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Thermochemical conversion of sugarcane bagasse and catalyticupgrading of fast pysolysis bio-oil as a potential conversion route sugarcane refineries

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3.2 Technologies of biorefineries

Thermochemical conversion of sugarcane bagasse and catalytic upgrading of fast pyrolysis bio-oil as a potential conversion route in sugarcane refineries

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Sugarcane in Brazil

Brazil biggest producer worldwide

635.3 million tons sugarcane 2018/2019

448 million tons sugarcane bagasse 2018/2019

- ✓ **Bioelectricity generation;**
- ✓ **2G ethanol production;**

FAST PYROLYSIS
500 °C
Up to 5 s
N_2

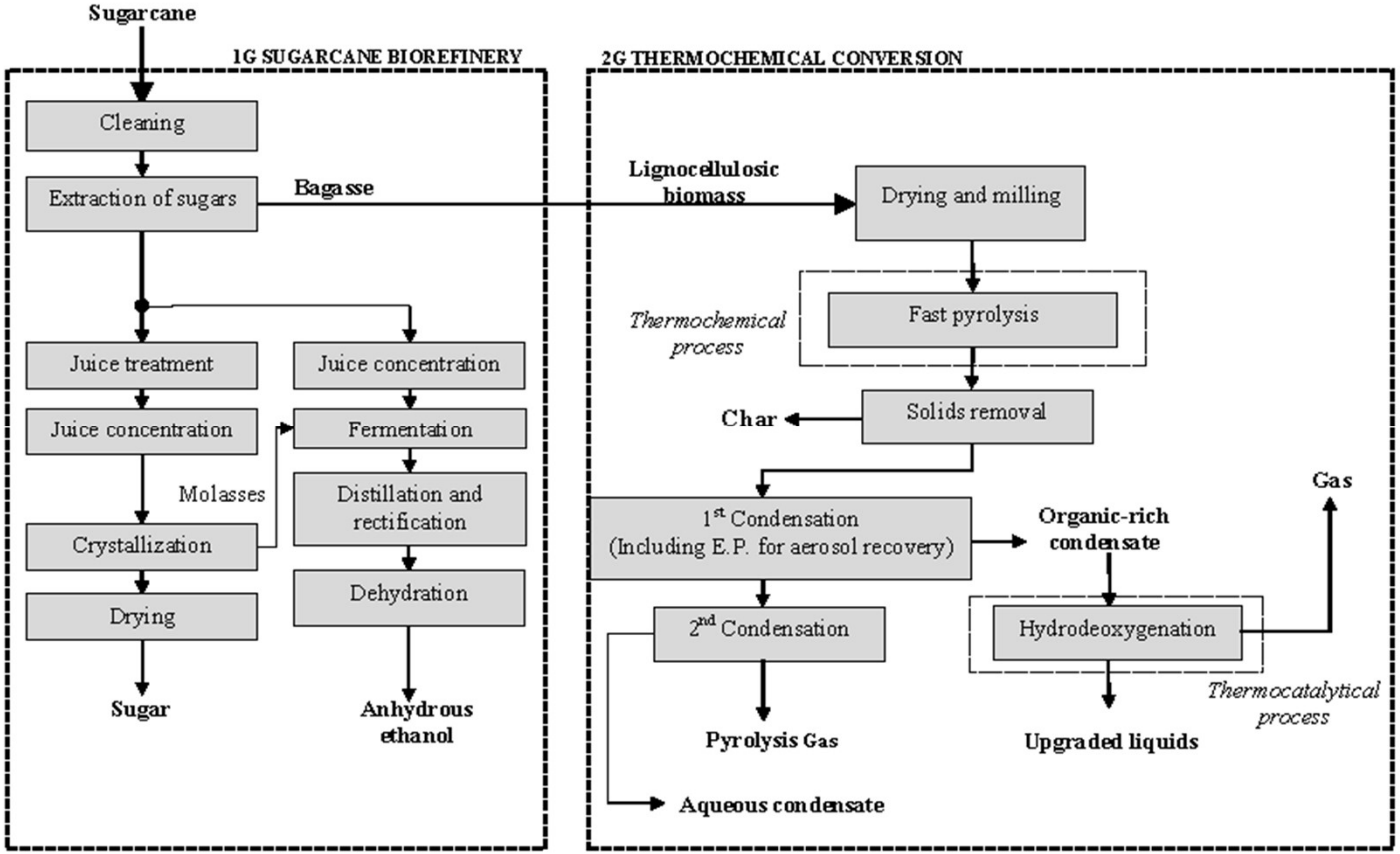
Fast pyrolysis bio-oil

ADVANTAGES THERMOCHEMICAL ROUTE:

- **Sugarcane bagasse already centrally collected;**
- **↑ [lignin] = 17-32 wt.%: interesting for thermochemical conversion: functionalized aromatic compounds;**
- **Expantion of the range of chemicals obtained in sugarcane refinery**

3.2 Technologies of biorefineries

Integration 2G thermochemical conversion routes for sugarcane biorefinery



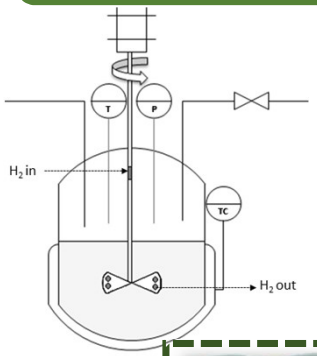
AIM OF THE STUDY

The aim of this study is to present for the first time a comprehensive investigation from sugarcane bagasse characterization, fast pyrolysis and hydrotreatment to the final upgraded products.

This approach allows identification of the feedstock specific characteristics, advantages, and disadvantages of the whole process chain.

MATERIALS and METHODOLOGY

Sugarcane bagasse collection → Sugarcane bagasse preparation and characterization → Fast pyrolysis → Hydrotreatment → Characterization



Sugarcane bagasse collection, preparation and characterization

COLLECTION

São Paulo, Brazil

PREPARATION

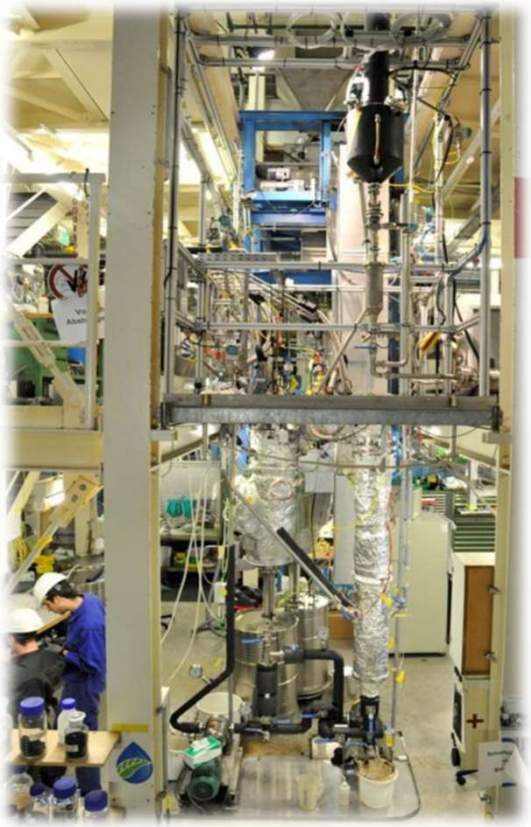
Dried to moisture content below 10 wt.% and milled to ≤2mm

CHARACTERIZATION

- ELEMENTAL ANALYSIS
- MOISTURE CONTENT
- ASH CONTENT
- VOLATILE MATTER
- HHV
- INORGANIC COMPOSITION

Thermochemical conversion: Fast Pyrolysis

Sugarcane bagasse
≤2 mm



Phyton unit (10 Kg/h)
500 °C up to 3 s
FPBO condensated at 90 °C

Fast pyrolysis
bio-oil (FPBO)
main product

CHARACTERIZATION

- ELEMENTAL ANALYSIS
- H_2O CONTENT
- HHV
- pH value
- GC-MS/FID
- INORGANIC COMPOSITION
- MOLECULAR WEIGHT

3.2 Technologies of biorefineries

Thermocatalytic treatment of fast pyrolysis bio-oil: Hydrotreatment with two Ni-based catalysts

Fast pyrolysis bio-oil (FPBO) main product

- Low pH value;
- High [H_2O];
- High [O];

Hydrotreatment

50 mL FPBO, 2.5 g catalyst
Catalyts: Ni/SiO_2 and Ni/Cr_2O_3-SiO_2
2 h, 325 °C, 90 bar of H_2
autoclave of 300 mL

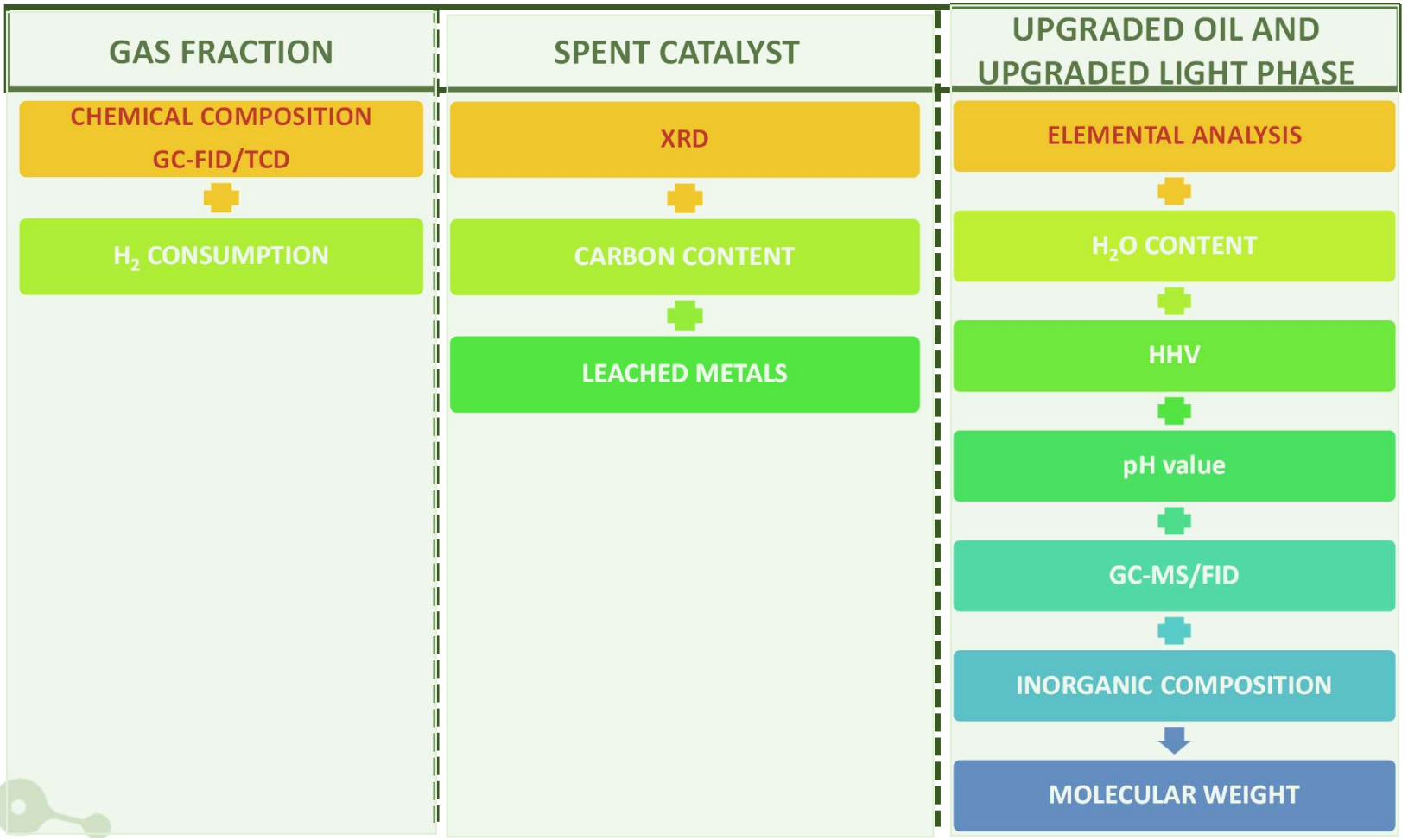
Gas fraction

Upgraded oil + upgraded light phase

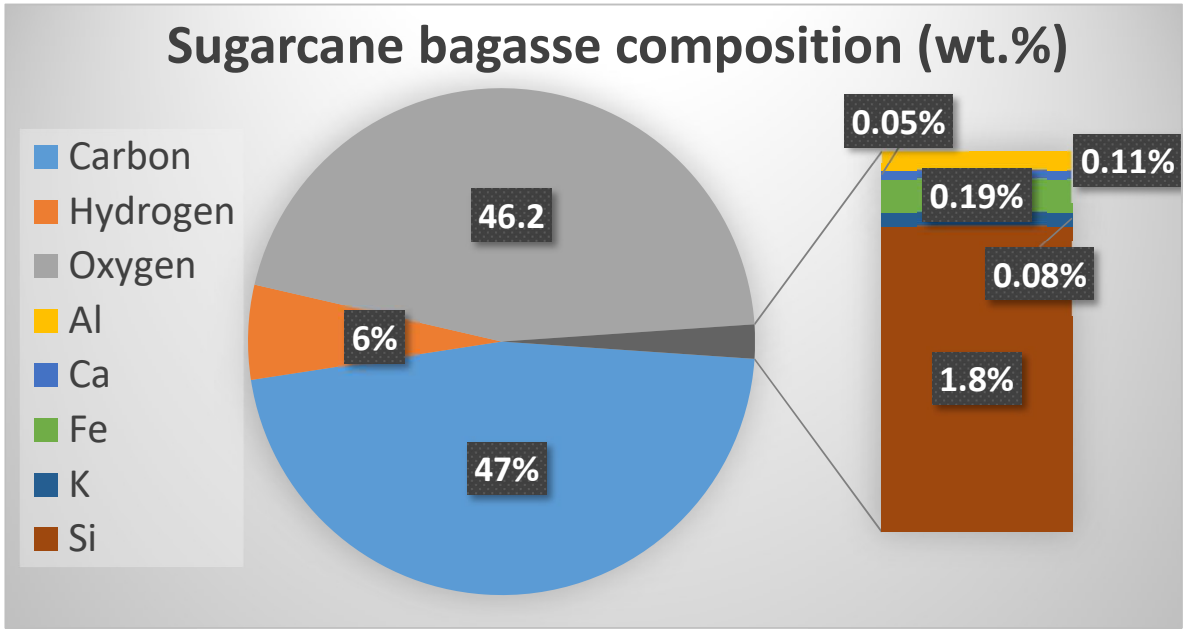
Spent catalyst + solid residue

3.2 Technologies of biorefineries

Hydrotreatment products: Characterization



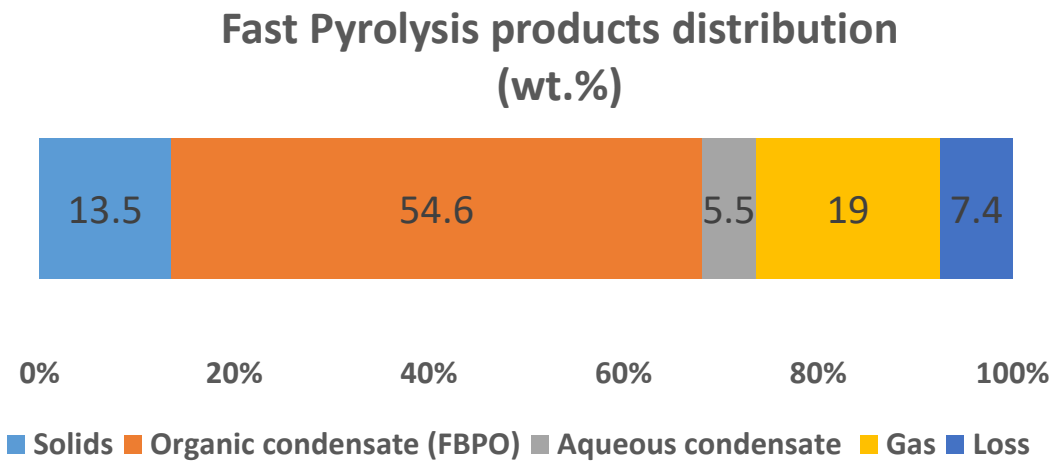
Results: Sugarcane bagasse characterization



	SCB*
Residual moisture (wt. %)	2.80
HHV (MJ/kg)	18.51
Proximate analysis	
Ash (wt.%)	6.75
Volatile matter (wt.%)	80.32
Fixed carbon (wt.%)	10.14

↑ ash content!
↓ potassium content! (0.08 wt.%)!

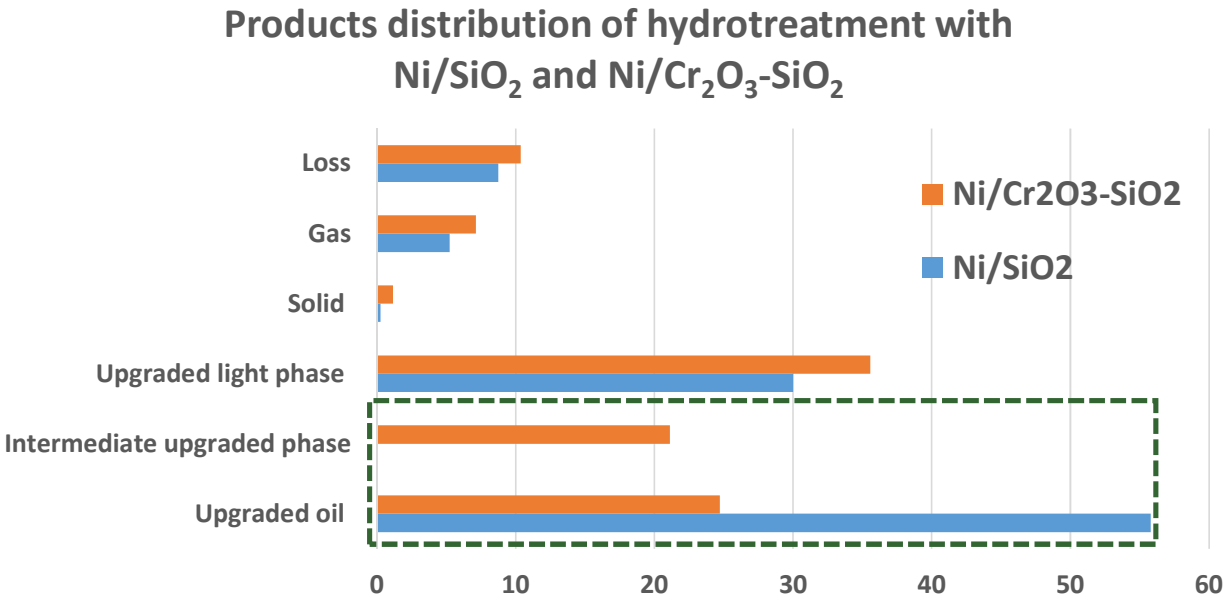
Results: Fast pyrolysis of sugarcane bagasse



↓ potassium content (catalytic effect) ↑ FPBO yield!

Physicochemical properties and elemental analysis FPBO (dry basis)	
Solid (wt.%)	0.8
pH value	2.9
H_2O (wt.%)	20.9
Density (g/cm^3)	1.18
HHV (MJ/kg)	23.79
Carbon (wt.%)	56.89
Hydrogen (wt.%)	6.55
Oxygen (wt.%)**	36.56
Nitrogen (wt.%)	<0.2

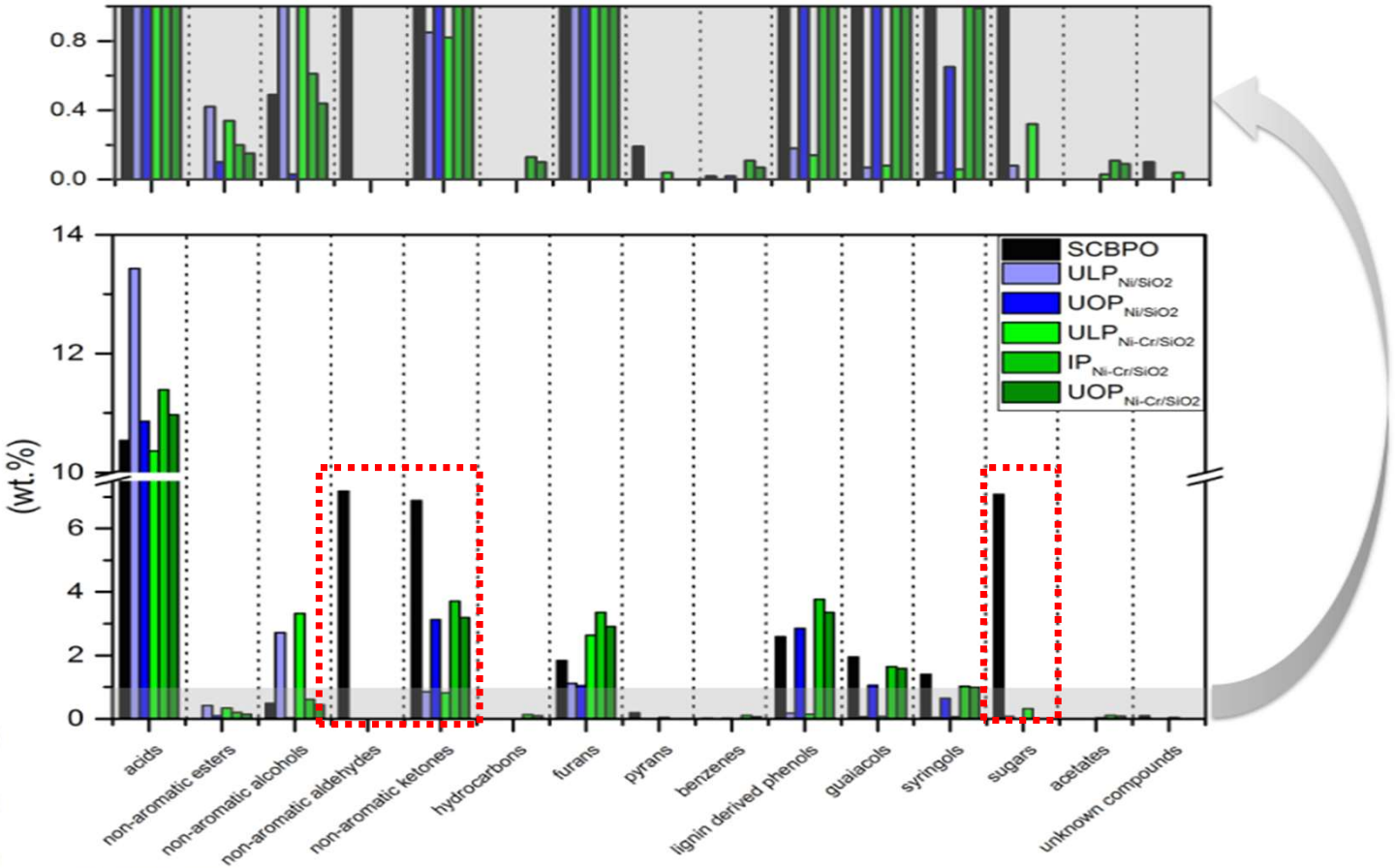
Results: Hydrotreatment of fast pyrolysis bio-oil



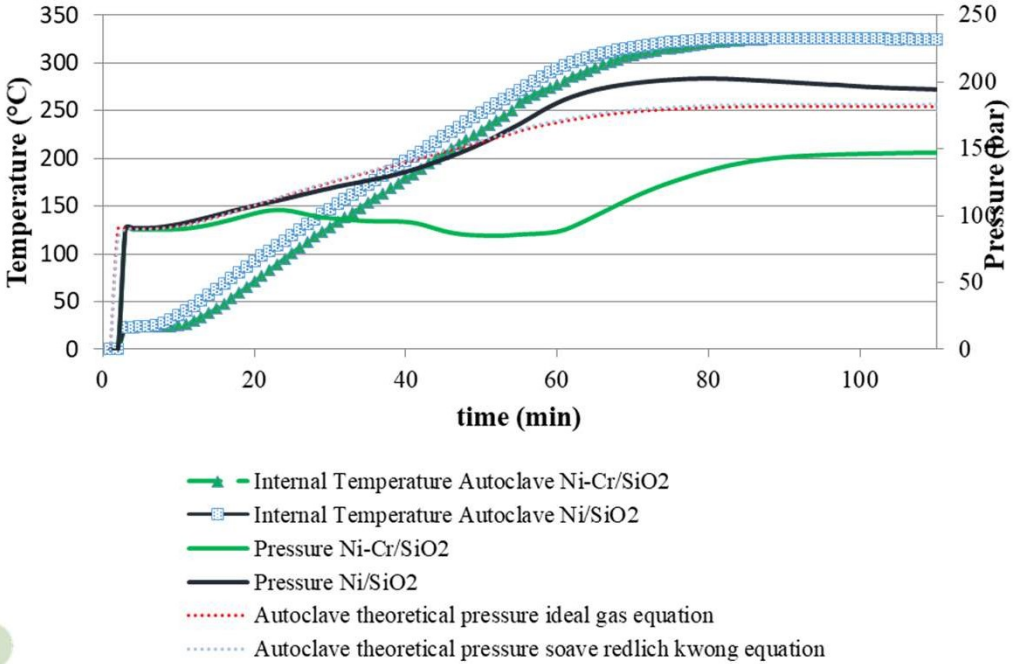
	FPBO	$UOP_{Ni/SiO2}$	$IUP_{Ni-Cr/SiO2}$	$UOP_{Ni-Cr/SiO2}$
H_2O (wt.%)	20.9	8.3	8.8	8.6
pH value	2.9	-	3.8	-
HHV (MJ/kg)	23.79	31.89	31.73	30.42
Carbon (wt.%)	56.89	71.1	68.31	66.63
Hydrogen (wt.%)	6.55	7.83	8.69	8.25
Oxygen (wt.%)**	36.56	20.74	22.67	24.79
Nitrogen (wt.%)	<0.2	0.33	0.33	0.33
DOD (%)*	-	43.3	38.0	32.2

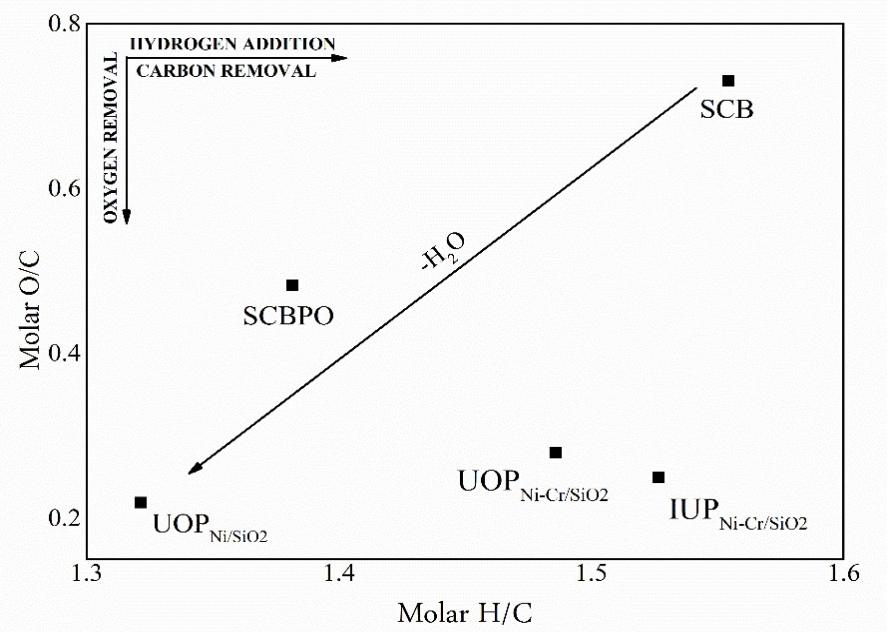
*DOD: degree of deoxygenation

Results: Hydrotreatment of fast pyrolysis bio-oil



Results: Hydrotreatment Fast pyrolysis bio-oil

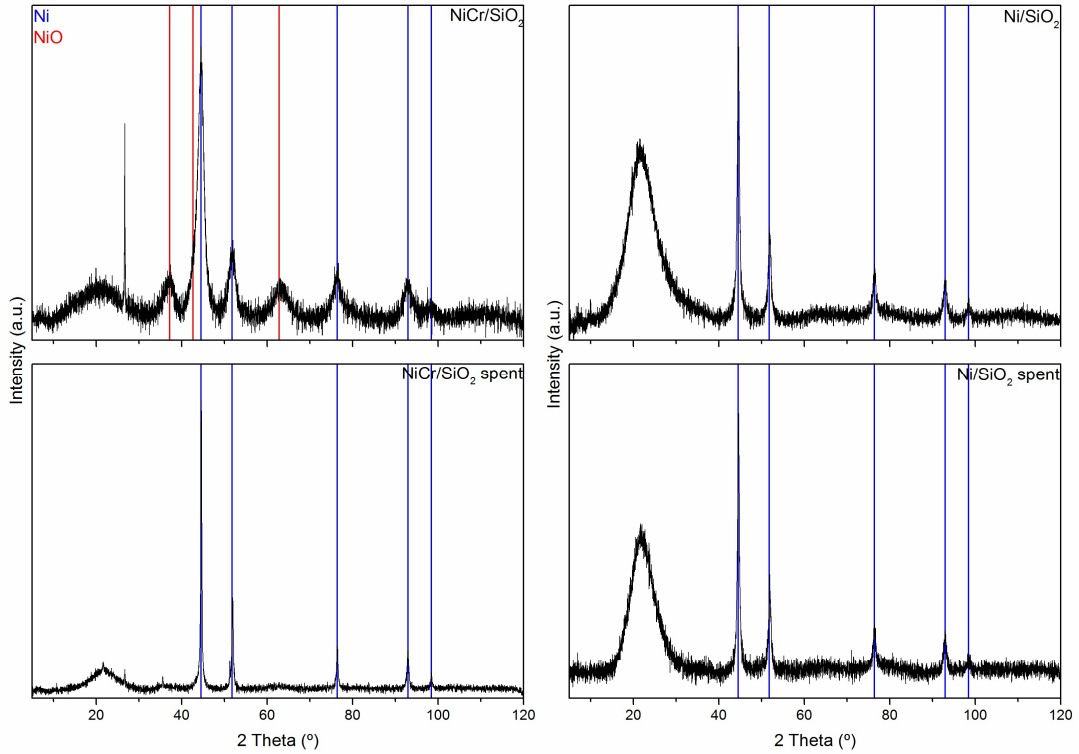




	Ni/SiO_2	$Ni\text{-}Cr/SiO_2$
Hydrogen consumption (NL/Kg feed)	199.43	326.2
Gas composition		
Carbon dioxide (mol/kg feed)	1.146	1.263
Carbon monoxide (mol/kg feed)	0.041	0.058
Methane (mol/kg feed)	0.016	0.718

Results: Catalyst characterization

	Ni/SiO_2	Ni/Cr_2O_3-SiO_2
Carbon (wt.%)	0.36	18.5
Leached metal to ULP (wt.%)	Ni: 0.73	Ni: 0.054 Cr: <0.09



Crystalitte size

Ni/SiO_2:17.7 nm before and after reaction;

Ni/Cr_2O_3-SiO_2: 4.4 nm (before) to 38.2 nm after reaction → sintering

Conclusions

A comprehensive study from sugarcane bagasse characterization to upgraded products after treatment was presented.

- Low moisture and low K content in the sugarcane bagasse were reflected in the high yield of FBPO **OUTSIDE** the range expected for residual biomass;
- Hydrotreatment with both catalysts resulted in upgraded oils with around 30% less O and approx. 43% less water in comparison to the FPBO;
- **Ni/Cr_2O_3-SiO_2** showed higher **hydrogenation** activitiy whereas **Ni/SiO_2** showed higher **hydrodeoxygenation** activity;
- Sugarcane bagasse proved to be an attractive feedstock for 2G biorefineries with overall yield of 30.5 wt.%;
- Further studies will target higher FPBO yields (fast pyrolysis) and upgraded oils with lower oxygen content.

Thank you!