



Pyrolysis & Gasification of Biomass & Residues from Levulinic Acid Production from Biomass

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Objectives

The aim of this research is to derive useful products by thermally processing acid hydrolysis residues (AHR) formed in the production of levulinic acid from biomass as well as biomass for energy self sufficient processes.

Introduction

Levulinic acid can be esterified with ethanol to produce ethyl levulinate which can be blended with diesel. Levulinic acid, formic acid and furfural is derived from sugarcane bagasse (SCB) by acid hydrolysis, leaving a high lignin content residue. SCB, SCBP (sugarcane bagasse pellets) and AHR are shown in Figure 1.



Figure 1. SCB (left) SCBP (middle) and AHR (right)

Fast pyrolysis produces up to 75wt.% liquid bio-oil yield. However, bio-oil deoxygenation is required to render it miscible with diesel. Gasification produces a gaseous fuel, which needs to be extensively cleaned, catalytically or thermally, to produce a usable gas for electricity generation and potentially syngas. Figure 2 shows the overall process.

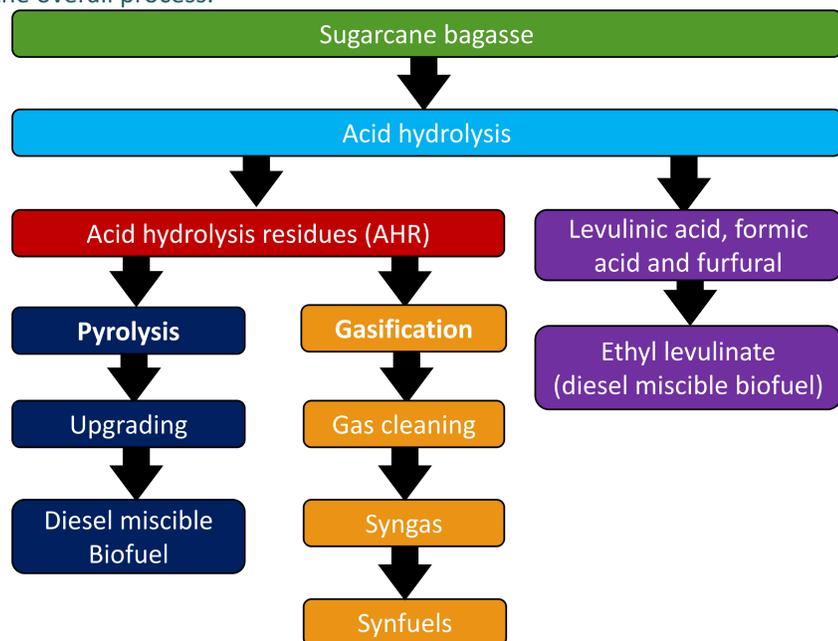


Figure 2. Biofuel production from sugarcane bagasse and AHR

Experimental

TGA pyrolysis was carried out to evaluate the suitability of AHR and SCBP for thermal processing. Pyrolysis and pyrolytic gasification was carried out using nitrogen out on a 300g/h continuous fluid bed system (Figure 3). Oxidative gasification was carried out using air on a batch reaction system from 650°C up to 950°C to compare product yields from SCBP and high lignin AHR.

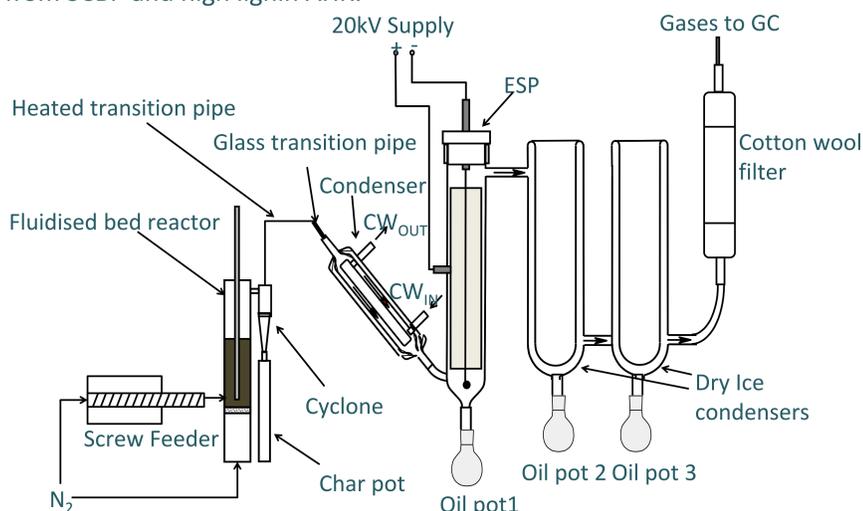


Figure 3. Continuous fluid bed fast pyrolysis and allothermal gasification system

Results and Discussion

Highly volatile feedstocks are suitable for fast pyrolysis to maximise liquid yield. The volatile content of SCBP is 75.85wt.% suggesting a high liquid yield from fast pyrolysis (Table 1). However, the volatile content of AHR is much lower (36.17wt.%) suggesting pyrolysis of these residues would give low liquid and high char yields.

Table 1. Product yields from fast pyrolysis of SCBP (dry feed basis)

Product and recovery	Yield (wt.% dry feed basis)
Liquid	73.14wt.% (60.45wt.% organics and 12.69wt.% total water)
Char	17.32wt.%
Gas	14.01wt.%
Recovery	93.83wt.%

Gasification of AHR was more promising to maximise gas yields from a high char content feedstock. Pyrolytic gasification cracks pyrolysis vapours into fuel gas but low volatiles in AHR limit the yield of pyrolytic fuel gas. Oxidative gasification further reduces liquid and char yield and increases gas yields. In the batch system, the time when CO concentration peaked was defined as completion of gasification (Figure 4). At this point, any excess oxygen lowered the gas HHV. Increasing the initial reactor temperature reduced the time taken for CO to peak, but AHR took longer for CO to peak compared to SCBP at lower temperatures. This suggests that AHR is more refractory than SCBP and so rate of reaction is slower at lower temperatures.

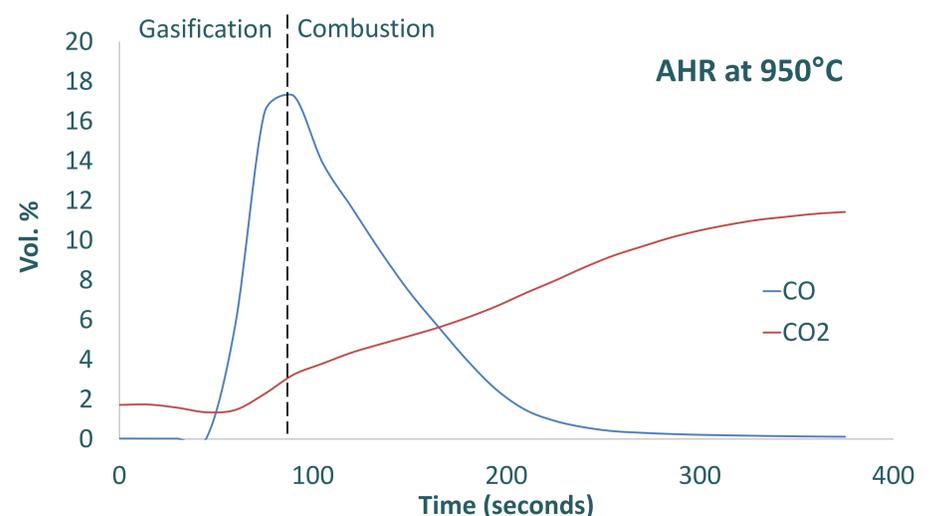


Figure 4. Effect of temperature on CO and CO₂ production from AHR at 950°C

Increasing initial reactor temperature from 650°C to 950°C reduced solid and liquid yields, but increased gas yield. The maximum gas yield from SCBP at 950°C is 80.85wt.% (dry feed basis) and from AHR is 74.21wt.%. The gas HHV for SCBP was 7.28MJ/Nm³ and for AHR was 5.78MJ/Nm³ at 950°C.

Conclusions

- Fast pyrolysis of SCBP gives up to 73 wt.% liquid on a dry feed basis, but upgrading is required for miscibility with diesel.
- Fast pyrolysis of AHR was unsuccessful.
- Pyrolytic gasification of AHR was limited to 650°C and was unsuccessful.
- Oxidative gasification of AHR with air was successful. Product gas composition and HHV results at 950°C were representative of typical biomass air gasification producing a fuel gas with a HHV of approximately 5-7MJ/Nm³.
- AHR is more refractory than SCBP and so rate of reaction is slower. Temperature, equivalence ratio and residence times are important factors in maximising gas yields or HHV.
- Tars are unlikely to be problem with AHR gasification. From biomass, nickel or dolomite-based catalysts could be introduced into the fluid bed (if used) or could be introduced in a close coupled fixed bed reactor to crack the tars. Oxygen gasification will give a better quality gas. Steam can be added to improve the hydrogen content.

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