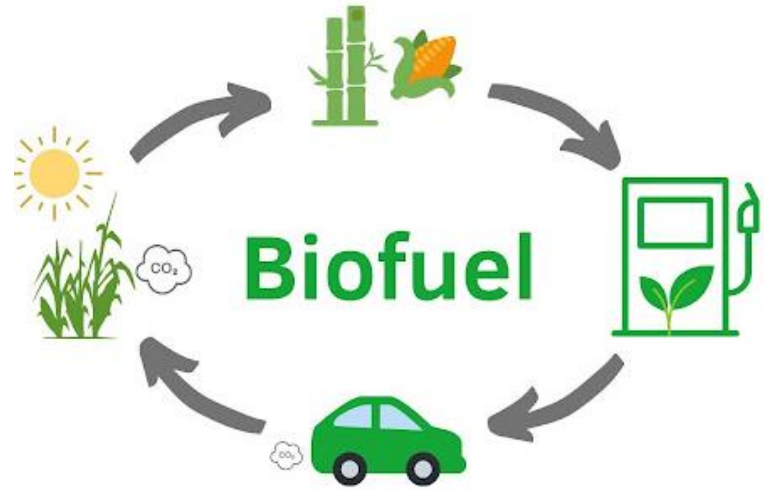
HIROSHIMA UNIVERSITY



Conversion of lignocellulosic biomass in hydrothermal conditions

Name: Johannes Lovisa Panduleni

Affiliation: Hiroshima University

Advanced Science and Engineering

Mechanical Engineering

Sustainable Energy

Thermal Laboratory

2022/09/07

Introduction

Problem

- **Energy depletion.**
- **Global warming.**
- **Efforts are being made worldwide to find sustainable means of energy production and to reduce carbon gas emissions into the atmosphere in order to mitigate climate change as per Paris Agreement and SDG 13.**

Solution: Renewable energy resources.

Introduction; Classification of biomass

- **Organic compounds produced by living organisms and can be used as energy or material.**

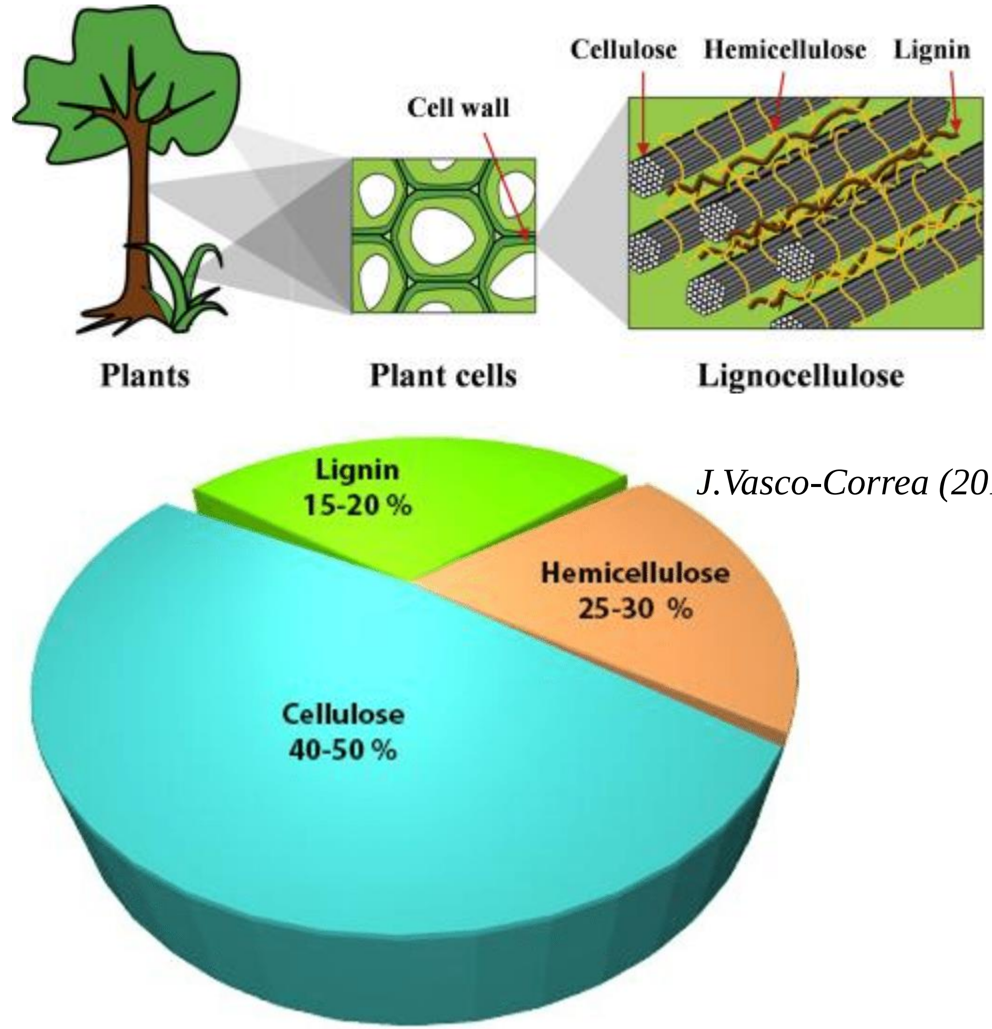
- **Renewable**
- **Sustainable**
- **Carbon neutral**
- **Available in abundance**

Table 1. Biomass classification

Commercialization → / Utilization ↓	Waste	Unused	Produced
Dry	Sawmill residue Maize/millet residue (Agricultural waste)	Rice straw Millet straw Sorghum straw	Plantation
Wet	Food waste Animal manure Sewage sludge	Water hyacinth	Micro and macro algae
Other	Waste oil Molasses	Landfill gas	Palm oil Sugar Corn

Lignocellulosic biomass

- **Dry plant matter**
- **Most abundant for the production of biofuels**
- **Contains cellulose, hemicellulose and lignin**
- **Model compounds glucose, xylose and guaiacol are studied to understand the reaction mechanism of real biomass.**



J.Vasco-Correa (2016)

Fig.1 Lignocellulosic biomass composition

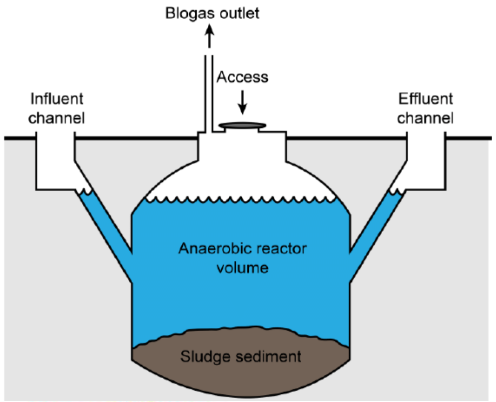
Biomass Conversion Methods

Physical

- **Chipping**
- **Palletization**
- **Briquetting**

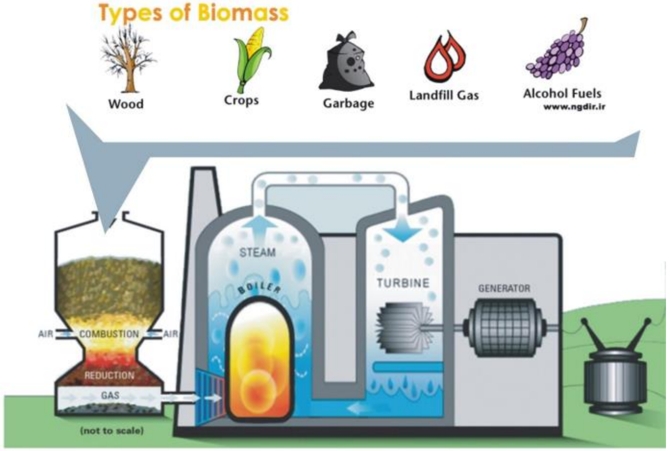
Biochemical

- **Anaerobic fermentation**
- **Ethanol fermentation**



Thermochemical

- **Pyrolysis**
- **Combustion**
- **Gasification**
- **Liquefaction**



Supercritical water gasification

- **Temperature and pressure above 374℃ and 22.1MPa.**
- **Promising hydrothermal conversion technology to convert waste biomass into rich H_2 syngas.**
- **Wet biomass can be converted with no drying step.**
- **Reactions take place fast at this conditions.**
- **Short residence time.**
- **Solid products like char and tar are minimized.**

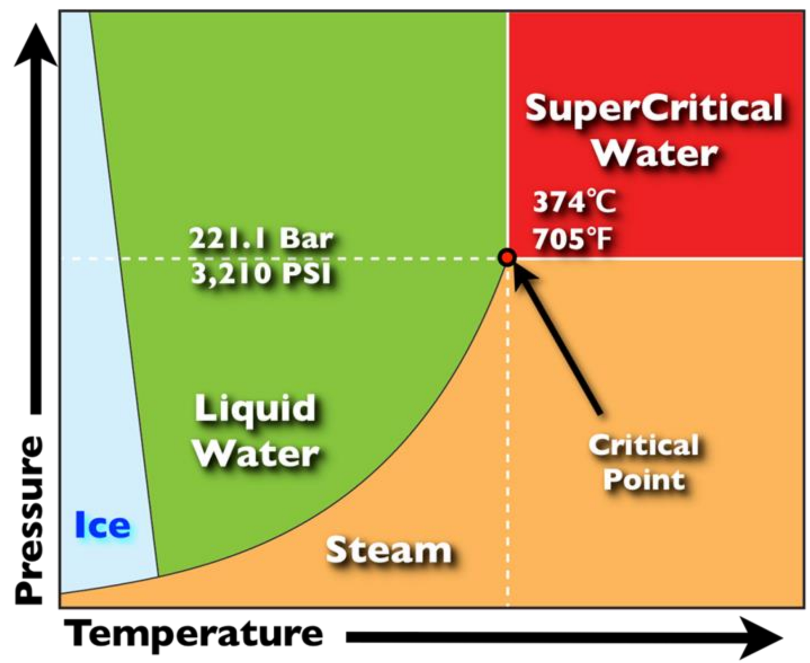


Fig.2 SCW conditions

Significance

In order to achieve a sustainable society in terms of energy production, utilization of biomass is promising for the production of green fuels such as hydrogen and methane and chemical products.

Originality

To date, most studies have focused on single components of biomass in supercritical water to produce hydrogen rich syngas however this is not sufficient to help us understand the mechanism of biomass containing multiple components to produce hydrogen rich syngas. This study focuses on the gasification of the model compounds of the 3 major components of lignocellulosic biomass.

Objectives

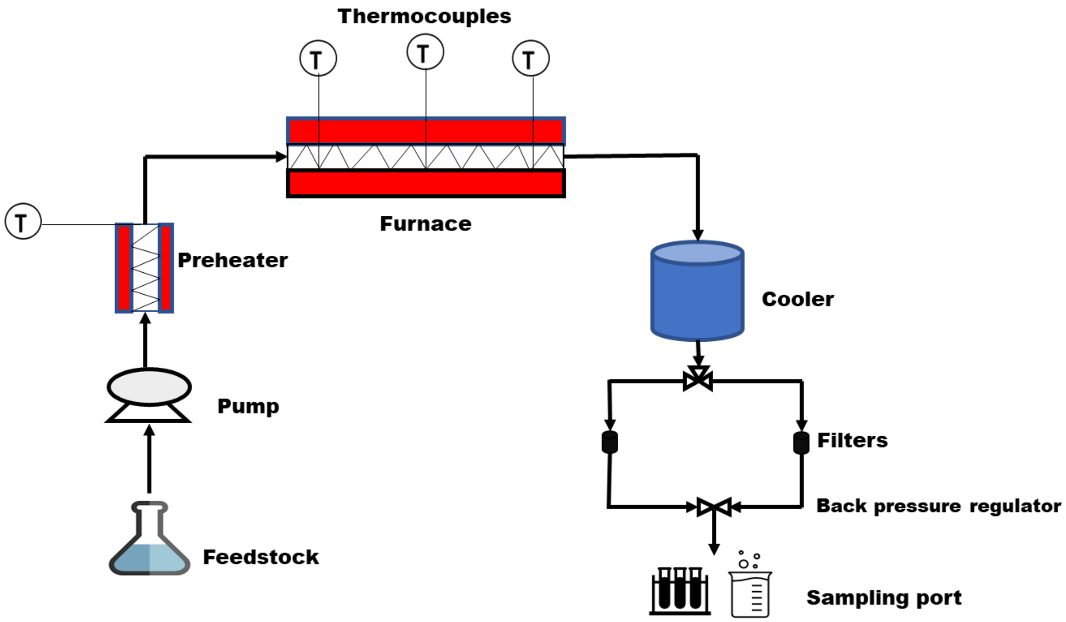
To study the effect of temperature on the supercritical water gasification of the 3 model compounds of lignocellulosic biomass for useful products.

Experimental Conditions

Table 2. Experimental conditions

Ex run	Temperature [℃]	Pressure [MPa]	Feedstock [wt.%]	Flow rate [mL/min]	Residence time [s]
1	450, 600	25	Glucose [0.2] Xylose [0.2]	7.76	40
2	450, 600	25	Glucose [0.4] Guaiacol [0.1]	7.76	40
3	450, 600	25	Xylose [0.4] Guaiacol [0.1]	7.76	40
4	450	25	Glucose [0.2] Xylose [0.2] Guaiacol [0.1]	7.76	40

Experimental Apparatus and procedure



Continuous flow reactor
Material: SS316
Inner diameter: 2.17 mm
Length of reactor: 12 m

Fig.3 Apparatus

1. **Adjust back pressure valve to desired pressure and start heating until target temperature.**
2. **Send feedstock (biomass) for 1 hour to reach steady state before collecting samples.**
3. **Collect gas and liquid products.**
4. **Analyze gas by Gas Chromatography and liquid by Total Organic Carbon and High Performance Liquid Chromatograph.**

Results and discussion; Gas composition

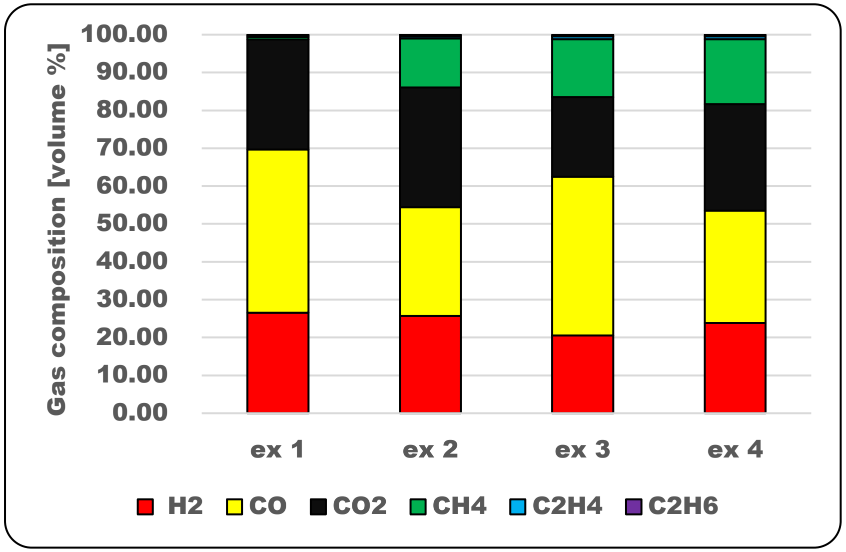


Fig.4 Gas composition 450 ℃

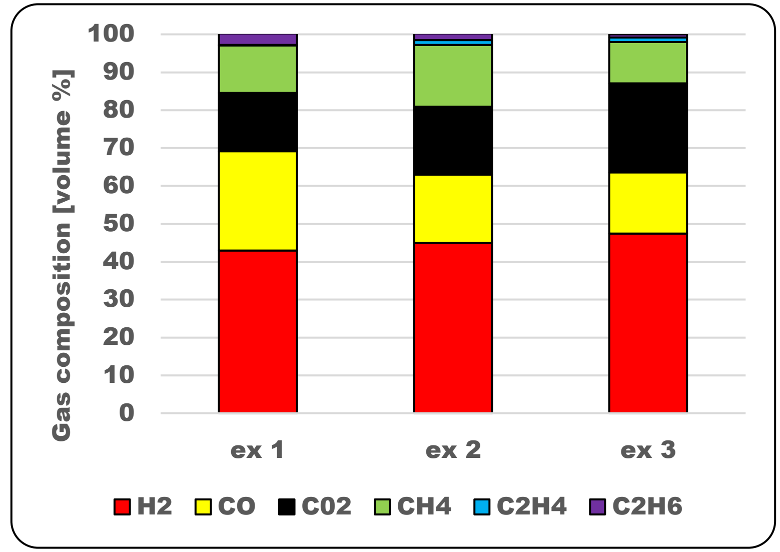


Fig.5 Gas composition 600 ℃

- **The main gases produced were H2, CO and CO2 and CH4 for all the experiments.**
- **Hydrogen yield increased to over 40% at 600 ℃ from below 30% at 450 ℃.**

Water gas shift

CO + H2O ↔ CO2 + H2 (1)

Methanation

CO + 3H2 ↔ CH4 + H2O (2)

Results and discussion; Carbon Yield

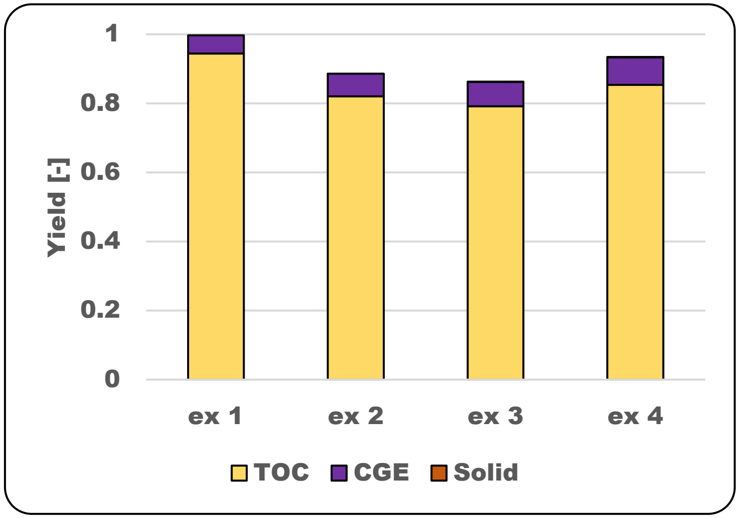


Fig.6 Carbon Yield 450 ℃

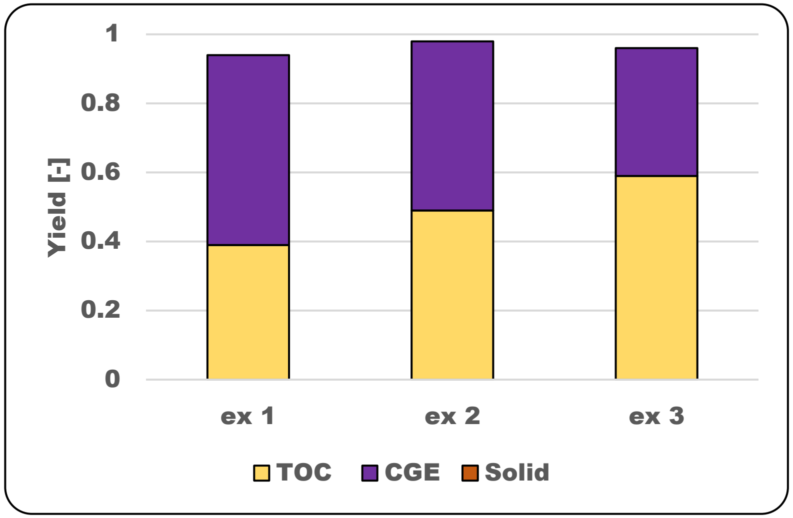


Fig.7 Carbon Yield 600 ℃

$$TOC = \frac{Carbon\ content\ in\ liquid\ product\ \left[mg-\frac{c}{min}\right]}{Carbon\ content\ in\ feedstock\ \left[mg-\frac{c}{min}\right]}$$

- **At 450 ℃ liquid products were dominant over gas products with a yield above 80%, ionic reactions responsible for liquid products were more dominant, however at 600 ℃ gasification was improved up to around 50 %. At 600 ℃ gas products were favored.**

Results and discussion; HPLC analysis

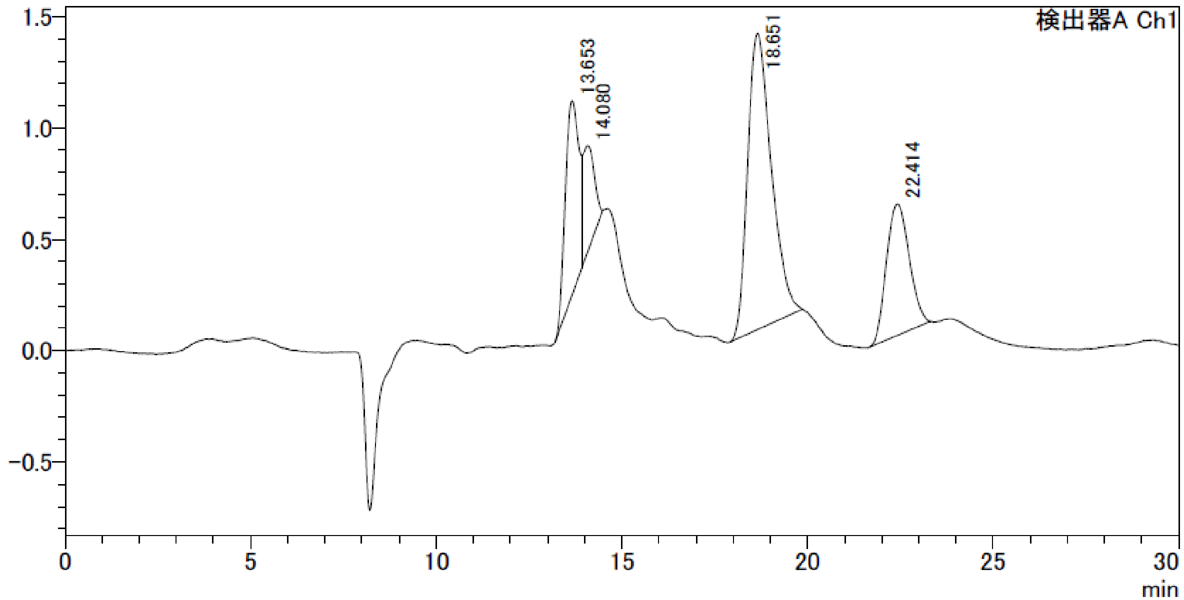


Fig.8 Chemicals found in the liquid products of ex 1 450 ℃

- **Glyceraldehyde; polyesters and adhesives**
- **Formic acid; preservatives and antibacterial agent**
- **Acetic acid; Inks, dyes, pharmaceuticals**
- **Dihydroxy acetone; beauty products**

Conclusion

- **Hydrothermal gasification of biomass model compounds ensures a future alternative to the waste management of waste unused dry biomass**
- **The main gases produced are hydrogen, methane, carbon dioxide and carbon monoxide. High temperature of 600 ℃ has improved gasification and has shown to have equal yields on both liquid and gas products compared to 450 ℃ were liquid products are more dominant.**
- **The decomposition of biomass model compounds in hydrothermal conditions was found to produce intermediate organic compounds that are useful in the chemical industry.**
- **The yield of the liquid compounds observed will be calculated.**
- **The effect of a catalyst will be studied next to compare the yields of both liquid and gas products with the experiments conducted with no catalyst.**

Thank you for your kind attention.