Potential of lignocellulosic biomass for octane and jet fuel precursors production through catalytic transformation technologies

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Introduction

Oil crude

- Uncertainty on reserves
- Prices
- Climate change

New alternatives to produce valuable chemicals and fuels

Energy demand has generated a renewed interest in producing fuels from biomass

Introduction

Colombia as tropical country

Sugarcane bagasse

Coffee cut-stems

Fique bagasse

Lignocellulosic biomass

Cellulose
Hemicellulose
Lignin

- ✓ **Availability**
- ✓ **Relatively low cost**

Introduction

W. Shen et al. (2011) reported that jet fuels range alkanes could be obtained from lignocellulosic biomass by a novel route, wherein C5 sugar was firstly produced by hydrolysis of biomass and then converted into furfural.

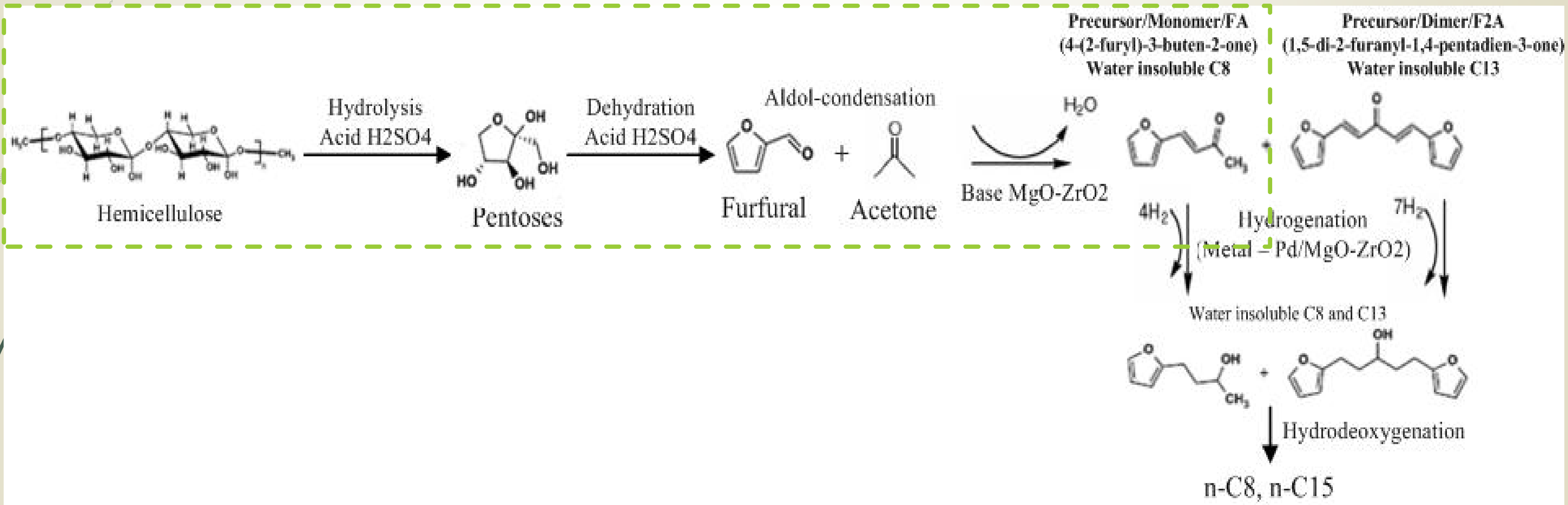
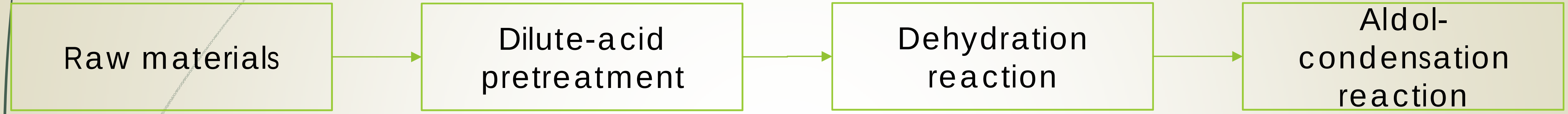


Figure 1 Sequence of hydrolysis, dehydration and aldol-condensation reactions to produce precursor jet fuel from lignocellulosic biomass.

Materials and methods. Overview

Experimental steps



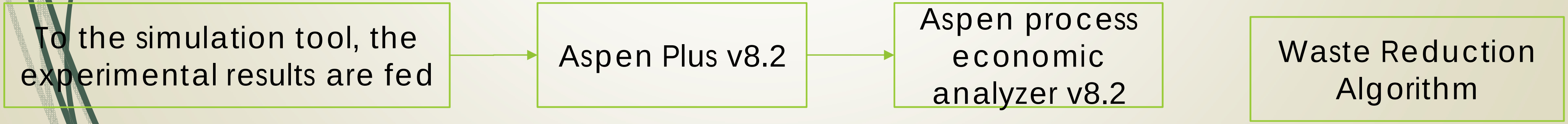
Raw materials → Dilute-acid pretreatment → Dehydration reaction → Aldol-condensation reaction

Sample analysis

Sugars and furan-based compounds determination

Alkane precursor determination

Simulation procedure



To the simulation tool, the experimental results are fed → Aspen Plus v8.2 → Aspen process economic analyzer v8.2

Waste Reduction Algorithm

Materials and methods

Raw materials

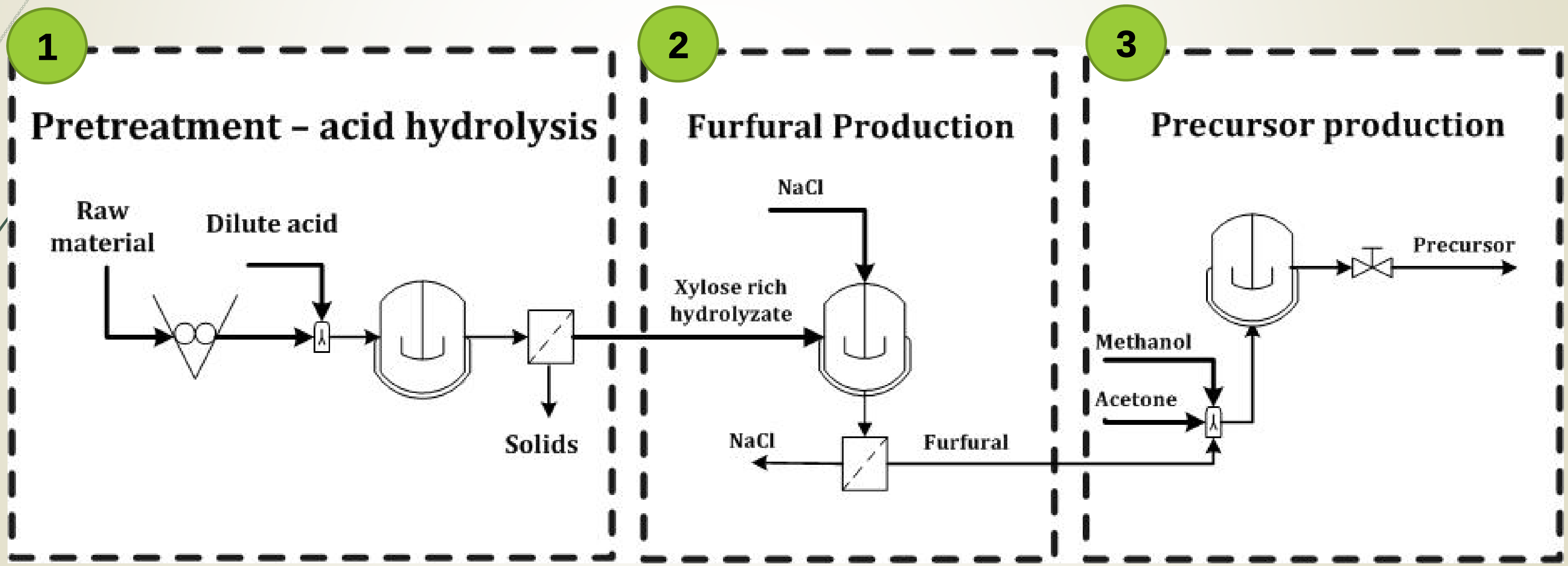
Table 1 Composition of the lignocellulosic biomass used in this work (% wt dry basis).

Component	Sugarcane bagasse	Coffee cut-stems	Fique bagasse
Cellulose	46.74	40.39	50.79
Hemicellulose	23.62	34.01	14.19
Lignin	19.71	10.13	12.47
Ash	1.13	1.27	21.84
Extractives	8.79	14.18	0.69

Materials and methods

Experimental process description

Figure 2 Flowsheet for process to obtain jet fuel precursor.



Materials and methods

Experimental process description

1

Dilute-acid pretreatment
110ºC, 1:10 (%wt) solid:liquid
i) H_2SO_4 solution (2 %v/v), 5h.
ii) H_2SO_4 solution (10% v/v), 30min.

2

Dehydration reaction
90ºC,1.5h, 500rpm, 2.4g NaCl
i) H_2SO_4 solution (2 %v/v)
ii) H_2SO_4 solution (10% v/v)

3

Aldol-condensation reaction
120ºC, 7-10atm, 24h,
40mg MgO-ZrO_2
i) 55 wt. % total organics,
furfural/acetone= 1 by moles,
methanol/water= 1.85 by volume

Materials and methods

Sample analysis

Sugars and furan-based compounds determination

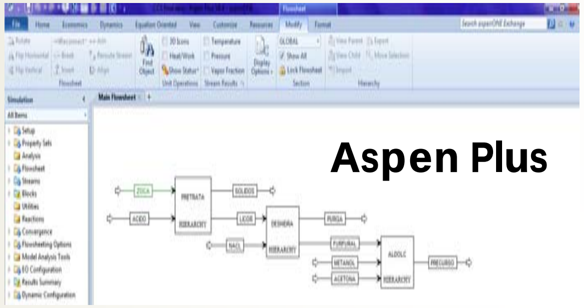
Sugars and furan-based compounds during the acid hydrolysis, dehydration and aldol-condensation reactions are quantified by the **HPLC** system (ELITE LaChrom) using an ORH-801 Transgenomic® column.

Alkane precursor determination

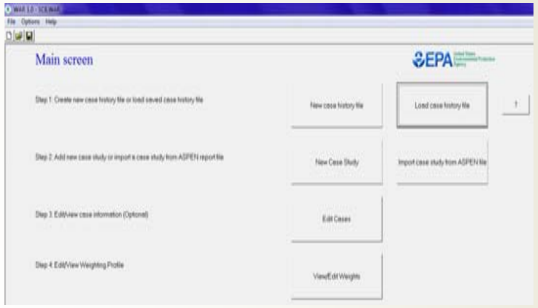
Alkane precursor (4-(2-furyl)-3-buten-2-one) identification is made with a **gas chromatograph** (Agilent Technologies 6850 Series II) equipped with a mass selective detector (MSD 5975B).

Materials and methods

Simulation procedure



Aspen Plus



Main screen

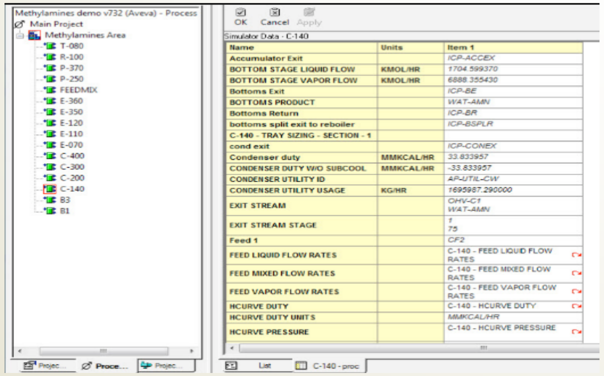
Step 1. Create new case history file or load saved case history file

Step 2. Add new case study or import a case study from ASPEN report file

Step 3. Edit/view case information (Optional)

Step 4. Edit/View Weighting Profile

WAR



Methylamines demo v732 (Aveva) - Process
Main Project
Methylamines Area
T-080
R-100
P-370
P-250
FEEDMIX
E-360
E-350
E-120
E-110
E-070
C-400
C-300
C-200
C-140
B3
B1

Simulator Data - C-140

Name	Units	Item 1
Accumulator Exit		ICP-ACCEX
BOTTOM STAGE LIQUID FLOW	KMOL/HR	1704.599370
BOTTOM STAGE VAPOR FLOW	KMOL/HR	6888.355430
Bottoms Exit		ICP-BE
BOTTOMS PRODUCT		WAT-AMN
Bottoms Return		ICP-BR
bottoms split exit to reboiler		ICP-BSPLR
C-140 - TRAY SIZING - SECTION - 1		
cond exit		ICP-CONEX
Condenser duty	MMKCAL/HR	33.833957
CONDENSER DUTY W/O SUBCOOL	MMKCAL/HR	-33.833957
CONDENSER UTILITY ID		AP-UTIL-CW
CONDENSER UTILITY USAGE	KG/HR	1695987.290000
EXIT STREAM		OHV-C1 WAT-AMN
EXIT STREAM STAGE		1 75
Feed 1		CF2
FEED LIQUID FLOW RATES		C-140 - FEED LIQUID FLOW RATES
FEED MIXED FLOW RATES		C-140 - FEED MIXED FLOW RATES
FEED VAPOR FLOW RATES		C-140 - FEED VAPOR FLOW RATES
HCURVE DUTY		C-140 - HCURVE DUTY
HCURVE DUTY UNITS		MMKCAL/HR
HCURVE PRESSURE		C-140 - HCURVE PRESSURE

Aspen process economic analyzer

Results and discussion

Acid hydrolysis

Table 2 Results of the acid hydrolysis.

Raw material	**Condition 1**		**Condition 2**	
	g xylose/g hem	**g furfural/g hem**	**g xylose/g hem**	**g furfural/g hem**
SCB	0.81±0.004	0.054±0.001	0.60±0.016	0.076±0.003
CCS	0.50±0.030	0.024±0.002	0.51±0.010	0.023±0.002
FB	0.58±0.017	0.019±0.003	0.54±0.025	0.017±0.001

hem: hemicellulose

Xylose and furfural are the interesting products and a platform to obtain the precursor of jet fuels.

Results and discussion

Dehydration reaction

Table 3 Results of dehydration reaction.

Raw material	**Condition 1 (g furfural/g xylose)**	**Condition 2 (g furfural/g xylose)**
SCB	0.060±0.008	0.060±0.005
CCS	0.063±0.002	0.067±0.005
FB	0.092±0.009	0.045±0.005

Rong et al. (2012) reported that xylose dehydration to furfural has a yield below 10% when acid concentration is nearly to 2.5% w/w. On the other hand, the yield reduces to 0.51% when the concentration of sulfuric acid reaches 12.5% w/w[10].

Results and discussion

Aldol-condensation reaction

Table 4 Results of aldol-condensation reaction.

Raw material	Condition 1 (% disappearance of furfural)	Final FA (4-(2-furyl)-3-buten-2-one) yield (g/g of hemicellulose)
SCB	71.7±0.018	0.14± 0.004
CCS	96.5±0.014	0.12± 0.004
FB	92.9±0.008	0.08± 0.002

The data reported in literature indicate a disappearance percentage of 66% in the same conditions of the procedure developed in this work [12].

When aldol-condensation reaction is carried out for operation condition 2, the formation of interest products is not recorded for any raw material.

Results and discussion

Simulation results

- According to results from the technical assessment, SCB, CCS and FB have relative high FA (4-(2-furyl)-3-buten-2-one) yields 0.14, 0.13 and 0.08 grams of precursor per gram of lignocellulosic biomass, respectively. The good content of hemicellulose in these residues, the efficiency in acid hydrolysis and dehydration stages, involve good flows of product.

- The production cost is 6.02, 5.57 and 10.22 USD per kilogram of precursor for SCB, CCS and FB, respectively. In this sense, the economic margins are -20.45, -11.41 and -104.34% for SCB, CCS and FB, respectively.

Results and discussion

Simulation results

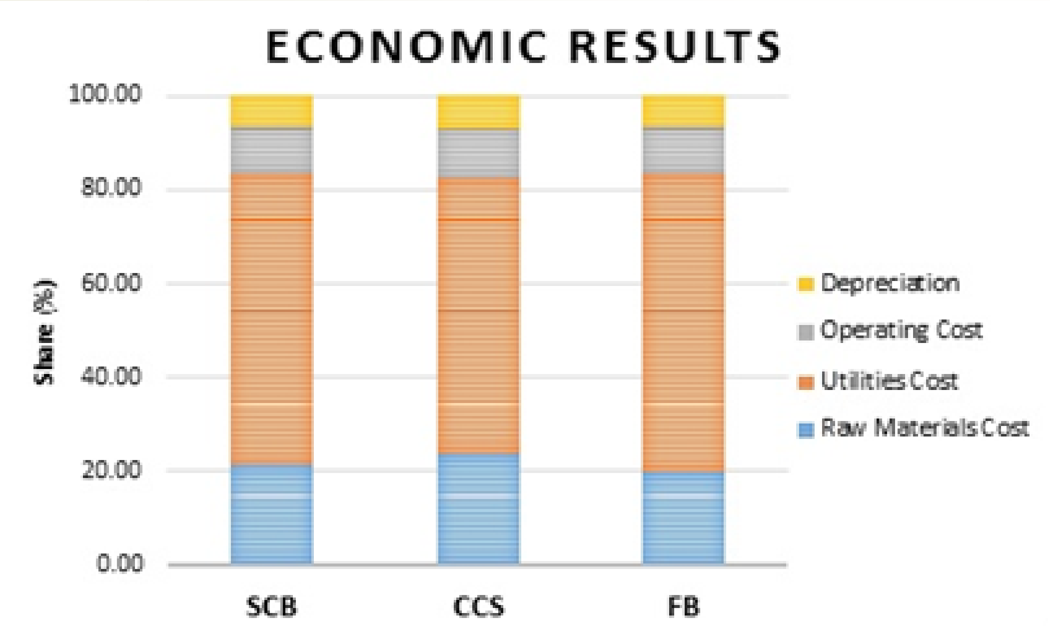


Figure 3 Total costs distribution for SCB, CCS and FB to produce jet fuel precursor.

The utilities cost represents approximately more than 50% of total production cost which is related with the great amount of energy that demands the aldol-condensation reaction to generate the FA. As can be seen there are not significant changes in the percentages of distribution between the residues.

Results and discussion

Simulation results

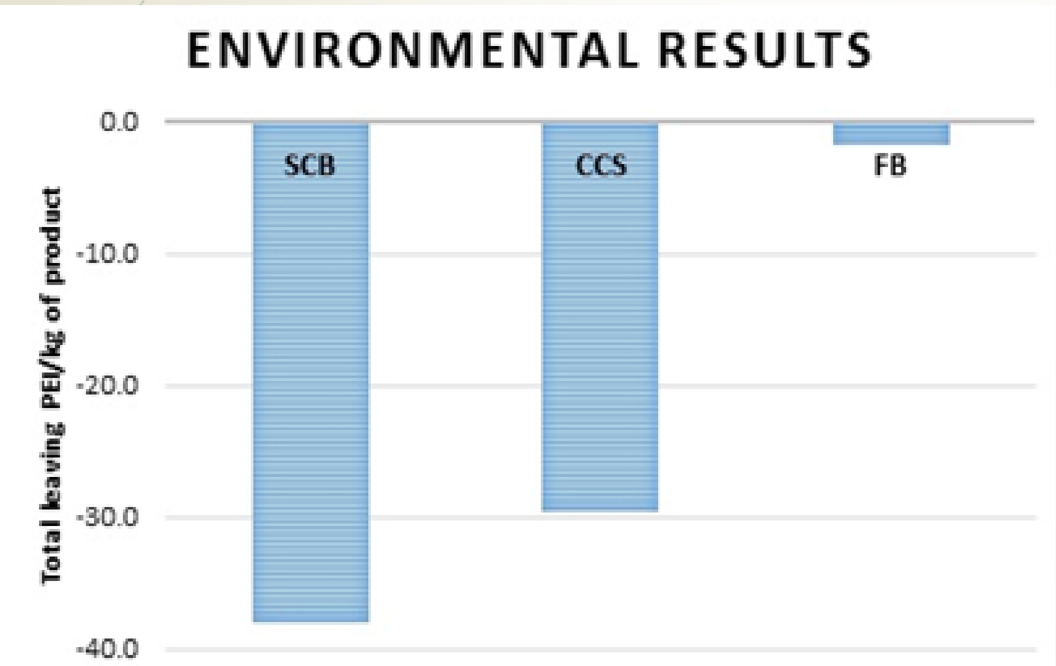


Figure 4 Environmental results for SCB, CCS and FB to produce jet fuel precursor.

SCB is the process with greater flow of FA and released energy that can be exploited, consequently is the friendliest environmental process.

Conclusions

- This work contributes to the implementation of simultaneous processes for the transformation of agroindustrial wastes to obtain sugars, furan-based compounds and precursor of liquid alkane range jet biofuel, focusing on the comprehensive utilization of raw materials.

- Additionally, this work shows that MgO-ZrO_2 catalyst allows converting carbohydrate-derived compounds, like furfural, to water-soluble intermediates (precursor FA). These compounds are the base for future production of liquid alkanes.

Acknowledgements

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Thank you for your attention

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