Effects of Hot Water Extraction (HWE) Pre-process on the Downstream Sulfite Pretreatment to Overcome Recalcitrance of Lignocellulose (SPORL) and Sugar Yields of Douglas fir

Rui Zhu, Vikram Yadama
Composite Materials and Engineering Center (CMEC), Washington State University, Pullman, WA, 99164-4630

INTRODUCTION

Relatively less research has focused on utilizing softwood for biofuels production due to its strong recalcitrance to bioconversion.

Low severity pre-processes at the depots will increase the availability of biomass in their economical transportation range and reduce the feedstock supply risk [1].

HWE, which uses water at elevated temperature to solubilize saccharides, could be a very promising pre-process.

HWE could also provide other value-added products during the initial fractionations.

HWE can be effective because:

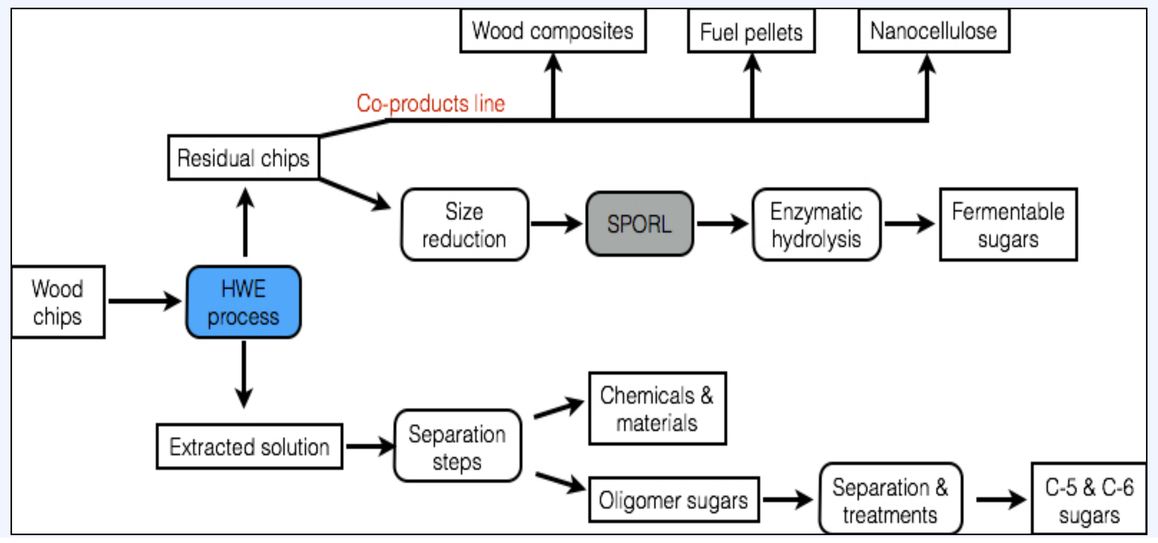
- *It improves hydrophobicity of biomass due to the partial removal of hemicellulose*
- *It opens the cell wall structures thereby facilitating the downstream pretreatment process*
- *Hot water extracted residues have higher heating value, lower ash content and higher carbon percentage*

SPORL produces readily digestible substrates and low amount of fermentation inhibitors, and has been shown to be effective for softwood bioconversion [2].

A rigorous optimization of the pretreatment conditions is critical to effectively reduce the overall cost.

The considerable high energy and chemical dosages are still the drawbacks of SPORL.

This study examines the influences of HWE on SPORL process, such that these technologies can be integrated to produce portfolio products as depicted below.



OBJECTIVES

It is envisioned that the partial removal of hemicelluloses and disruption of cell wall structure during HWE pre-process could facilitate the downstream SPORL.

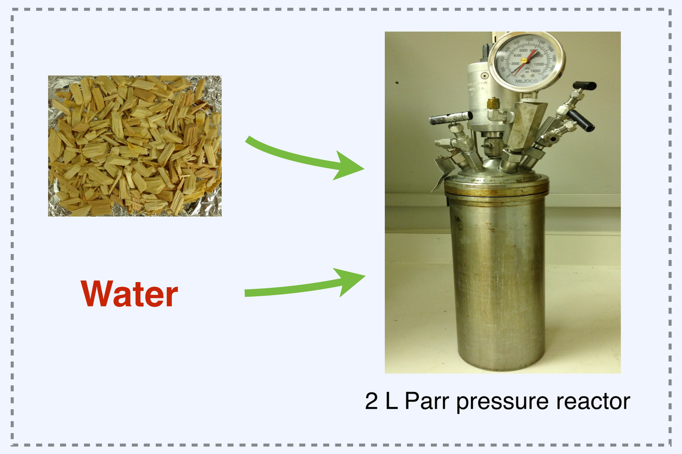
Main objective of the study: to investigate the effects of HWE pre-process on reducing the severity of downstream SPORL that derives high yield of fermentable sugars.

Tasks to achieve this goal:

- Investigate the impacts of HWE pre-process on biomass characteristics
- Evaluate the effects of HWE pre-process on SPORL by varying duration time, temperature and sulfuric acid dosage of SPORL
- Define the optimal SPORL condition by measuring the amount of fermentable sugars from enzymatic hydrolysis

METHODS AND RESULTS

Effects of HWE on biomass characteristics



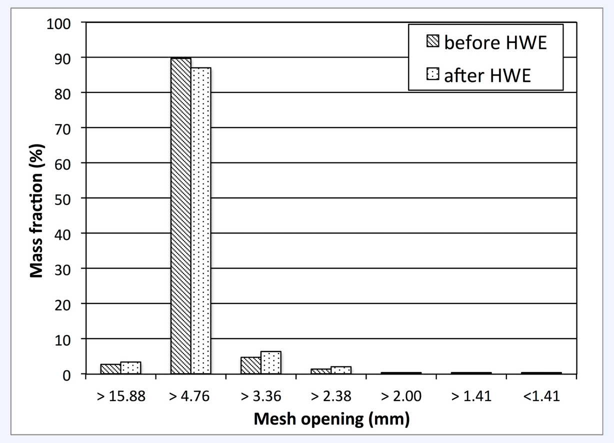


FIGURE 1. Particle size distribution of wood chips before and after HWE pre-process.

TABLE 1. Specific surface area and chemical compositions of untreated and HWE pre-processed Douglas fir.

Sample	Specific surface area (m^2/g)	Klason lignin (%)	Glucan (%)	Xylan/Mannan (%)	Galactan (%)	Arabinan (%)
Untreated Douglas fir	0.67770	27.93	46.13	16.59	2.92	1.20
HWE pre-processed Douglas fir	1.4153	31.30	51.24	10.58	1.14	0.00

SPORL formulations

TABLE 2. SPORL conditions for Douglas fir.

Run label	HWE	Time (min)	Temperature (°C)	Acid volume fraction (%)	CSF
Control	no	120	155	0.4	1.82
t120-T135-A4	yes	120	135	0.4	1.23
t40-T155-A4		40	155	0.4	1.34
t120-T155-A2		120	155	0.2	1.45
t120-T145-A4		120	145	0.4	1.52
t80-T155-A4		80	155	0.4	1.64
t120-T155-A3		120	155	0.3	1.71
t120-T155-A4		120	155	0.4	1.82

$$CSF = \log\left(t * \exp[(T_H - T_R)/14.75]\right) - pH$$

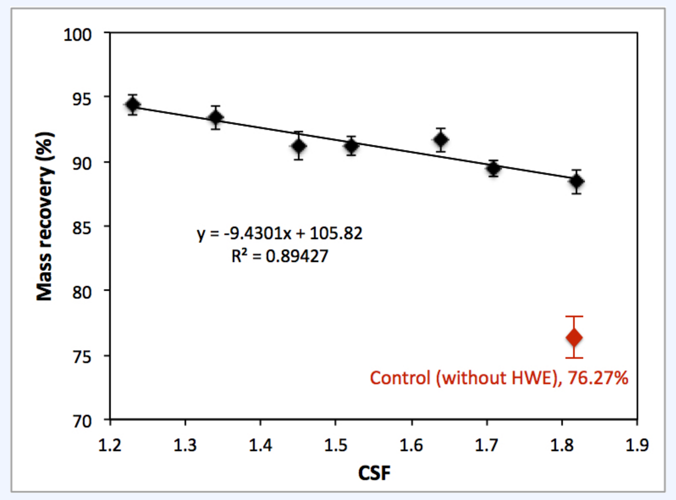


FIGURE 2. Correlation of biomass mass recovery (%) with the CSF in the SPORL pretreatment.

Compositional changes of substrate & Monomeric sugar recovery in spend liquor

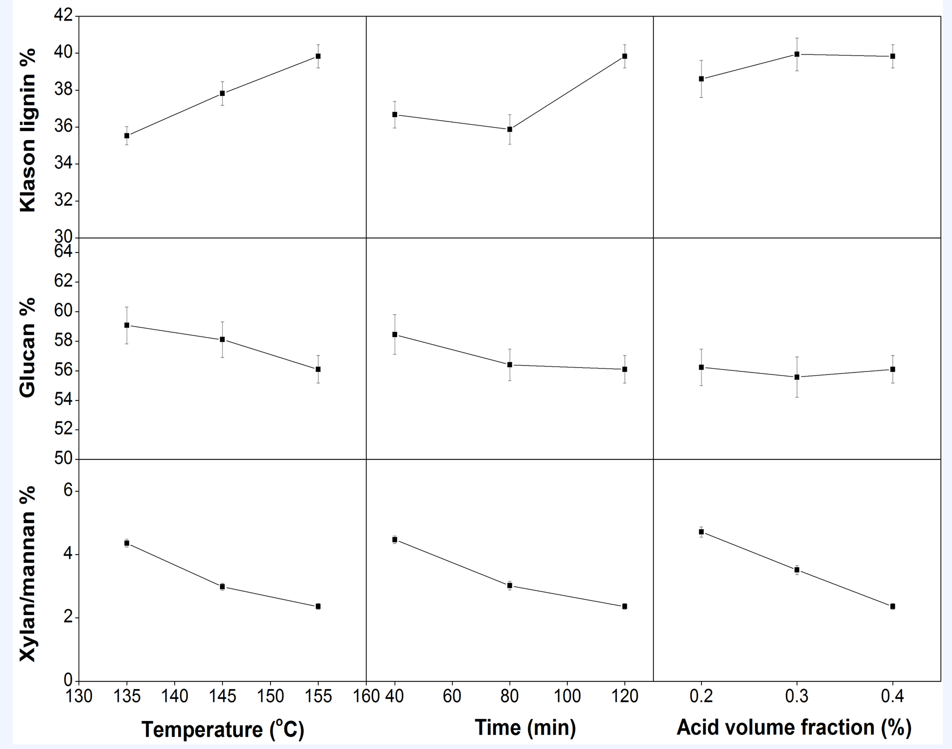
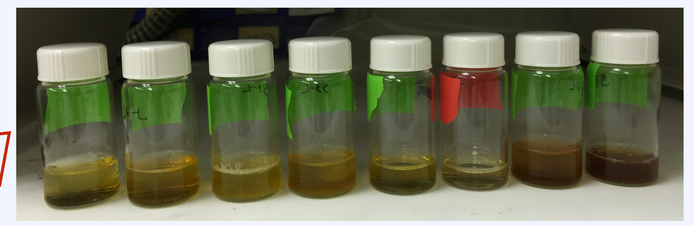


FIGURE 3. Effects of SPORL conditions on the chemical composition (klason lignin, glucan and xylan/mannan) of solid substrates.



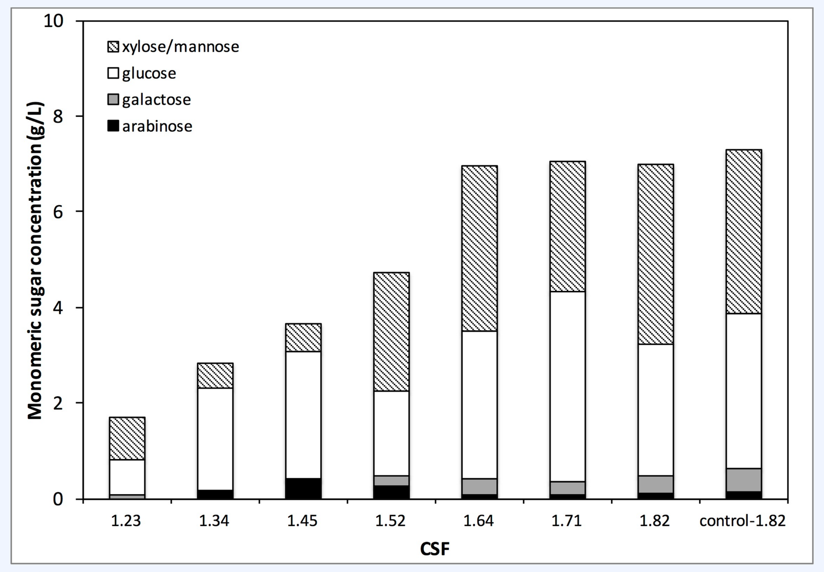


FIGURE 4. Monomeric sugar concentrations in the spend liquor under different CSF.

Sugar yields from enzymatic hydrolysis

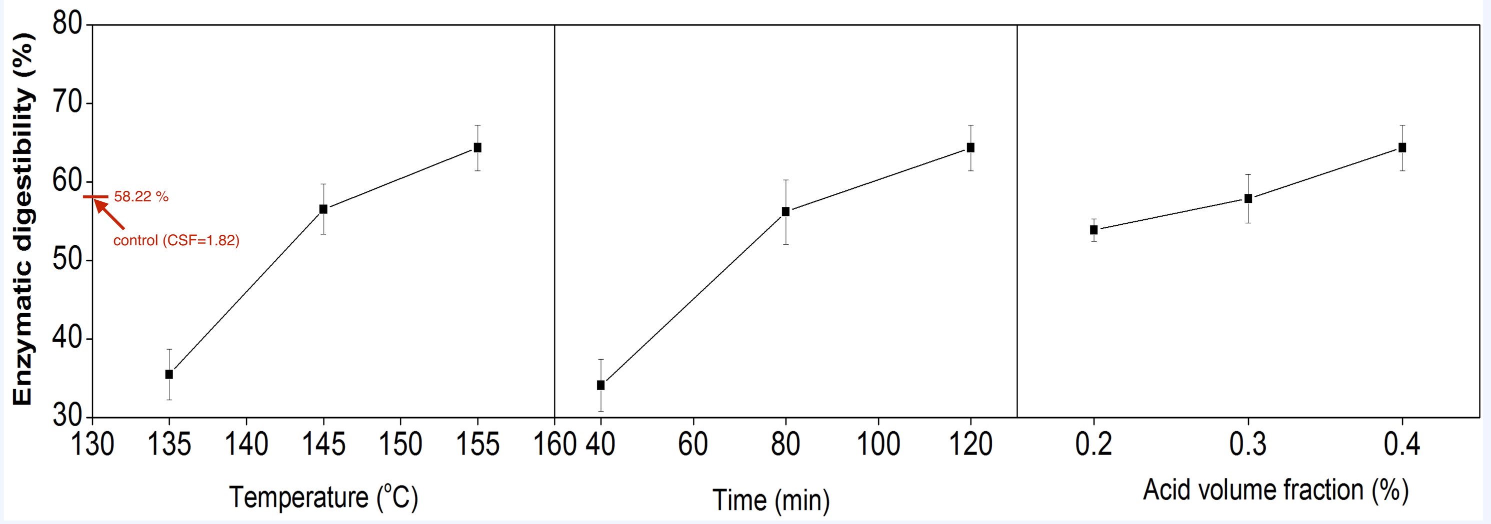


FIGURE 5. Effects of pretreatment conditions on enzymatic digestibility. (a) variation of temperature; (b) variation of duration time; (c) variation of acid volume fraction.

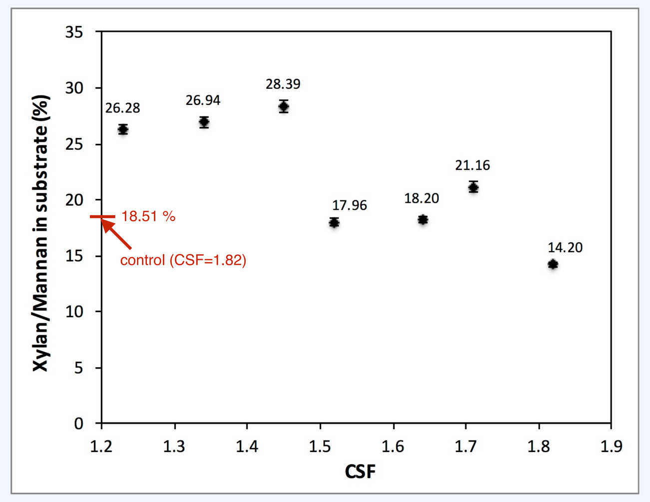


FIGURE 6. Xylan/mannan content in the solid substrate after SPORL.

- The extraction efficiency of hemicellulose sugars is considerably low at low CSF (1.23-1.52).
- The changes of xylan/mannan content corresponds well with the changes of mass removal (FIGURE 2).
- By using HWE pre-processed substrate, SPORL can be conducted at lower CSF (1.64).

CONCLUSIONS

High CSF resulted in more dissolution of hemicelluloses sugars during SPORL.

Maximum enzymatic digestibility of 64.35 % was observed when SPORL was conducted at 155 °C for 120 min with sulfuric acid volume of 0.4 %.

Enzymatic digestibility was slightly improved (~10%) by incorporating HWE prior to SPORL.

HWE pre-process could reduce the severity of SPORL (lower temperature (145 °C), shorter time (80 min), and lower acid volume (0.3 %)), while still maintaining considerably high enzymatic digestibility (~55-60 %).

HWE, as a pre-process at a depot, offers the flexibility for producing an array of products from simple sugars for biofuels to less hydrophilic raw material for wood-based composites; HWE extracted wood also produces higher quality fuel pellets [3].

REFERENCES

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