Testing Residual Lignin As An Binder For Wood Pellets

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Background

The United States Environmental Protection Agency (USDA) has set a new regulation to reduce our greenhouse gas emissions by 25 percent by 2020. Greenhouse gas emissions are one of the biggest contributing factors to global warming. Reducing these emissions will greatly help the longevity of the planet. The goal of this research was to bond residual Douglas-fir lignin from various methods of enzymatic hydrolysis with wood particles in order to create wood pellets. It was specifically focused on testing these bonded pellets for breakage strength and gross calorific value. This data could serve as a foundation for future research in the terms of utilizing wood lignin as a solid fuel source to help reduce our usage of coal. Our hopes are that future researchers will use this information and consider lignin bonded pellets as a possible alternative to coal in the production of power and heat.

Objectives

This investigation tested if lignin could be bonded with wood to create wood pellets with high durability as measured by the breakage strength of the pellets and with high heating value as measured by the gross calorific value. The purpose was to find lignin residues a value-added application, which will compensate the cost of biofuel production.

Materials

H_2SO_4	NaOH	H_2O	Blank
Ball milled, 35.4 mm; Autoclaved at 121 °C for 3h, 15% solid, 0.5% H_2SO_4; Enzymatic hydrolyzed, 5.5% enzymes/dry wood and vacuum filter separated	Ball milled, 35.4 mm; Autoclaved at 121 °C for 3h, 15% solid, 0.5% NaOH; Enzymatic hydrolyzed, 5.5% enzymes/dry wood and vacuum filter separated	Ball milled, 35.4 mm; Autoclaved at 121°C for 3h, 15% solid; Enzymatic hydrolyzed, 5.5% enzymes/dry wood and vacuum filter separated	Ball milled, 35.4 mm; 15% solid; Enzymatic hydrolyzed, 5.5% enzymes/dry wood and vacuum filter separated

Table 1 Sources of hydrolysis lignin residues. Post milling treatment conditions and the control (blank)

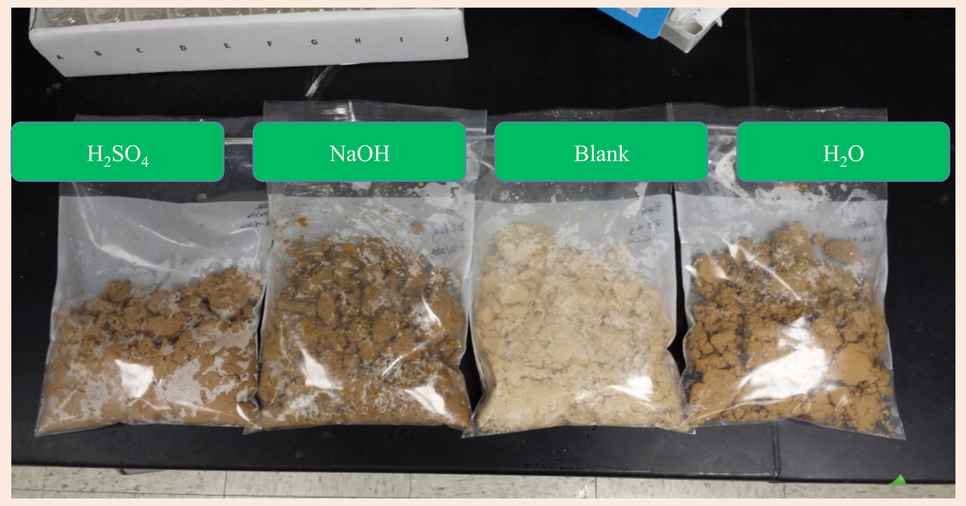

Fig. 1 Wet lignin residues after vacuum filtration, Moisture is around 250%

Fig. 2 dry lignin residues. moisture is around 5%

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Pellet Making

The wet lignin residues (Fig. 1) were air dried to be 4-5 percent of moisture content. The dried lignin residues formed clumps of balls and stuck to itself firmly (Fig. 2). To resolve the issue, the lignin residues were ground with a Wiley mill to pass 20 mesh. The particles were then combined at 30 and 60 percent with the ball milled Douglas-fir wood powders or 100 percent lignin. The mixtures of wood and/or lignin were then consolidated into the pellets through a pelletizer at 120 °C.

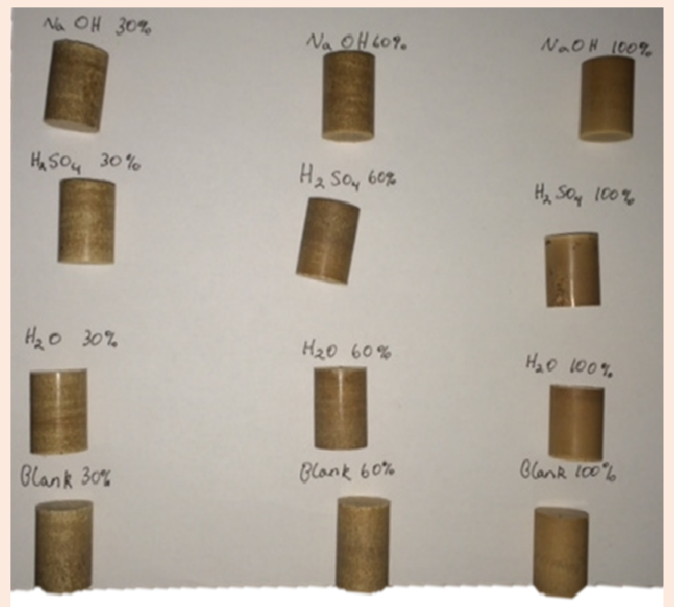

Fig. 3 Pellets made from lignin residues and wood

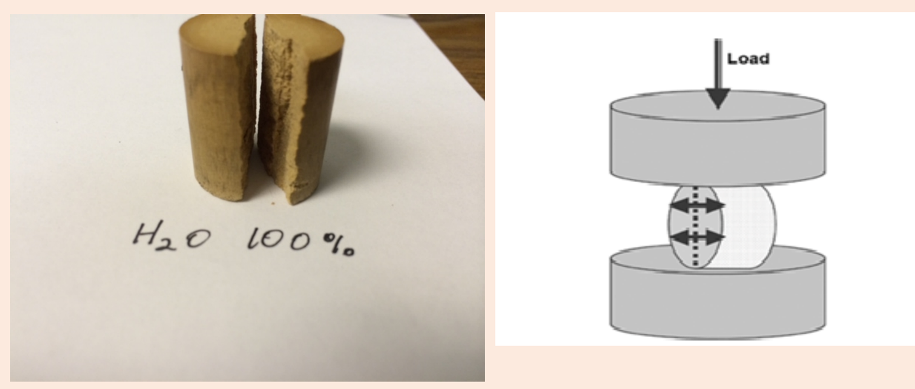

Fig. 4 Failure mode under diametric compression (left); the specimens were compressed diametrically introducing tensile stress in the pellet in the plane of the force application (Right)

Breakage Strength of Pellet

The pellets were tested for breakage strength by diametrical compression. The maximum force at their breaking point in pounds test provides a quick measurement of the quality of pellets .

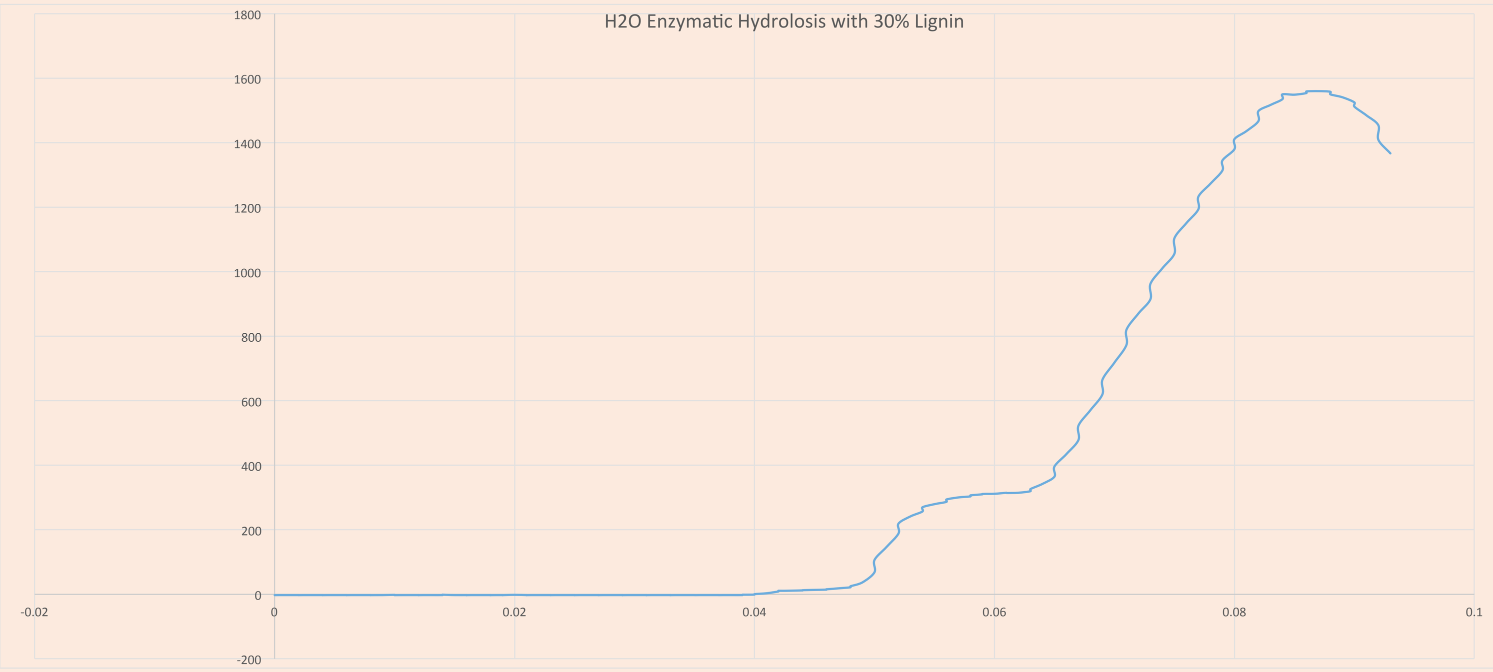

Fig. 5 the force (lb) vs. displacement (mm) graph of the pellet under diametric compression made with 30% lignin from the hot H_2O treated.

	30% Lignin	60% Lignin	100% Lignin
H_2SO_4	1271 lb	1707 lb	1152 lb
NaOH	1513 lb	2167 lb	1766 lb
H_2O	1560 lb	2142 lb	1693 lb
Blank	1406 lb	1707 lb	2658 lb

Table 2 The breakage strength (load P) of the pellets made from different lignin residues. It is important to note that the pellets made from 100% lignin residues broke in half typically in the plane of the force application.

Heating Value of Pellets

Each pellet was afterwards tested for its gross calorific value. Specifically, the part of each pellet was oven-dried, placed in the bomb, and then filled with pure oxygen. The bomb was then placed in a calorimeter filled with distilled water and equipped with a stirring device and a thermometer. Combustion was started and released heat was measured through the difference between the initial temperature and the maximum temperature of the distilled water. Their averages of three replicates are shown in Table 3. It appeared to be that the calorific value of the pellets decreased with increasing lignin content, which was against common knowledge that lignin has a higher heating value than other wood components. Dilute acid (H_2SO_4) and dilute alkali (NaOH) treated had lower gross calorific values likely due to the increase of their lignin carbon oxidation state by acid or alkaline treatments.

	30% Lignin	60% Lignin	100% Lignin
H_2SO_4	8699	8619	8413
NaOH	8714	8629	8425
H_2O	8744	8722	8750
Blank	8723	8660	8559

Table 3. The averages of gross calorific values of three samples for each lignin percentage and hydrolysis type measured in Btu/lb

Conclusion

1. Lignin residues with a wet moisture content directly after vacuum filter separation is not a good binder for making pellets.
2. While dried to 5 percent moisture content, lignin residues were a good binder for making wood pellets stronger as indicated by high diametrical breakage strength.
3. However, lignin residues did not prove to be an energy enhancer as their heating values decreased with increasing their content.
4. Pellet became more brittle the higher the percentage of lignin in the pellet.

Future Directions

- Discover if enzymatic hydrolysis actually damages lignin.
- Figure out why lignin becomes more brittle as its content increases when making pallets
- It is suggested that chemical composition of lignin residues and lignin residue bonded pellets be analyzed to see if burning the pellets in homes is actually safe to the environment.

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