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Revision 1

Western Juniper Feedstock Properties

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1. INTRODUCTION

The interagency Southwest Idaho Juniper Utilization Working Group's objectives are to (1) remove western juniper (WJ) from rangelands in southwest Idaho for habitat restoration to benefit sage grouse, watersheds, and grazing on public and private property, and (2) establish emerging markets for harvested WJ for economic benefits (e.g., co-generation combined heat and power, pelletizing, commercial use, and residential applications). The working group is composed of the following agencies and private partners:

- Owyhee County
- U.S. Bureau of Land Management
- Idaho Department of Lands
- Idaho Office of Energy Resources
- Idaho Department of Commerce
- National Resource Conservation Service
- Southwest Idaho Resource Conservation and Development
- Idaho Woody Biomass Utilization Partnership
- Western Alliance for Economic Development
- Growing Excellence, Inc.
- Parma Post and Pole
- University of Idaho
- The Nature Conservancy.

Characterization of the juniper varieties is explicitly needed for possible commercialization, because little characterization data exist in the peer literature. Juniper and pinyon woodlands are a major ecosystem type found in the Southwest and the Intermountain West of the United States, intermittently ranging from Texas and the Dakotas to eastern Oregon and central California (http://www.na.fs.fed.us/pubs/silvics_manual/Volume_1.htm). These widespread ecosystems are characterized by the presence of several different species of pinyon *(Pinus sp)* and juniper (*Juniperus sp*) as the dominant plant cover. Since the 1800s, pinyon-juniper (PJ) woodlands have rapidly expanded their range at the expense of existing ecosystems. In addition, existing woodlands have become denser, progressively increasing the potential fire hazards as seen with the 2015 Soda Fire that burned more than 400 square miles (i.e., 40 miles southwest of Boise). Land managers responsible for these areas often desire to reduce juniper coverage on their lands for a variety of reasons (as stated in the Working Group's objectives described above); however, the cost of thinning PJ stands can be prohibitive. One reason for this is the lack of commercial utilization options for the resulting biomass, which could help recover some of the cost of PJ stand management. The goal of this Technical Assistance Program effort was to assess the feedstock characteristics of WJ (*Juniperus occidentalis)* harvested from Owyhee County to evaluate possible fuel and conversion utilization options.

2. SAMPLE CHARACTERIZATION

Two WJ feedstock samples were provided by the Working Group for fuel properties characterization (i.e., proximate, ultimate, and calorimetric analysis):

- Whole tree limbs (Figure 1, left)
- Wood slash – mixed chips (Figure 1, right).

Figure 1. Juniper whole tree limbs (left); juniper wood slash – mixed chips (right).

Whole WJ tree limbs were removed from standing trees; sample limbs did not come in contact with the ground. The wood slash - mixed chips were collected from pre-cut juniper; piles were in direct contact with the ground.

Upon receipt, the WJ samples from Owyhee County were fed into grinders within the Biomass Feedstock Process Demonstration Unit at Idaho National Laboratory. The samples were fed into the Vermeer HG 200 grinder (Vermeer Corporation – Pella, Iowa) with a 3/4-in. screen (Figure 2), ground to 2 mm with the Thomas Wiley Model 4 knife mill, and then ground to 0.2 mm using a Retsch ZM200 (Verder Scientific Inc., Newtown, PA). The 0.2-mm biomass was characterized to determine fuel characteristics (i.e., proximate, ultimate, and calorimetric analysis). Proximate analysis was done in accordance with American Society for Testing and Materials (ASTM) D 5142-09, "Standard Methods for Proximate Analysis of the Analysis Sample of Coal and Coke by Instrumental Procedures," and ultimate analysis was conducted using a modified ASTM D5373-10, "Standard Test Methods for Determination of Carbon, Hydrogen, and Nitrogen in Analysis Samples of Coal and Carbon in Analysis Samples of Coal and Coke," method (i.e., flour and plant tissue method) that uses a slightly different burn profile. Elemental sulfur content was determined using ASTM D4239-10, "Standard Test Methods for Sulfur in the Analysis Sample of Coal and Coke Using High-Temperature Tube Furnace Combustion Methods," and oxygen content was determined by difference. High and low heating values were determined with a calorimeter using ASTM D5865-10, "Standard Test Method for Gross Calorific Value of Coal and Coke."

Figure 2. Juniper sample being ground using a Vermeer HG 200 horizontal hammermill.

3. FUEL PROPERTIES

Based on previous work (*Assessing Pinyon-Juniper Feedstock Properties and Utilization Option*s, Technical Report INL/EXT-15-36368), the % ash for the various mulch-and-baled PJ (Table 1) reveals notable variability in the measured ash content between the PJ bales. It is not uncommon to encounter variability in the ash content between bales of herbaceous biomass, which is a result of the inherent variability of the ash in the biomass itself, with significant variability introduced in some harvesting methods. From the previous research, PJ Bale #4 had the most ash measured at 7.85% and Bale #1 had the least ash measured at 2.36%. These values of ash are markedly higher than what is observed for clean, chipped hybrid poplar, debarked lodgepole pine, or ponderosa pine at 1.24% ± 0.12 (n = 19), 0.40% ± 0.04 (n = 3), and 0.61% ± 0.26 (n = 2), respectively (data attributed to the Biomass Characterization Laboratory Team and the Bioenergy Feedstock Library*,* U.S. Department of Energy, and Idaho National Laboratory; bioenergylibrary.inl.gov [accessed, date]). One of the primary conclusions in the *Assessing Pinyon-Juniper Feedstock Properties and Utilization Options* technical report (INL/EXT-15-36368) was the need for additional testing to differentiate the sources of ash (i.e., physiological versus introduced) and understand the source of ash variability. The whole limbs provided by the Southwest Idaho Juniper Utilization Working Group, which had not come into contact with the ground, provided a good baseline for understanding intrinsic whole tree ash content and pulling apart where the ash may be coming from. In addition, by debarking the whole limb samples, we could better understand if higher ash content was present in the bark as was seen with other woody feedstocks. As observed in Table 1, the ash content varied little, from 0.47% for the debarked WJ whole limbs to 0.75% for the wood slash – mixed chip. This is less than 0.3%, which is well within or equivalent to the sample-to-sample variability for most woody sample measurements. Of significance, the overall ash content for these WJ samples was relatively low with respect to the mulch-baled PJ samples and consistent with the observed values for debarked lodgepole pine and ponderosa pine.

Table 1. Proximate and calorimetric values for the PJ, WJ and exemplar woody biomass, including hybrid poplar, lodgepole pine, and ponderosa pine. All values reported on oven dry basis.

Sample	% Volatile	% Ash	% Fixed Carbon	High Heating Value (BTU/lb)	Low Heating Value (BTU/lb)
WJ Whole limb	83.27 ± 0.58 [a]	0.63± 0.01[a]	16.10± 0.58[a]	8747.2 ± 98.7[a]	7307.1 ± 98.7[a]
WJ Whole limb debarked	82.90 ± 0.19[a]	0.47± 0.01[a]	16.63± 0.18[a]	8771.4 ± 61.7[a]	7313.1 ± 61.7[a]
WJ Wood slash	82.37 ± 0.14[a]	0.75± 0.00[a]	16.88± 0.14[a]	8880.4 ± 80.26[a]	7465.5 ± 80.26[a]
PJ Bale #1[b]	79.76 ± 0.39[a]	2.36 ± 0.10[a]	17.88 ± 0.45[a]	8762.5 ± 135.6[a]	7378.1 ± 135.6[a]
PJ Bale #2[b]	80.50 ± 1.62[a]	3.13 ± 0.01[a]	16.38 ± 1.61[a]	8646.7± 84.60[a]	7264.6 ± 84.60[a]
PJ Bale #3[b]	80.07 ± 0.24[a]	3.71 ± 0.01[a]	16.22 ± 0.24[a]	8506.6 ± 152.9[a]	7177.3 ± 152.9[a]
PJ Bale #4[b]	75.61 ± 0.23[a]	7.85 ± 0.18[a]	16.55 ± 0.24[a]	8306.1 ± 116.4[a]	6997.2 ± 116.4[a]
PJ Bale #5[b]	78.44 ± 0.50[a]	4.86 ± 0.11[a]	16.70 ± 0.50 [a]	8471.3 ± 113.2[a]	7133.7 ± 113.2[a]
Hybrid Poplar	83.97 ± 0.61[c]	1.24 ± 0.12[c]	14.79 ± 0.61[c]	8702.2 ± 121.8[c]	7297.7 ± 75.3[c]
Lodgepole Pine	86.02 ± 0.30[d]	0.40 ± 0.04[d]	13.57 ± 0.27[d]	8804.4 ± 11.4[d]	7394.7 ± 75.29[d]
Ponderosa Pine	86.36 ± 0.24[e]	0.61 ± 0..26[e]	13.03 ± 0.26[e]	8713.3 ± 503.4[e]	7255.1 ± 488.2[e]

a. n = 1 samples (standard deviation based on individual analytical replicates run in triplicate).
b. U.S. Forest Service-baled PJ biomass after grinding with a Bliss hammermill with a 3/16-in. screen installed.
c. n = 19 samples (individual samples run in triplicate; standard deviation based on individual sample replicates).
d. n = 3 samples (individual samples run in triplicate; standard deviation based on individual sample replicates).
e. n = 2 samples (individual samples run in triplicate; standard deviation based on individual sample replicates).

Proximate analysis revealed marginally higher % volatiles for each of the WJ samples tested and equivalent % fixed carbon content relative to the mulch-baled, PJ samples. The respective WJ high heating values and low heating values are marginally higher than the PJ bale average, with exception of

Bale #1, and equivalent relative to clean chipped hybrid poplar, debarked lodgepole pine, or ponderosa pine exemplars. The WJ values for % hydrogen content, % elemental carbon and % oxygen content seen in Table 2 were consistent between each of the WJ samples and consistent to mulch-baled, PJ samples. Percent sulfur was slightly higher for mulch-bale samples relative to the WJ samples. WJ values for % nitrogen content were slightly higher, on average, relative to the mulch-bale samples.

Table 2. Ultimate analysis values for PJ and WJ. All values reported on an oven dry basis.

Sample	% Hydrogen	% Carbon	% Nitrogen	% Oxygen	% Sulfur
WJ whole limb	5.88 ± 0.02[a]	50.34 ± 0.14[a]	0.16 ± 0.01[a]	42.97 ± 0.17[a]	0.02 ± 0.001[a]
WJ whole limb debarked	5.99 ± 0.04[a]	51.20 ± 0.04[a]	0.16 ± 0.01[a]	42.16 ± 0.05[a]	0.02 ± 0.001[a]
WJ wood slash	5.88 ± 0.03[a]	50.74 ± 0.17[a]	0.21 ± 0.01[a]	42.39 ± 0.20[a]	0.02 ± 0.000[a]
PJ Bale #1[b]	5.98 ± 0.03[a]	51.90 ± 0.17[a]	0.00 ± 0.03[a]	39.77 ± 0.19[a]	0.036 ± 0.001[a]
PJ Bale #2[b]	6.00 ± 0.05[a]	51.75 ± 0.10[a]	0.00 ± 0.02[a]	39.15 ± 0.16[a]	0.036 ± 0.000[a]
PJ Bale #3[b]	5.80 ± 0.10[a]	51.06 ± 0.04[a]	0.23 ± 0.25[a]	39.17 ± 0.14[a]	0.035 ± 0.003[a]
PJ Bale #4[b]	5.76 ± 0.01[a]	49.31 ± 0.10[a]	0.08 ± 0.05[a]	36.95 ± 0.16[a]	0.046 ± 0.001[a]
PJ Bale #5[b]	5.84 ± 0.02[a]	50.78 ± 0.17[a]	0.00 ± 0.01[a]	38.52 ± 0.18[a]	0.039 ± 0.001[a]

a. n = 1 sample (individual sample run in triplicate).
b. U.S. Forest Service-baled PJ biomass after grinding with a Bliss hammermill with a 3/16-in. screen installed.

4. CONCLUSION

Results revealed a notably lower ash content of the single whole and wood slash-mixed chip WJ samples, averaging only 0.62% relative to the PJ mulch-bale samples, which ranged from 2.36% to 7.85%. There was little observed difference in the ash content of the WJ whole limb and the debarked limb. Elevated ash content primarily due to soil inclusion during harvesting is the most likely entrainment method for the PJ mulch-bale samples discussed and, although limited, these data support this conclusion. The ash content of the WJ samples readily lends their use in thermal conversion processes, which ideally require low ash content (i.e., equal to or less than 1%).