Title: Chemical and physical properties of Pinyon Pine and Juniper from Lincoln County, NV

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Company: Lincoln County Regional Development Authority

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1. Project Summary

There has been extensive expansion of pinyon pine and juniper into the sagebrush ecosystem in the Great Basin over the last century (DOI-BLM, 2013). This encroachment is a source of concern because of loss of the amount and quality of habitat for wildlife, risk for large and high intensity wildfires, and alterations to hydrologic and riparian functions (DOI-BLM, 2013). The Bureau of Land Management (BLM) is proposing to thin more than 700,000 acres of pinyon pine and juniper woodlands in Lincoln County, Nevada over the next 20 years. Lincoln County Regional Development Authority (LCRDA) is actively working to attract industries that might use these woody resources as a biomass feedstock; however, quality information currently does not exist for pinyon pine or juniper growing in Lincoln County. It is of interest to understand the quality attributes of trees harvested from different stages of pinyon-juniper encroachment, so that the biomass can be mapped to appropriate conversion or other end use processes. There are three stages of pinyon-juniper encroachment; in Phase I trees are present, in Phase II trees are co-dominant, and in Phase III trees are dominant (DOI-BLM, 2013). The scope of this project focused on pinyon pine and juniper growing in Phase II and III stands in Lincoln County, Nevada.

The specific objective was to analyze the chemical and physical characteristics of pinyon pine and juniper from Phase II and a Phase III sites and determine the variability between the different woody materials. The Biomass Feedstock National User Facility at Idaho National Laboratory completed chemical composition, elemental speciation of ash, fuel properties, and particle characterization on pinyon pine and juniper samples from a Phase II and a Phase III site that were provided by LCRDA.

Results were presented by the Lincoln County Regional Development Authority at the International Biomass Conference and Expo on April 11-14, 2016, and are available to the public in the Bioenergy Feedstock Library (bioenergylibrary.inl.gov). Ultimately the analytical results will be used by the LCRDA to market these woody resources to potential bioenergy and biopower feedstock users.

2. Biomass Characterization Methods

2.1. Biomass

Pinyon pine and juniper samples were harvested using a chainsaw from BLM land on the west side of Panaca Summit off of Nevada State Route 319 in January of 2016. The samples were chipped using a 30.00 Commercial DR Rapid-Feed Chipper. The samples were further milled to pass through a ¼-inch sieve using a Schutte Buffalo Hammermill. The samples were then dried at 40°C for 48 hours to reduce the moisture for storage, and then analyzed for particle characteristics. Samples were milled to pass through a

2-mm sieve using a Thomas Model 4 Wiley Mill for composition and elemental ash. The samples were ground to 0.2mm using a Retsch ZM200 for fuel properties.

2.2. Fuel Properties

Samples were analyzed for moisture, volatiles, fixed carbon and ash using a LECO Thermogravimetric Analyzer (TGA) 701 (St. Joseph, MI, USA) following ASTM D 5142-09. Ultimate analysis (C,H,N) was performed with a LECO TruSpec CHN Analyzer following a modified ASTM D 5373-10 method (Flour and Plant Tissue Method) that uses a slightly different burn profile. *Elemental sulfur content was determined using ASTM D4239-10. Oxygen content was determined by subtracting percent carbon, nitrogen, hydrogen, and sulfur from 100 percent.* Calorimetry (high heating and low heating value) was done with a calorimeter using ASTM D5865-10.

2.3. Chemical Composition

Chemical composition was completed using NREL laboratory analytical procedures (Sluiter et al., 2010).

2.4. Elemental Ash

The elemental composition of ash was determined as described in ASTM standards D3174, D3682 and D6349.

2.5. Particle Characteristics

A digital image processing system (CAMSIZER®, Horiba Instruments Inc.) equipped with two digital cameras was used to determine particle morphology for triplicate samples ground to ¼ inch. Particle size distributions, particle diameter for the 16th, 50th, and 84th percentiles (d_{16}, d_{50}, d_{84}), and the 16%, 50%, and 84% theoretical cumulative passing percentile sieve sizes (t_{16}, t_{50}, and t_{84}; Westover et al., 2013) were calculated for $x_{c\ min}$ (width; particle diameter that is the shortest chord of a set of measured maximum chords of a particle projection) and $x_{Fe\ max}$ (length; particle diameter that is the longest Feret diameter for a set of measured Feret diameters of a particle). The cumulative passing percentile sieve sizes (e.g., t_{16}) were calculated by interpolation and represent theoretical sieve sizes that would retain 16, 50 or 84% of the particles by mass.

3. Results

3.1. Fuel Properties

Table 1. Proximate, ultimate, and calorific values for phase II pinyon pine (Bioenergy Feedstock Library GUID: 08a5c880-4853-48e8-bea6-26f37b55e1ba; reported on a dry basis)

Proximate			Ultimate					Calorimetry	
%Volatile	%Ash	%Fixed Carbon	%Hydrogen	%Carbon	%Nitrogen	%Oxygen	%Sulfur	HHV	LHV
79.26	1.90	18.84	6.28	52.49	0.58	38.70	0.04	9268	7819

Table 2. Proximate, ultimate, and calorific values for phase III pinyon pine (Bioenergy Feedstock Library GUID: 55341a91-8891-43dd-bf8b-729e2b92ec6d; reported on a dry basis)

Proximate			Ultimate					Calorimetry	
%Volatile	%Ash	%Fixed Carbon	%Hydrogen	%Carbon	%Nitrogen	%Oxygen	%Sulfur	HHV	LHV
79.64	1.85	18.52	6.27	52.70	0.52	38.63	0.04	9355	7901

Table 3. Proximate, ultimate, and calorific values for phase II juniper (Bioenergy Feedstock Library GUID: 031c749d-b618-43c3-bd9a-2fb52d2aac89; reported on a dry basis)

Proximate			Ultimate					Calorimetry	
%Volatile	%Ash	%Fixed Carbon	%Hydrogen	%Carbon	%Nitrogen	%Oxygen	%Sulfur	HHV	LHV
79.70	2.89	17.41	6.30	53.12	0.60	37.04	0.05	9517	8068

Table 4. Proximate, ultimate, and calorific values for phase III juniper (Bioenergy Feedstock Library GUID: 00af89ac-084c-4f74-8d40-1202f6c0d352; reported on a dry basis)

Proximate			Ultimate					Calorimetry	
%Volatile	%Ash	%Fixed Carbon	%Hydrogen	%Carbon	%Nitrogen	%Oxygen	%Sulfur	HHV	LHV
78.04	2.85	19.11	6.07	52.05	0.51	38.47	0.05	9129	7720

3.2. Chemical Composition

Table 5. Chemical composition of phase II pinyon pine (Bioenergy Feedstock Library GUID: 2FD580CA-A85B-BB41-AF49-2AF1F4F92E03)

%Structural Ash	%Extractable Inorganics	%Structural Protein	%Extractable Protein	%Water Extractives Others
1.48	0.95	1.94	0.34	11.02
%EtOH Extractives	**%Lignin**	**%Glucan**	**%Xylan**	**%Galactan**
9.60	31.66	22.57	5.38	3.62
%Arabinan + Mannan	**%Acetate**	**%Total**		
9.12	0.61	98.28		

Table 6. Chemical composition of phase III pinyon pine (Bioenergy Feedstock Library GUID: 5092A3E1-F73B-F24B-B6D8-FE84B35A25FB)

%Structural Ash	%Extractable Inorganics	%Structural Protein	%Extractable Protein	%Water Extractives Others
1.40	1.00	1.86	0.52	11.72
%EtOH Extractives	**%Lignin**	**%Glucan**	**%Xylan**	**%Galactan**
10.53	29.95	22.03	5.22	3.59
%Arabinan + Mannan	**%Acetate**	**%Total**		
10.13	0.79	98.73		

Table 7. Chemical composition of phase II juniper (Bioenergy Feedstock Library GUID: 2D4191C1-2483-7543-826A-7171833AE6F6)

%Structural Ash	%Extractable Inorganics	%Structural Protein	%Extractable Protein	%Water Extractives Others
3.11	0.81	2.28	0.37	11.72
%EtOH Extractives	**%Lignin**	**%Glucan**	**%Xylan**	**%Galactan**
11.53	30.98	20.11	5.37	3.47
%Arabinan + Mannan	**%Acetate**	**%Total**		
6.55	0.85	97.14		

Table 8. Chemical composition of phase III juniper (Bioenergy Feedstock Library GUID: E04E08C7-3B7A-5C47-AD20-0C9A6EF8328C)

%Structural Ash	%Extractable Inorganics	%Structural Protein	%Extractable Protein	%Water Extractives Others
3.37	1.16	1.86	0.37	9.30
%EtOH Extractives	**%Lignin**	**%Glucan**	**%Xylan**	**%Galactan**
6.63	35.13	22.94	5.65	3.72
%Arabinan + Mannan	**%Acetate**	**%Total**		
6.84	0.98	97.93		

3.3. Elemental Ash

Table 9. Elemental ash composition[a] of phase II pinyon pine (Bioenergy Feedstock Library GUID: 2fd580ca-a85b-bb41-af49-2af1f4f92e03)

%Al as Al_2O_3	%Ca as CaO	%Fe as Fe_2O_3	%K as K_2O	%Mg as MgO	%Mn as MnO	%Na as Na_2O	%P as P_2O_5	%Si as SiO_2	%Ti as TiO_2	%S as SO_3
1.61	46.05	1.09	19.64	9.59	0.21	0.22	7.75	6.28	0.08	4.21

[a]Total ash was 2.00% (held at 750°C for 8 hours).

Table 10. Elemental ash composition[a] of phase III pinyon pine (Bioenergy Feedstock Library GUID: 5092a3e1-f73b-f24b-b6d8-fe84b35a25fb)

%Al as Al_2O_3	%Ca as CaO	%Fe as Fe_2O_3	%K as K_2O	%Mg as MgO	%Mn as MnO	%Na as Na_2O	%P as P_2O_5	%Si as SiO_2	%Ti as TiO_2	%S as SO_3
1.49	44.63	1.20	20.12	8.06	0.17	0.30	7.20	5.74	0.08	4.48

[a]Total ash was 1.89% (held at 750°C for 8 hours).

Table 11. Elemental ash composition[a] of phase II juniper (Bioenergy Feedstock Library GUID: 2d4191c1-2483-7543-826a-7171833ae6f6)

%Al as Al_2O_3	%Ca as CaO	%Fe as Fe_2O_3	%K as K_2O	%Mg as MgO	%Mn as MnO	%Na as Na_2O	%P as P_2O_5	%Si as SiO_2	%Ti as TiO_2	%S as SO_3
1.46	58.55	0.63	11.00	5.85	0.07	0.27	4.93	7.11	0.08	3.96

[a]Total ash was 3.06% (held at 750°C for 8 hours).

Table 12. Elemental ash composition[a] of phase III juniper (Bioenergy Feedstock Library GUID: e04e08c7-3b7a-5c47-ad20-0c9a6ef8328c)

%Al as Al_2O_3	%Ca as CaO	%Fe as Fe_2O_3	%K as K_2O	%Mg as MgO	%Mn as MnO	%Na as Na_2O	%P as P_2O_5	%Si as SiO_2	%Ti as TiO_2	%S as SO_3
1.33	63.50	0.63	10.77	4.33	0.10	0.24	4.28	6.21	0.07	3.79

[a]Total ash was 3.18% (held at 750°C for 8 hours).

3.4. Particle Characteristics

Table 13. A digital image processing system (CAMSIZER®) was used to determine particle morphology for 1/4-inch phase II pinyon pine (Bioenergy Feedstock Library GUID: ed191925-0666-dc4d-b736-638350560be3). Particle diameter for the 16th, 50th, and 84th percentiles (d_{16}, d_{50}, d_{84}) and the 16%, 50%, and 84% theoretical cumulative passing percentile sieve sizes (t_{16}, t_{50}, and t_{84}) were calculated for $x_{c\ min}$ (width) and $x_{Fe\ max}$ (length).

Width						Length					
d_{16}	d_{50}	d_{84}	t_{16}	t_{50}	t_{84}	d_{16}	d_{50}	d_{84}	t_{16}	t_{50}	t_{84}
0.39	1.04	2.28	0.33	0.91	2.02	0.72	2.37	5.69	0.63	2.08	5.34

Table 14. A digital image processing system (CAMSIZER®) was used to determine particle morphology for 1/4-inch phase III pinyon pine (Bioenergy Feedstock Library GUID: fab4d633-2dc3-da4f-89a9-958e3e7ce597). Particle diameter for the 16th, 50th, and 84th percentiles (d_{16}, d_{50}, d_{84}) and the 16%, 50%, and 84% theoretical cumulative passing percentile sieve sizes (t_{16}, t_{50}, and t_{84}) were calculated for $x_{c\ min}$ (width) and $x_{Fe\ max}$ (length).

Width						Length					
d_{16}	d_{50}	d_{84}	t_{16}	t_{50}	t_{84}	d_{16}	d_{50}	d_{84}	t_{16}	t_{50}	t_{84}
0.41	1.05	2.18	0.34	0.87	1.86	0.77	2.33	5.00	0.66	2.00	4.26

Table 15. A digital image processing system (CAMSIZER®) was used to determine particle morphology for 1/4-inch phase II juniper (Bioenergy Feedstock Library GUID: 13953d73-b1e0-ac4f-8b56-0ec8b541f0ce). Particle diameter for the 16th, 50th, and 84th percentiles (d_{16}, d_{50}, d_{84}) and the 16%, 50%, and 84% theoretical cumulative passing percentile sieve sizes (t_{16}, t_{50}, and t_{84}) were calculated for $x_{c\ min}$ (width) and $x_{Fe\ max}$ (length).

Width						Length					
d_{16}	d_{50}	d_{84}	t_{16}	t_{50}	t_{84}	d_{16}	d_{50}	d_{84}	t_{16}	t_{50}	t_{84}
0.41	0.98	1.82	0.35	0.83	1.54	0.40	0.81	1.43	0.33	0.68	1.21

Table 16. A digital image processing system (CAMSIZER®) was used to determine particle morphology for 1/4-inch phase III juniper (Bioenergy Feedstock Library GUID: 07bf40b6-72b9-b441-aa55-2b2933201f91). Particle diameter for the 16th, 50th, and 84th percentiles (d_{16}, d_{50}, d_{84}) and the 16%, 50%, and 84% theoretical cumulative passing percentile sieve sizes (t_{16}, t_{50}, and t_{84}) were calculated for $x_{c\ min}$ (width) and $x_{Fe\ max}$ (length).

Width						Length					
d_{16}	d_{50}	d_{84}	t_{16}	t_{50}	t_{84}	d_{16}	d_{50}	d_{84}	t_{16}	t_{50}	t_{84}
0.38	0.92	1.71	0.32	0.78	1.41	0.70	1.82	4.22	0.59	1.52	3.56

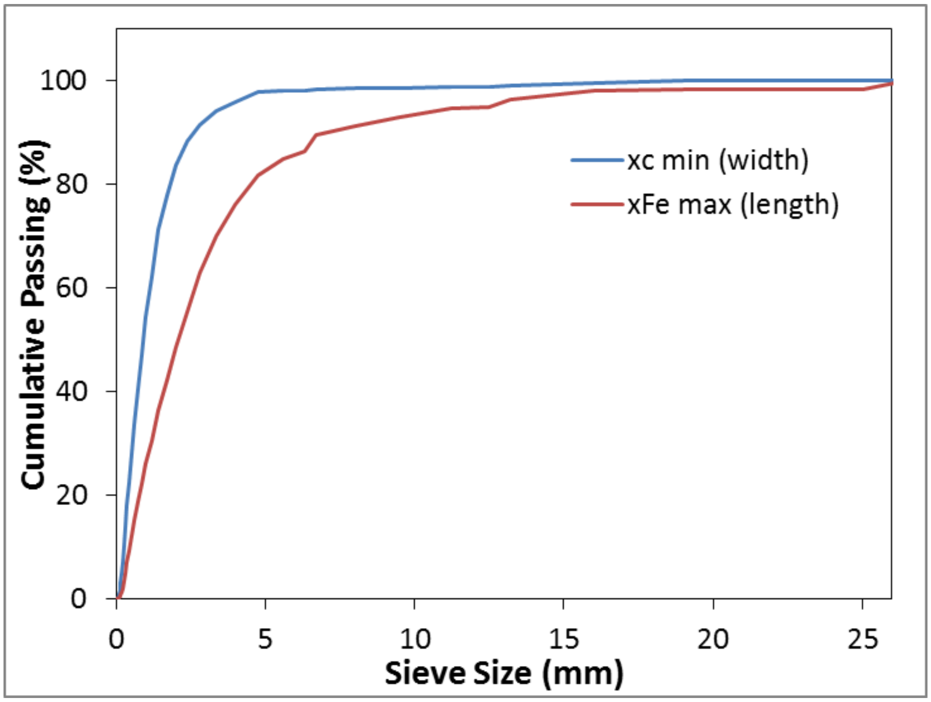

Figure 1. Cumulative passing percent of 1/4-inch phase II pinyon pine (Bioenergy Feedstock Library GUID: ed191925-0666-dc4d-b736-638350560be3) determined using a digital image processing system (CAMSIZER®).

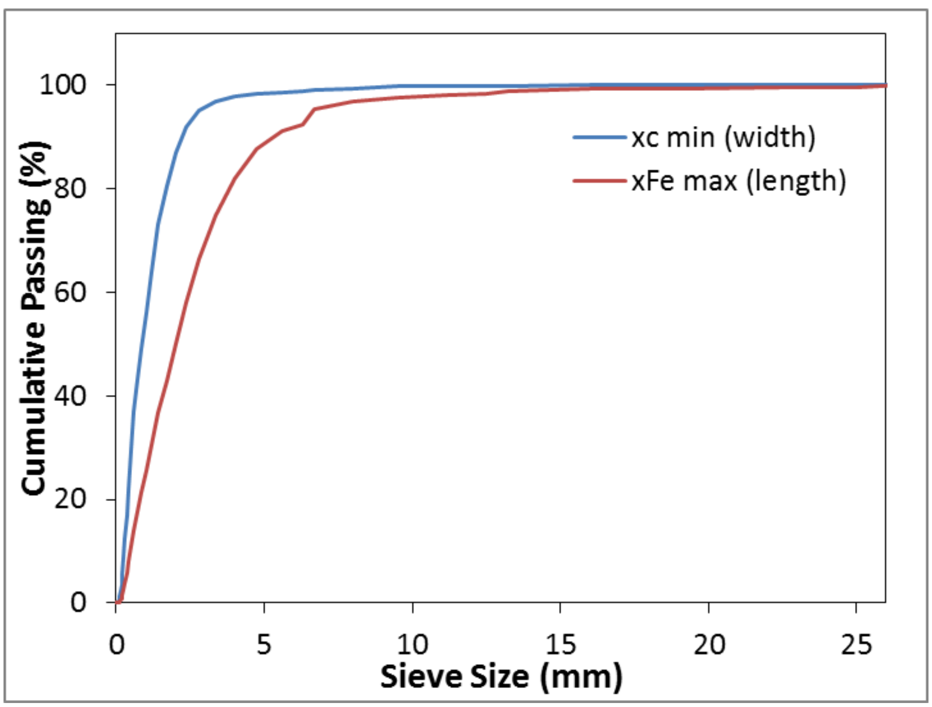

Figure 2. Cumulative passing percent of 1/4-inch phase III pinyon pine (Bioenergy Feedstock Library GUID: fab4d633-2dc3-da4f-89a9-958e3e7ce597) determined using a digital image processing system (CAMSIZER®).

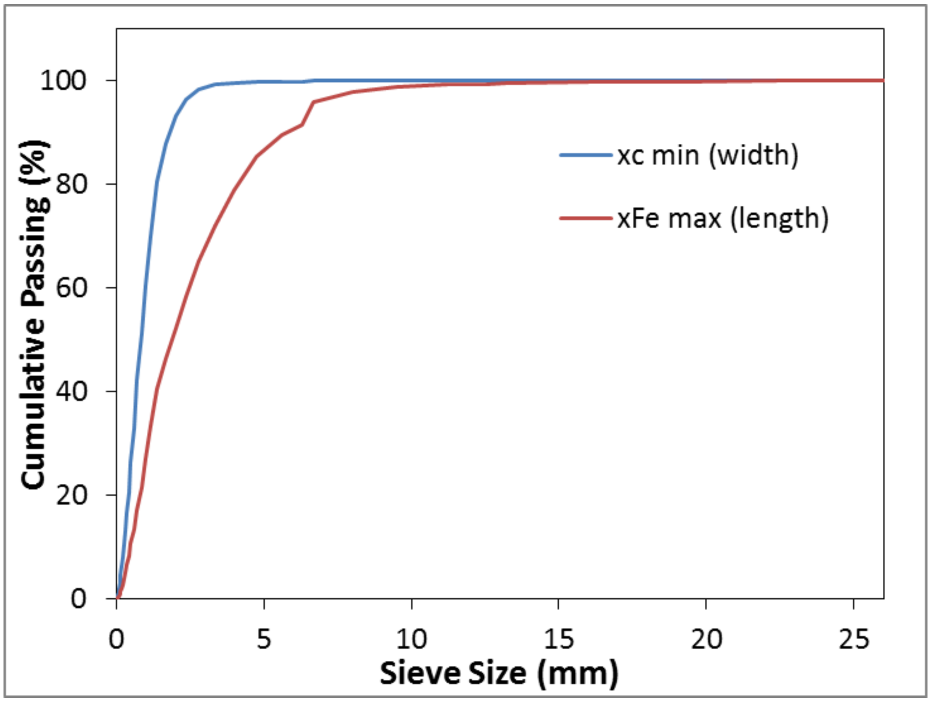

Figure 3. Cumulative passing percent of 1/4-inch phase II juniper (Bioenergy Feedstock Library GUID: 13953d73-b1e0-ac4f-8b56-0ec8b541f0ce) determined using a digital image processing system (CAMSIZER®).

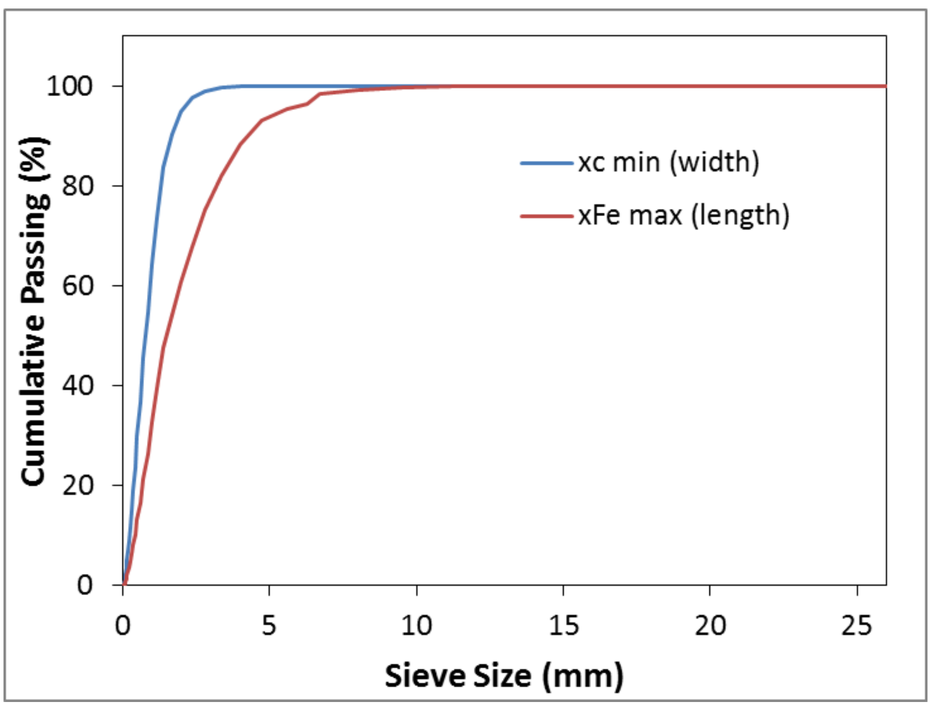

Figure 4. Cumulative passing percent of 1/4-inch phase III juniper (Bioenergy Feedstock Library GUID: 07bf40b6-72b9-b441-aa55-2b2933201f91) determined using a digital image processing system (CAMSIZER®).

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