively, for doghair stands. These proportions would lead to an expectation of higher energy values for whole-tree chips. Crown material has even higher proportions of bark and includes foliage, which results in even higher energy values, the exception is western redcedar, which has a Btu value for crown material less than the value for wood shown in the above tabulation; which may in part be attributed to the lower energy value for bark. A common figure used in manyr analyses of converting woody biomass to energy is,8,500 Btu pe^pouhd. Although this figure is usually represented as.a generalization, results from this study indicate that a higher value should be used for crowns and whole-tree chips.

The Btu values given in this report are higher heating values. This energy value is not usually available to the user because of moisture in the material. Moisture has a negative effect on heating value because heat is required to drive off the moisture. Corder (1973) shows a heat loss, required to drive off moisture, of about 13 percent for Douglas-fir bark with a moisture content of 100 percent, dry basis (that is, half the weight is water). This moisture content is about the same as that reported by Pong and Waddell (1985) for Douglas-fir wood but lower than that for western hemlock and western redcedar. Other factors in the process of converting biomass to energy lead to lower delivered heat values. Many of these losses, although differing somewhat in effect, are common to most biomass sources. Biomass sources with a higher initial heating value, therefore, usually result in greater delivered energy. Results from this study indicate that the energy values for whole trees and crowns may be greater than for wood and should be considered when the energy potential associated with whole-tree chipping operations is evaluated. Higher energy content should mean higher product values, making a relatively low-value product worth more to the seller.

Definition of Terms

Crown: The portion of a tree containing the branches (live and dead), twigs, and foliage.

Doghair: The term used in this report to describe dense stands of small-diameter trees that are overstocked and growing very slowly.

Foliage: The portion of the crown of softwood trees comprised of needles and buds.

Higher heating value: Heat released by burning a known quantity of fuel in laboratory conditions, where the heat of condensation is captured, resulting in the maximum energy potential; used as a basis for comparing fuels.

Hog fuel: Woody biomass that has been processed by a hammer hog, shredder, or similar grinding device so that it may be easily converted into heat energy (also called hogged fuel).

In-woods processing: Harvesting system in which the complete breakdown of trees into products is done at the landing, and the products are transported to markets.

Moisture content: The amount of water contained in biomass material; moisture-content, ovendry basis, commonly used by the forest products industries, is expressed as the weight of water divided by the weight of dry substance.

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Metric Conversions

1 inch = 2.54 centimeters

1 pound = 0.454 kilogram

1 ton = 0.907 metric ton

1 gallon = 3.785 liters

1 acre = 0.405 hectare

1 British thermal unit (Btu) = 1055.87 joules

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