

## Abstract

Very fine feedstock required by conventional pyrolysis resulted in substantial energy consumption for grinding and size reduction. This study investigated microwave assisted pyrolysis of corn stover with particle sizes from 0.5 to 4 mm, and determined the effects of pyrolytic conditions on the yields of biooil, biogas, and biochar. The pyrolysis process variables included reaction temperature and residence time. A prediction model was satisfactorily developed to describe the biofuel conversion yield as a function of particle size. GC/MS analysis indicates that the biooil contained a series of important and useful chemical compounds: phenols, aliphatic hydrocarbons, aromatic hydrocarbons, and furan derivatives. These chemical compounds evolved were related to the pyrolysis conditions. The research results indicate that thermochemical conversion reactions can take place rapidly in large-sized biomass materials thanks to the nature of fast internal heating by microwave energy. Therefore, very fine feedstock grinding required by conventional pyrolysis is not necessary for microwave pyrolysis process, resulting in substantial energy savings.

## Introduction

Corn stover is currently regarded as the most promising biomass resource in the US with 60–80 million tons/yr available for conversion into fuels and chemicals. Biomass pyrolysis is a thermo-chemical process conducted at 450–550°C in which biomass is rapidly heated in the absence of oxygen.<sup>1</sup> In the last decade, biomass pyrolysis has received considerable interest due to its ability to produce a biofuel product with yields up to 80 wt% on dry biomass.<sup>2</sup> Very fine feedstock grinding is required by conventional pyrolysis. Pyrolysis oil and char yields were found to be largely dependent of particle size.<sup>3</sup> The particle size of biomass feed material is an important parameter in determining the efficacy of pyrolysis. Yi et al<sup>4</sup> used 0.117 to 0.173 mm of biomass for lab and pilot scale pyrolysis studies. Moghtaderi et al<sup>5</sup> used 0.09 to 0.125 mm of pine wood. In conventional pyrolysis system, large sized particles are difficult to agitate and process in the fluid bed, as they tend to settle to the bottom of the bed where heat transfer and speed of thermal processing are reduced. This has a negative effect on the efficiency of production of bio-oil, which is increased when the particle size is reduced. Fine particles increase overall heat transfer, but require substantial amount of energy and effort for size reduction, pre-processing and sizing of biomass feed material.

## Objectives

Objectives of this research were to study the performance of pyrolysis on corn stover thermo-conversion and to identify optimum pyrolysis conditions for converting corn stover into biofuels.

- To study the effect of process conditions such as temperature, reaction time, and particle size on the corn stover conversion.
- To characterize the corn stover bio-oil.

## Materials

Raw Material: Corn Stover

### Particle size distribution of ground corn stover

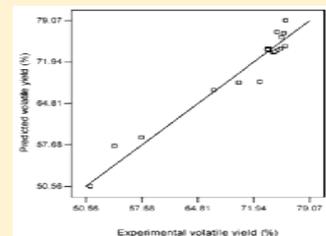
sieve size (mm)	mill screen size (mm), % pass through the sieve				
	4	3	2	1	0.5
4	99.82	99.93	100.00	100.00	100.00
3	98.61	99.52	99.93	100.00	100.00
2	65.19	90.90	99.57	99.83	99.96
1	13.12	56.04	81.90	89.85	99.41
0.5	7.08	30.02	40.77	41.46	59.90
0.2	1.81	8.31	9.40	8.39	9.85

## Methods

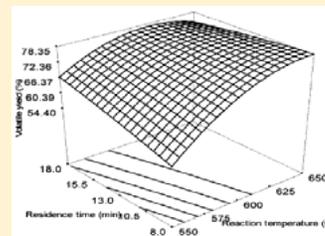
Microwave pyrolysis

- Experiment variables
  - Temperature: 400-650°C
  - Reaction time: 0-40 min
  - Particle size: 1-4mm
- Analysis
  - GC/MS

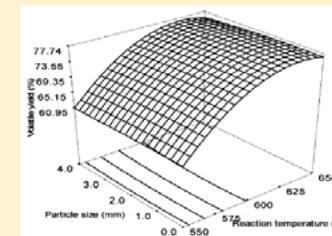
## Results



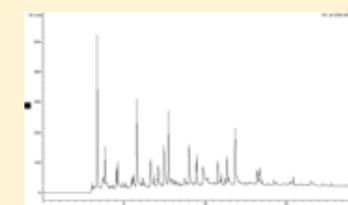
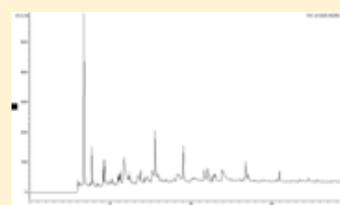
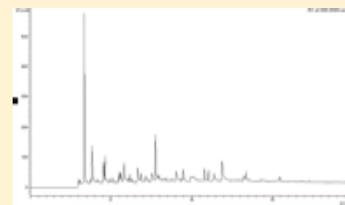
Predicted and experimental volatile yields using model equation



Response surface and contour line of volatile as a function of time and temperature at a particle size of 2 mm



Response surface and contour line of volatile as a function of temperature and particle size at the reaction time of 13 minutes



GC/MS profile for biooils from pyrolysis conditions (A) 550°C and 8 min (B) 550°C and 18 min, and (C) 650°C and 18 min

$$Y_i = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{21}X_2X_1 + b_{22}X_2^2 + b_{31}X_3X_1 + b_{32}X_3X_2 + b_{33}X_3^2$$

$$Y = -1020.82 + 3.26X_1 + 10.26X_2 - 0.0024X_1^2 - 0.016X_2X_1$$

Model terms  $X_3$  (P-value=0.85),  $X_3^2$  (P-value=0.87),  $X_2^2$  (P-value=0.45),  $X_1X_3$  (P-value=0.93), and  $X_2X_3$  (P-value=0.23) were insignificant (P-values > 0.05). Equation was reduced by using backward statistical analysis, and the Equation was obtained with its significant terms (P-value < 0.0001) reaction temperature ( $X_1$ , °C) and reaction time ( $X_2$ , min), particle size ( $X_3$ , mm).  $R^2$  was 0.94

## Conclusions

The maximum volatile matter of corn stover was 76%, with biooil yield of 34% and biogas yield of 42% at a reaction temperature of 650 °C, residence time of 8 minutes, and with corn stover particle size of 4 mm. A prediction model was satisfactorily developed to describe the biofuel conversion yield as a function of reaction temperature and time. The effect of particle size was found insignificant on the pyrolysis of corn stover. The research results indicate that thermochemical conversion reactions can take place rapidly in large-sized biomass materials. We concluded that very fine feedstock grinding required by conventional pyrolysis is not necessary for microwave pyrolysis process, resulting in substantial energy savings.