Influence of Hemicellulose Extraction on Physical and Mechanical Behavior of OSB

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Introduction

The use of wood (cellulose) for the production of biofuel is progressing rapidly, but the utilization of wood in biofuel is historically not economically viable in part because the remaining solids are not used for other goods **(Lasure and Zhang 2004)**.

Hemicellulose is most easily removed since it is an amorphous and branched polysaccharide. Wood strands are a good candidate due to minimal mass transport restrictions (thickness less than 0.045").

U.S. and Canada OSB production in 2006 was 14.24 millions tonnes **(Adair 2004)**. Assuming a 15% weight removal of hemicellulose by hydrolysis of the strands would result in an annual production of 2.14 million tonnes of hemicellulose.

Considering that the hemicellulose removed is 87% xylose **(Boussaid et al. 1998)**, and assuming a modest conversion rate from xylose to ethanol of 0.35 g. ethanol/g. xylose **(Jeffries 1985)**, then we could have around 0.65 million tones of ethanol. If the ethanol density is 0.789 g/cm3 and one-cubic centimeter represents 6.29 x 10^6 barrels (US. petroleum), this would translate to 5.19 million barrels of ethanol/year. U.S. corn-based production in 2006 was 100 millions barrels **(Service 2007)**. U.S. consumption was over 5,475 millions barrels /year of petroleum products in 2004 **(U.S Department of Energy 2007)**.

Research Overview and Objective

The general objective of this research is to investigate, the influence of the hemicelluloses by hot water extraction on physical, mechanical, and microstructure properties of wood strand and the production of OSB panels from the modified wood. Determination of the chemical composition of the extracted compounds is the focus of a comparison study. Conversion of the extract to ethanol is not within the scope of this study.

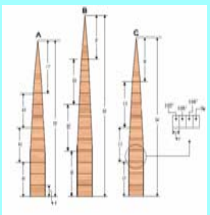
Hot Water Extraction

Background

- ✓ **Prehydrolysis**: mildly acidic by heating water at 170 °C **(Lai 1990)**.
- ✓ **Auto hydrolysis**: steam (175-220°C) by organic solvents **(Lai 1990)**.
- ✓ **Steam explosion**: at 200-250°C by explosive discharge **(Puls & Saake 2004)**.
- ✓ **Enzymatic hydrolysis**: by a group of enzymes **(Jeoh 1998)**.
- ✓ **Hot Water Extraction**: high pressure at 140-190°C **(Yoon et al. 2006)**.

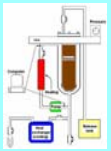
Materials & specimen preparation

- ✓ Red maple (Acer rubrum), debarked and stranded mechanically.
- ✓ Strands were dried and conditioned at 100°F and 60% RH (MC = 10.1%).

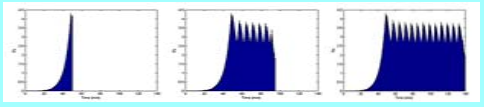


Extraction process

- ✓ 1.1 pound batches.
- ✓ Liquid-solid = 4.
- ✓ Preheating time of 50 min and two extraction times (45 or 90 min).
- ✓ 3 replicas (54 samples).
- ✓ Weight loss was determined by freeze drying the extract.
- ✓ Extraction conditions were equated to an Ro **(Overend and Chornet 1987, Mosier et al. 2002)**.



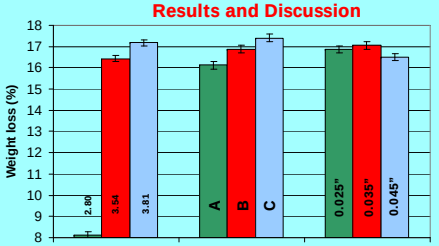
$$Ro = \int_0^t \exp\left[\frac{T_r - T_b}{14.75}\right] dt$$



Ro_2.80 Ro_3.54 Ro_3.81

Hot Water Extraction

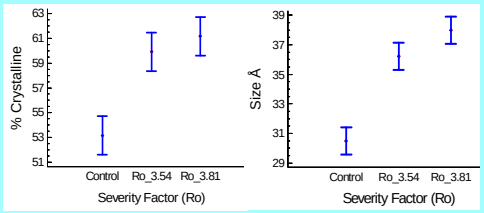
Results and Discussion



Wood Modification

Cellulose Crystallinity and Size

By Panalytical X'Pert XRD

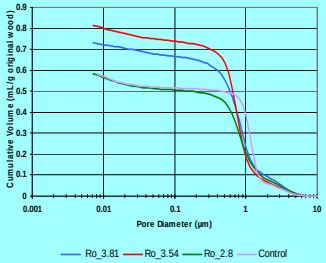


Porosity Distribution

Sample And Preparation Procedure

Matched specimens from micro-structure were used and randomly selected (10 replicas). Every specimen was trimmed to 1 in. in diameter and oven dried (102 C).

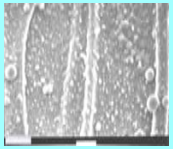
- ✓ Poresizer 9320
- ✓ ISO/AWI 15901-1 standard.

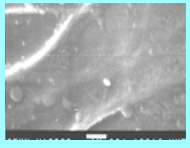


Microstructure

Sample preparation After specimen selection, individual strands were submerged in acetone (100%) for 3 minutes until saturated to dissolve surface deposits.

Before After





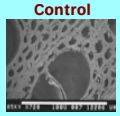
Procedure

- ✓ AMRAY 1000 SEM to 5 kV **(Kultikova 1999)**.
- ✓ Gold coated to 400 Å in a vacuum evaporator.

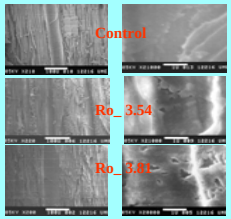
Microstructure

Cross section Surface evaluation

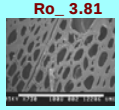
Control



Low magnification High magnification



Ro_ 3.81

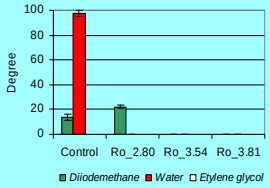


Contact Angle

Procedure

Drop size of 5 microliters and 12 replicas, all combinations.

Faster-penetration of the liquids (few seconds).



Panel Properties

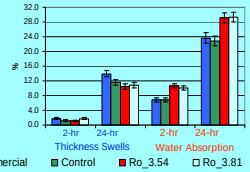
OSB Panel preparation and procedures

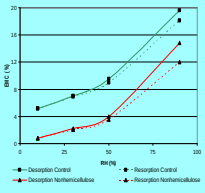
- ✓ A total of 27 source combinations (3 factors in 3 levels with 3 repetitions).
- ✓ Strands were conditioned to 8-10% MC, blended with 3.2% pMDI (name) at 2.72 ounce/min. No wax was added.
- ✓ The press temperature was 350 °F. Closing time: 30 sec., press time: 5 min. and 30 sec. of decompression cycle. Target panel thickness and density was 0.5 in. and 42 pcf (12% MC basis), respectively.
- ✓ Panels were edge trimmed, measured, and conditioned at 70 °F, 65% RH until constant weight was attained.

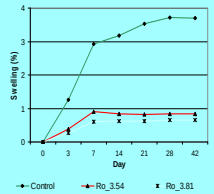
Results and Discussion

Physical properties

- ✓ ASTM D-1037
- ✓ ASTM D-4933
- ✓ At 70°F & 65% RH



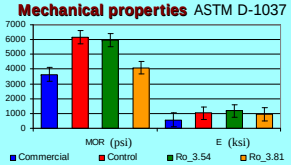




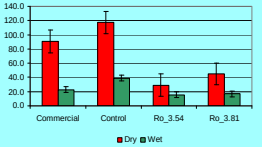
Results and Discussion

Mechanical properties ASTM D-1037

Flexure



Internal Bond



Conclusions

1. *Extraction process*
   - ✓ The severity factor (extraction time, Ro) and Tree source significantly influenced weight loss.
   - ✓ Strand thickness had no significant impact on weight loss.
2. *Wood modification*
   - ✓ Cellulose crystallinity and size increased.
   - ✓ The intra cell wall porosity was shown to be approx. 12% higher.
   - ✓ Cell wall damage was shown to occur as evidenced by pitting.
   - ✓ A significant increase in liquid penetration rate was exhibited.
3. *Panel properties*
   - ✓ The water absorption mainly in 24-hour was significantly greater.
   - ✓ The sorption curves of extracted wood strands were strongly lowered compared to control material.
   - ✓ Dimensional stability in air of OSB panels were enhanced after hemicellulose removal.
   - ✓ The flexural strength (MOR) was similar for control for Ro_3.54 but exhibited a significant decrease at Ro_3.81.
   - ✓ The internal bond in dry and wet conditions from both extractions were significantly lower.

General Conclusion: The Ro_3.54 (15% weight loss) provide the better physical and mechanical properties.

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