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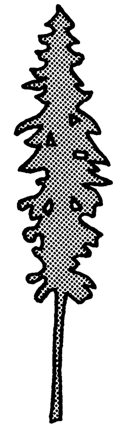
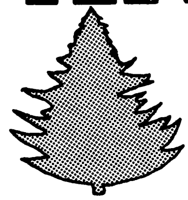
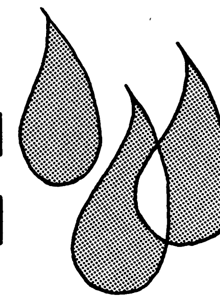
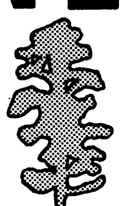
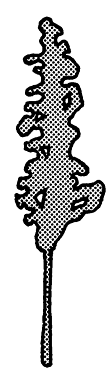


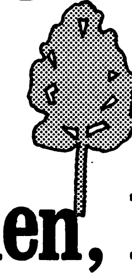
WOOD AND BARK PERCENTAGES AND MOISTURE CONTENTS OF MINNESOTA PULPWOOD SPECIES











Richard M. Marden, David C. Lothner, Edwin Kallio

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

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CONTENTS

WOOD AND BARK PERCENTAGES AND MOISTURE CONTENTS OF MINNESOTA PULPWOOD SPECIES

Richard M. Marden, David C. Lothner, and Edwin Kallio

APPLICATION

Bark has been an undesirable by-product and usually has been burned as waste or dumped as landfill--both expensive means of disposal. Recently, however, confronted with environmental concerns, the energy crisis, and a threatening fiber shortage, wood using industries have made use of bark primarily as fuel.

Those individuals involved in the roundwood market will need data on certain properties of both bark and wood as the use of bark increases. Some will need such data because weight scaling is replacing volumetric scaling in the market.

Proportion of Bark by Cubic Foot Volume

For weight scaling, it helps to know what proportion of the rough volume (wood plus bark) is bark as follows:

Species	Proportion of bark
Jack pine	6.3
Pinus banksiana Lamb.	(5.6 to 7.0)[1]
Black spruce	7.2
Picea mariana (Mill.) B.S.P.	(6.6 to 7.8)
Balsam fir	10.7
Abies balsamea (L.) Mill.	(10.1 to 11.2)
Quaking aspen	11.8
Populus tremuloides Michx.	(11.4 to 12.1)
Balsam poplar	17.5
Populus balsamifera L.	(15.6 to 19.4)

[1]*Calculated at a 95 percent confidence interval, which indicates that authors can be 95 percent certain that the values within the parentheses include the true mean.*

When this is known, the solid wood volume of pulpwood can be calculated from the rough wood volume. Furthermore it is possible to estimate a conversion factor (pounds of wood and bark per cubic foot of wood) that can be used to develop basic data for weight scaling pulpwood (Lothner, Marden, and Kallio 1974).

These data can also be used to estimate the amount of bark for use as a product or fuel that can be realized from a specified volume of rough wood. Also, the availability of this plus other information on bark weights and moisture contents can be used to develop specifications for boilers in which bark is to be used for fuel.

Dry Bark and Wood, and Moisture as a Percentage of Total Green Weight

In weight scaling, for example, if the green weight of rough wood is known, estimates can be made of dry wood and/or dry bark available for a species or process. If bark is to be used for fuel, the dry weight of bark should be determined since this value is directly related to fuel recovery. The green weight of material also has a bearing on transportation and processing costs.

The values in table 1, except for black spruce, are based on samples collected throughout a complete year. Although these values only indicate seasonal changes, there are monthly changes within a season. However, the sample sizes for any month or season for all species except aspen shown in table 1 were too small to give statistically reliable results. The monthly values for aspen are presented separately in table 2.

Table 1.--*Mean seasonal and annual ovendry weight of wood, ovendry weight of bark, and moisture weight as percentages of total green wood-bark weights*

Table 1.

Species	Period	Basis	Wood	Bark	Moisture
		No. of loads	*Percent*	*Percent*	*Percent*
Black spruce[1]	Winter	82	53.1 (52.3-53.9)[2]	5.1 (5.0-5.3)	41.8 (41.0-42.5)
Jack pine	Summer	19	50.8 (48.5-53.1)	3.9 (3.4-4.4)	45.3 (43.0-47.6)
	Winter	13	49.6 (47.0-52.2)	3.8 (3.3-4.2)	46.6 (44.1-49.1)
	Annual	32	50.3 (48.7-52.0)	3.9 (3.5-4.2)	45.8 (44.2-47.5)
Aspen	Summer	132	46.7 (46.1-47.3)	9.1 (8.8-9.4)	44.2 (43.7-44.8)
	Winter	107	40.8 (40.4-41.1)	8.6 (8.3-8.9)	50.6 (50.3-51.0)
	Annual	239	44.1 (43.5-44.6)	8.8 (8.6-9.1)	47.1 (46.6-47.6)
Balsam poplar	Summer	20	38.0 (36.8-39.2)	7.1 (6.5-7.6)	54.9 (53.8-56.0)
	Winter	22	36.0 (35.1-36.8)	8.1 (7.1-9.2)	55.9 (54.7-57.1)
	Annual	42	37.0 (36.2-37.7)	7.6 (7.0-8.2)	55.4 (54.6-56.2)
Balsam fir	Summer	18	34.9 (33.8-35.9)	6.3 (5.7-6.9)	58.8 (57.7-60.1)
	Winter	38	34.6 (33.8-35.4)	6.1 (5.8-6.4)	59.3 (58.3-60.3)
	Annual	56	34.7 (34.1-35.3)	6.2 (5.8-6.5)	59.1 (58.4-59.9)

[1] Black spruce was sampled during January, February, and March.
[2] Calculated at a 95 percent confidence interval, which indicates that authors can be 95 percent certain that values within the parentheses include the true mean.

Moisture Contents of Wood and Bark on an Ovendry Basis

The moisture content of wood or bark also can be expressed as the weight of water in the material in terms of a percentage of the ovendry weight (tables 3 and 4 and fig. 1). This provides a more understandable concept of the relative amounts of water in a material: specifically, wood or bark having equal amounts of water and dry material have a 100 percent moisture content on an ovendry basis.

Fuel moisture content is an important factor in determining air requirements and boiler design. Heat losses (heat required to drive off water) are higher for fuels having higher moisture contents. According to Corder (1973), this lowers boiler efficiency.

Seasonal and annual means are reported for most species. In table 4 and figure 1, monthly moisture contents are reported for aspen.

Table 2.--*Monthly and seasonal aspen ovendry weight of wood, ovendry weight of bark, and moisture weight as a percentage of green weight of wood and bark*

Table 2.

Month	Wood	Bark	Moisture	Basis
	Percent	*Percent*	*Percent*	*No. of loads*
June	46.2	8.9	44.9	35
	(45.2-47.2)[1]	(8.4-9.4)	(43.8-46.0)	
July	47.8	9.2	43.0	32
	(46.6-49.0)	(8.6-9.7)	(42.0-44.1)	
August	47.8	9.0	43.2	30
	(46.8-48.9)	(8.4-9.6)	(42.1-44.3)	
Sept.	46.6	9.5	43.9	22
	(45.3-47.9)	(8.7-10.4)	(42.7-45.2)	
Oct.	43.0	8.7	48.3	13
	(41.9-44.1)	(7.6-9.8)	(46.9-49.6)	
Summer	46.7	9.1	44.2	132
	(46.1-47.3)	(8.8-9.4)	(43.7-44.8)	
Nov.	41.2	8.3	50.5	9
	(39.1-43.2)	(7.2-9.4)	(48.8-52.3)	
Dec.	40.7	8.6	50.7	22
	(39.9-41.5)	(8.0-9.3)	(49.8-51.5)	
Jan.	40.3	9.2	50.5	25
	(39.5-41.0)	(8.5-10.0)	(49.6-51.4)	
Feb.	40.8	8.1	51.1	19
	(40.1-41.5)	(7.4-8.8)	(50.1-52.0)	
March	41.2	8.3	50.5	32
	(40.5-41.8)	(7.8-8.8)	(49.8-51.2)	
Winter	40.8	8.6	50.6	107
	(40.4-41.1)	(8.3-8.9)	(50.3-51.0)	

[1] Calculated at a 95 percent confidence interval, which indicates that authors can be 95 percent certain that the values within the parentheses include the true mean.

Table 3.--*Mean seasonal and annual moisture content of wood and bark on the ovendry basis*

Table 3.

Species	Period	Basis	Mean Moisture Content		
			Wood	Bark	Wood and Bark
		No. of loads	*Percent*	*Percent*	*Percent*
Black spruce[1]	Winter	82	71.6 (69.2-74.0)[2]	81.4 (78.7-84.2)	72.4 (70.1-74.7)
Jack pine	Summer	19	85.2 (76.9-93.5)	75.4 (63.7-87.1)	84.2 (76.1-92.3)
	Winter	13	89.4 (80.1-98.6)	75.1 (64.6-85.6)	88.3 (79.1-97.4)
	Annual	32	86.9 (81.0-92.8)	75.3 (67.5-83.0)	85.9 (80.1-91.6)
Aspen	Summer	132	82.5 (80.4-84.7)	67.5 (66.0-69.0)	80.0 (78.1-81.8)
	Winter	107	111.0 (109.3-112.8)	64.5 (63.1-65.8)	102.9 (101.4-104.5)
	Annual	239	95.3 (93.0-97.6)	66.1 (65.1-67.2)	90.2 (88.3-92.2)
Balsam poplar	Summer	20	129.0 (121.6-136.5)	89.3 (81.5-97.1)	122.3 (116.8-127.9)
	Winter	22	138.8 (132.4-145.2)	81.1 (70.0-92.3)	127.8 (120.7-134.7)
	Annual	42	134.1 (129.2-139.1)	85.0 (78.3-91.8)	125.2 (120.8-129.6)
Balsam fir	Summer	18	154.6 (147.0-162.1)	85.6 (78.9-92.4)	143.9 (136.6-151.2)
	Winter	38	156.8 (150.3-163.4)	89.8 (85.7-94.0)	146.8 (140.9-152.7)
	Annual	56	156.1 (151.2-161.0)	88.5 (85.0-92.0)	145.9 (141.4-150.4)

[1] Black spruce was sampled only during January, February, and March.
[2] Calculated at a 95% confidence interval, which indicates that authors can be 95% certain that values within parentheses include the true mean.

Table 4.

Month	Moisture Content: Wood	Moisture Content: Bark	Moisture Content: Wood and Bark	Basis
	Percent	*Percent*	*Percent*	*No. of loads*
June	84.2 (80.0-88.4)[1]	72.6 (69.1-76.1)	82.2 (78.4-86.0)	35
July	77.9 (73.8-81.9)	67.9 (64.7-71.1)	76.1 (72.7-79.5)	32
August	78.8 (74.7-82.8)	64.9 (62.5-67.3)	76.5 (73.0-80.0)	30
Sept.	82.2 (77.7-86.7	62.0 (59.5-64.5)	78.7 (74.8-82.6)	22
Oct.	98.8 (93.5-104.1)	67.7 (64.1-71.3)	93.6 (88.6-98.7)	13
Summer	82.5 (80.4-84.7)	67.5 (66.0-69.0)	80.0 (78.1-81.8)	132
Nov.	109.7 (101.8-117.7)	67.2 (64.4-70.0)	102.5 (95.6-109.4)	9
Dec.	111.4 (107.6-115.2)	63.9 (61.3-66.4)	103.0 (99.7-106.3	22
Jan.	110.6 (106.5-114.7)	66.3 (62.2-70.4)	102.4 (98.8-105.9)	25
Feb.	112.2 (108.1-116.4)	65.9 (62.9-68.9)	104.6 (100.6-108.6)	19
March	110.7 (107.2-114.2)	61.8 (59.9-63.7)	102.5 (99.5-105.4)	32
Winter	111.0 (109.2-112.8)	64.5 (63.1-65.8)	102.9 (101.4-104.5)	107

[1]Calculated at a 95 percent confidence interval, which indicates that authors can be 95 percent certain that values within the parentheses include the true mean.

Table 4.--*Monthly and seasonal aspen wood and bark moisture contents on an ovendry basis*

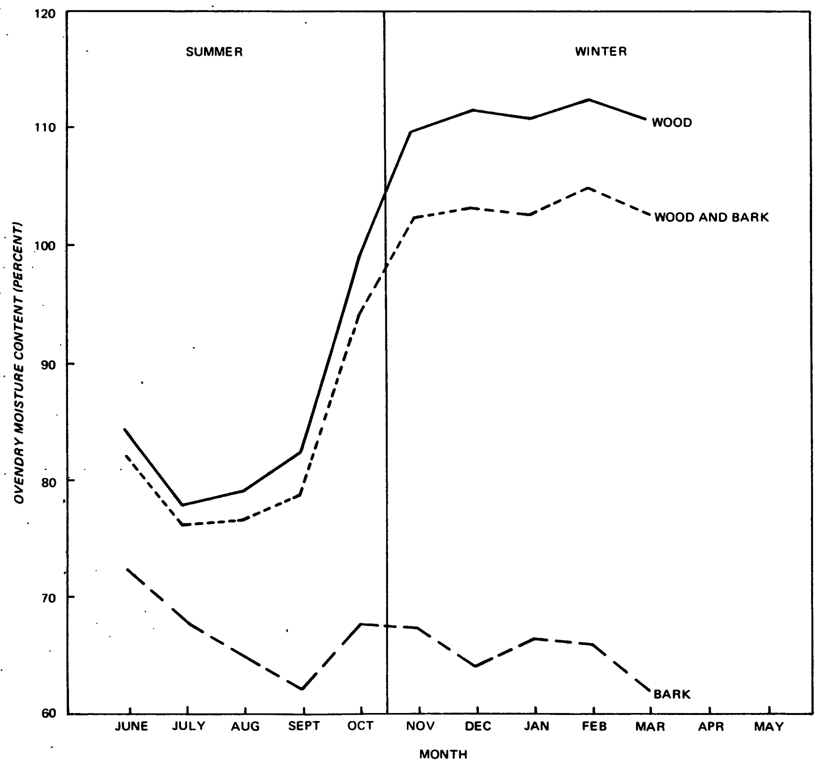

Figure 1.-- *Average monthly wood and bark moisture contents (ovendry basis) for aspen in northern Minnesota.*

DOCUMENTATION

Several early studies report on properties of wood and bark for northern pulpwood species: bark thickness and density (Hale 1955); bark volumes and fuel properties (Millikin 1955); moisture content and specific gravity (Yerkes 1967, Erickson 1972); and specific gravity (Lamb and Marden 1968). Weldon (1966) showed it is possible to estimate the amount of bark available for commercial use by applying bark weight data to production statistics. More recently, the prospects and problems of using bark for commercial products and fuel have been summarized in comprehensive reports by the Forest Products Laboratory (Harkin and Rowe 1971); Oregon State University (Van Vliet 1971, Corder 1973); and the University of Canterbury (Ellis 1973).

Study Methods

The data were collected as part of a weight scaling study that involved sampling loads of rough (bark on), 100-inch pulpwood delivered within one week after cutting in northern Minnesota during 1971-1972 (Lothner, Marden, and Kallio 1974). Inasmuch as the moisture content values obtained from this study vary with season, geographical location, time since felling, site, and sampling distribution through the year, the data are only representative of the particular sampling conditions. Likewise, the means and confidence intervals are applicable only to repeated sampling under conditions similar to those used in this study.

We cut a 1-inch disk from the middle of each of three pulp sticks randomly selected from each sample load. The average diameter outside bark (DOB) and average diameter inside bark (DIB) of the disks were measured for determining the bark percentage by volume. The disks were halved, the bark separated from the wood, and each portion weighed to a tenth of a gram.

The bark and wood portions were oven-dried and reweighed. Basic calculations were made (Appendix A) and analyses undertaken to obtain the information presented in tables 1-4.

ANALYSIS

We grouped sample load values by month and season (winter and summer), and calculated group averages and 95 percent confidence intervals accordingly. We used the one-way analysis of variance or the Kruskal-Wallis test, depending on the homegeneity of variance among groups to test for monthly and seasonal differences among group means.

The sample sizes of jack pine, balsam fir, and balsam poplar were not large enough to report statistically reliable monthly averages. Therefore, only seasonal and yearly averages and confidence intervals were determined.

For black spruce, practically all of the sample loads were obtained during the winter months (January, February, and March). Therefore, we could not analyze any other seasonal differences. In addition, our tests showed there were not any significant differences among the winter months. Therefore, only one average for the January, February, and March period is shown in table 2. The sample load distribution for aspen permitted us to test for monthly differences.

Only yearly averages are shown for percent bark by volume because measurements do not vary through the year. For the stick diameters[2] sampled, the bark percentage did not vary markedly, but the values for moisture content varied by month and season (tables 2 and 4 and fig. 1).

Moisture Content Differences Within the Pulpwood Stick

To check for moisture content variation within a pulpwood stick, we cut disks within 1 week after felling at the end and middle as well as at 1/2-, 1-, 2-, and 3-foot intervals of each of 33 aspen pulpwood sticks (12 during the summer season and 21 during the winter season). Admittedly this does not constitute a sufficient number of sample sticks to obtain sound statistical evidence, but we can make the following general observations. During the summer season, most drying of the wood takes place within the first foot from the end of the pulpwood stick and the average moisture content falls close to the 1-foot interval. For bark, drying occurs over the entire length of the pulpwood stick. During the winter season, there is not much drying of wood or bark along the stick (fig. 2).

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[2] *See Appendix B for stick DOB frequency distributions by species.*

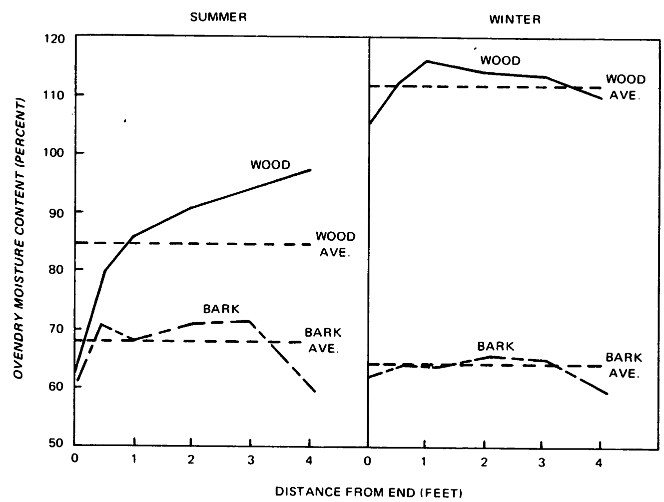

Figure 2.--*Aspen wood and bark summer and winter moisture content (ovendry basis) along pulpwood stick.*

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APPENDIX A

Basic Calculations

1. The proportion of bark by volume estimate for each load was determined as follows:

$$\text{Proportion bark by volume} = \frac{\sum_{i=1}^{\eta} DOB^2 - \sum_{i=1}^{\eta} DIB^2}{\sum_{i=1}^{\eta} DOB^2}$$

where η = number of disks cut from each load, 1-3.

2. The estimate of percent moisture content of bark and wood on an ovendry basis for each load was determined by:

$$\text{Percent moisture content} = \left[\frac{\sum_{i=1}^{\eta} \text{green wt.} - \sum_{i=1}^{\eta} \text{ovendry wt.}}{\sum_{i=1}^{\eta} \text{ovendry wt.}}\right] \times 100$$

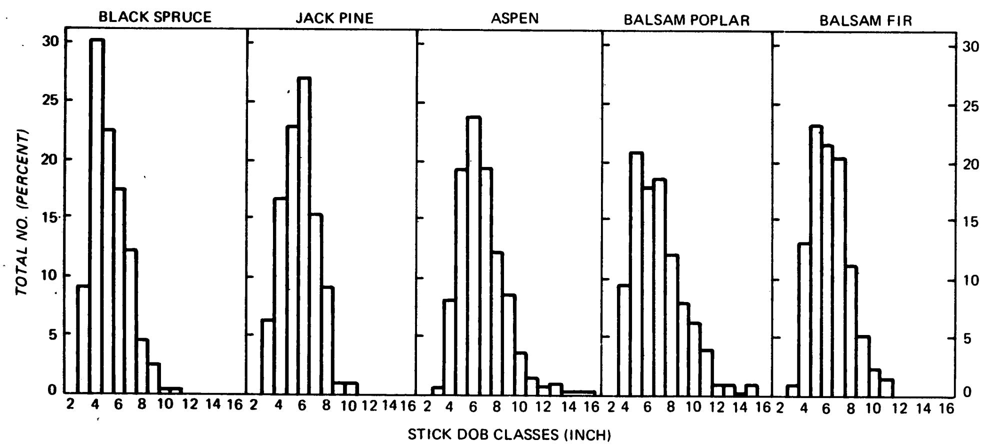
3. The percent of the total green weight represented by bark, wood, and moisture was determined as follows:

a. $$\text{Percent ovendry wt. wood (or bark)} = \frac{\sum_{i=1}^{\eta} \text{OD wt. wood (or bark)}}{\sum_{i=1}^{\eta} \text{green wt. of wood (or bark)}} \times 100$$

b. $$\text{Percent Moisture} = \frac{\sum_{i=1}^{\eta} \text{green wt. wood and bark} - \sum_{i=1}^{\eta} \text{OD wt. wood and bark}}{\sum_{i=1}^{\eta} \text{green wt. of wood and bark}}$$

APPENDIX B

Stick DOB Frequency Distribution by Species



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To help increase the use of bark for fuel or products, information is presented on the relative proportions of bark and wood by volume and weight, and also moisture contents (ovendry basis) for five northern Minnesota pulpwood species.

OXFORD: 861.0:523.0:812.211(776). KEY WORDS: weight scaling, Jack pine (*Pinus banksiana* Lamb.), Black spruce (*Picea mariana* (Mill.) B.S.P.), Balsam fir (*Abies balsamea* (L.) Mill.), Quaking aspen (*Populus tremuloides* Michx.), Balsam poplar (*Populus balsamifera* L.)

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AMERICAN REVOLUTION BICENTENNIAL

1776-1976