Evaluating Pretreatment Technologies for Converting Washington Biomass to Bio-ethanol

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INTRODUCTION

•The majority of biomass available in Washington State is cellulosic material in the form of green waste, straw, and forest residues.

•These organic residues consist of mainly *cellulose* and *hemicellulose,* whose basic units are sugars that can be fermented into ethanol or other useful chemicals.

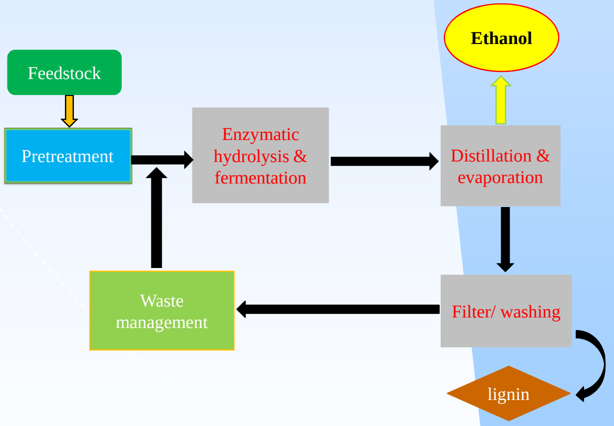
•Pretreating the biomass to release sugar is one of the main bottlenecks.

•The purpose of this project is to investigate three pretreatment technologies and five different feedstocks from Washington State and to optimize conditions for the generation of bio-ethanol.

Sources and quantities of raw materials in Washington State

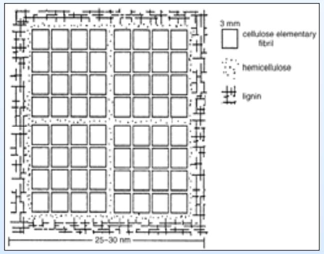
Feedstock	Production (tons/year)
Wheat straw	1,614,000
Barley straw	318,500
Logging residue	1,901,000
Forest thinning	506,000
Mill residue	5,278,000
Wood residues-MSW	834,000

A flowchart of ethanol production using lignocellulosic materials



Challenges of using lignocellulosics for ethanol production

Lignocellulosic materials are not easily degraded by microbial organisms because of the structure of the cell wall. Its primary function is to protect the structural integrity of the plant against exterior damages in nature. The cell wall is composed of a matrix polysaccharides in order to minimize the accessibility of hydrolytic enzymes to the plant. This poses a challenge in the enzymatic hydrolysis and fermentation step during ethanol production.



Structure of a plant cell wall

Pretreatment to degrade the cell wall

Pretreatment before hydrolysis is conducted in order to weaken biomass recalcitrance either by breaking into the structure and increasing the surface area of exposed cellulose or by removing lignin and hemicellulose and exposing the cellulose.

OBJECTIVES

1. Optimize the pretreatment conditions on the basis of enzymatic hydrolysis results for each of five kinds of feedstock from Washington State resources.
2. Evaluate the fermentability of the hydrolysates from the most promising pretreatment conditions for each pretreatment technology and each kind of feedstock.

EXPERIMENTAL DESIGN

Pretreatment	Conditions
Dilute acid	Treat samples in Parr reactor with 1% (w/w) sulfuric acid • Solid loading (w/v): 10%, 20% • Reaction temperature: 175 C, 200 C, 225 C • Reaction time: 30 min., 45 min.
Lime	Treat samples at controlled temperatures with a water loading of 5 g/g dry biomass • Lime loading (g/g dry biomass): 0.05, 0.1 • Reaction temperature:100 C, 120 C • Reaction time: 1 hr., 2 hr., 3 hr.
Soaking in aqueous ammonia (SAA)	Treat samples at 60 C • Solid-to-liquid ratio (w/v): 9%–15% • Reaction time: 36 hr. – 60 hr. • NH_3·H_2Oconcentration (wt%): 15 – 25
Control	Treat samples with water corresponding to the above pretreatment conditions as controls

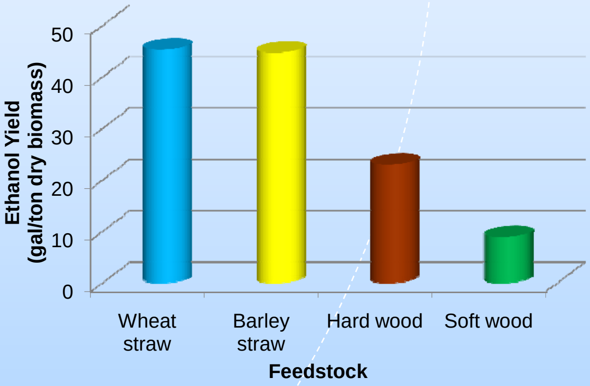
RESULTS

C6 sugar released after enzymatic hydrolysis and ethanol produced after SSF under optimal pretreatment conditions

Feedstock	Dilute Acid pretreatment			Lime pretreatment			SAA pretreatment		
	C5	C6	Ethanol	C5	C6	Ethanol	C5	C6	Ethanol
Wheat straw	11.1 (36.1)	179.2 (94.2)	147.8 (14.6)	80.1 (16.2)	176.8 (123.6)	131.5 (0.8)	26.1 (9.1)	179.1 (57.8)	**149.0** (0.5)
Barley straw	4.7 (28.1)	175.7 (135.1)	141.5 (20.0)	106.6 (23.5)	242.9 (171.7)	128.1 (1.2)	80.7 (12.5)	330.0 (70.6)	**147.1** (1.7)
Hard wood	0.6 (13.5)	53.8 (56.9)	42.4 (4.0)	37.6 (11.8)	93.6 (90.8)	66.0 (0.7)	17.0 (3.2)	119.3 (67.7)	**75.4** (0.1)
Soft wood	0.3 (4.4)	29.2 (34.9)	22.4 (0.9)	11.2 (20.8)	73.9 (75.5)	**29.1** (0.1)	4.3 (3.4)	36.3 (24.8)	25.6 (0.0)
Biomass mixture	1.2 (16.2)	80.5 (105.1)	90.2 (10.1)	55.8 (16.7)	152.1 (137.2)	85.6 (0.4)	30.1 (7.2)	157.6 (61.5)	100.6 (0.2)

C6 sugar values are all given in mg/g dry biomass. The values in parentheses are control values for C6 sugars yield and ethanol yield, as obtained by using the water pretreatment corresponding to each optimal pretreatment condition for each feedstock.

Ethanol yield for each chosen feedstock based on C6 sugar (gal/ ton dry biomass)



CONCLUSIONS

1. Pretreatment is extremely important in ethanol production from lignocellulosic material.
2. Based on the three pretreatment technologies investigated, straw samples can generate more sugars and produce more ethanol than woody biomass.
3. SAA pretreatment is recommended for wheat straw, barley straw, and hard wood based on ethanol yield.
4. Lime pretreatment is recommended for soft wood samples, based on ethanol yield.
5. Dilute acid pretreatment should be considered based on factors beyond ethanol yield.

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