Department of Chemical Engineering
University of the Philippines-Diliman

Fuels, Energy & Thermal Systems Research Laboratory

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Academics & Research Services

University of the Philippines
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ERDT

MSI

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FUELS ENERGY & THERMAL SYSTEMS
RESEARCH LABORATORY

Fuels, Energy and Thermal Systems Research Laboratory

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LISBP

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BÁCH KHOA

Research

University of the Philippines
Diliman

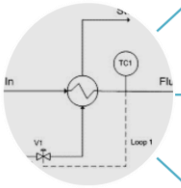
FETS
FUELS ENERGY & THERMAL SYSTEMS
RESEARCH LABORATORY

ENERGY SYSTEMS

- Energy Storage
  - Phase change materials
- System Analysis
  - Geothermal Wellbore Simulation
  - Downdraft rice hull carbonizer
  - PV panel
- Hybrid
  - Solar-assisted Egg Incubator

FUELS

- Source
  - Lignocellulose
  - Microalgae
  - Water
  - Industrial Waste
- Process
  - Catalyst Synthesis
  - Thermal
  - Biological
  - Separation
  - Microreactors
- Products
  - BioEthanol
  - Biodiesel
  - Hydrogen



THERMAL SYSTEMS

- PCM
  - Synthesis
  - Micro encapsulation
  - Characterization
- Nano fluids
  - Synthesis
  - Characterization
- Heat Exchangers
  - Oscillating Heat Pipe
  - Flat Plate Exchangers

Fuels

Source
- Lignocellulose
- Microalgae
- Water
- Industrial Waste

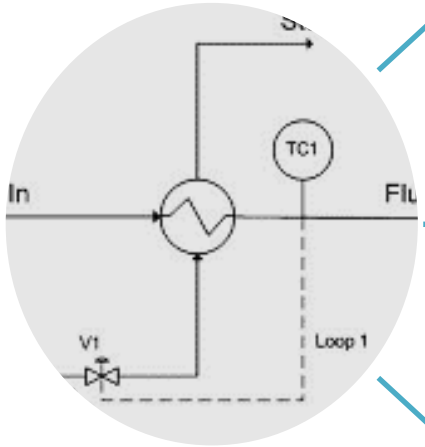
Process
- Catalyst Synthesis
- Thermal
- Biological
- Separation
- Microreactors

Products
- BioEthanol
- Biodiesel
- Hydrogen

Energy Systems

- **Energy Storage**
  - Phase change materials
- **System Analysis**
  - Geothermal Wellbore Simulation
  - Downdraft rice hull carbonizer
  - PV panel
- **Hybrid**
  - Solar-assisted Egg Incubator

Thermal Systems



PCM

- Synthesis
- Micro encapsulation
- Characterization

Nano fluids

- Synthesis
- Characterization

Heat Exchangers

- Oscillating Heat Pipe
- Flat Plate Exchangers

Fuels: Sources & Products

Microalgae ➔ Biodiesel/HVP

- *C. Vulgaris*
- *Nannochloropsis sp.*

Lignocellulose/ Cellulose ➔ Bioethanol/ Crude Oil/HVP

- *Bagasse*
- *Rice Straw*
- *Napier and other Grasses*
- *Macroalgae*

Industrial Waste ➔High-value products (HVP)

- *Peptone*
- *Antimelanogenic*
- *Antimicrobial*
- *Pectin*

Water & Light ➔ Hydrogen

- *Distilled water*
- *Sea water*

Fuels: Process

Microalgae

- *Effect of Cultivation Parameters on Lipid yields and profiles*

Lignocellulose/ Cellulose

- *Pretreatment*
- *Consolidated Bioprocessing*
- *Hydrothermal Treatment*
- *Torrefaction*

Water & Light

- *Photocatalyst Synthesis*
- *Effect of ions and int*

Equipment (Fuels)

Microalgae

- *Cultivation cabinet with CO2 bubbling*

Lignocellulose/ Cellulose

- *Mini hydrothermal reactors*
- *Sandbath*
- *Torrefaction reactor*
- *Incubators/Refrigerator*
- *HPLC*
- *Pressure Cookers (autoclaves)*

Water & Light

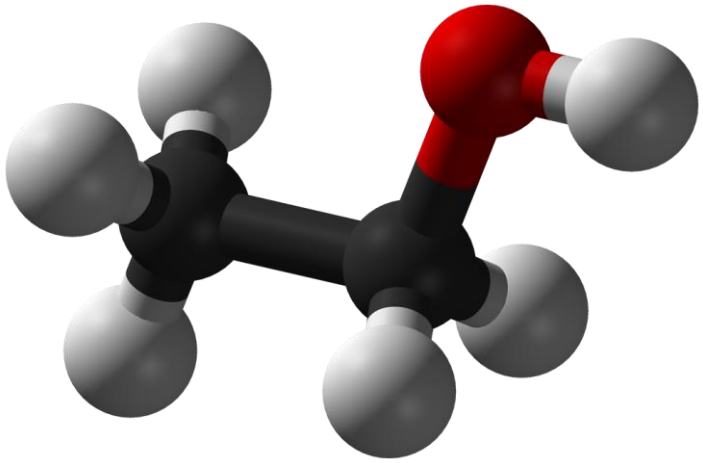
- *GC TCD*
- *Sunlight Simulation Chamber*
- *Photocatalytic Reactor*

Past Research on Products from Lignocellulosic

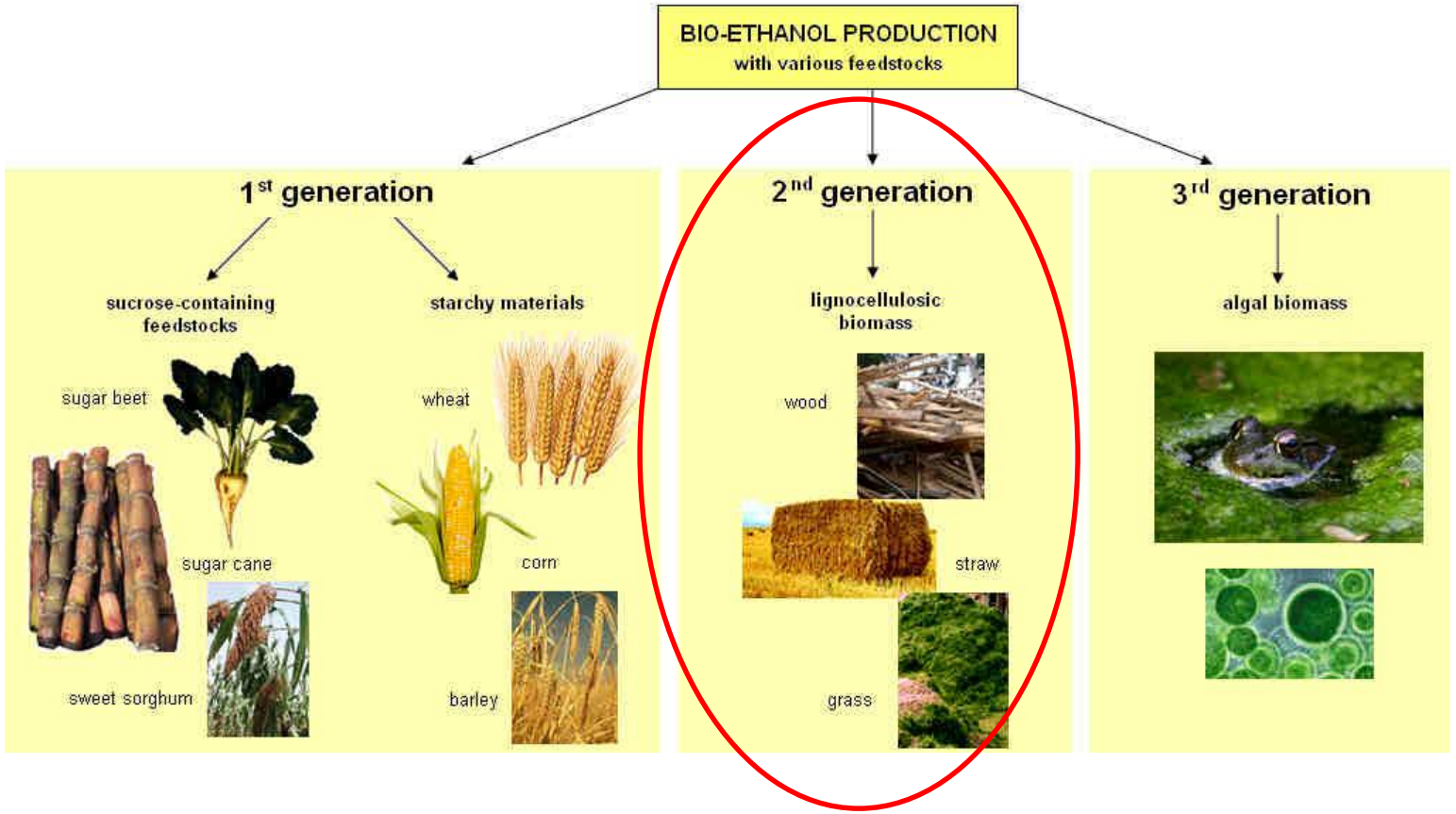
- ***Myra Borines,*** **Bioethanol from Macroalgae (Seaweed)**
- ***Le Duy Khuong,*** **Bioethanol via Consolidated Bioprocessing from Sugarcane Bagasse**
- ***Le Duy Khuong,*** **Bioactivity of the extracts from sodium hydroxide pretreatment waste water with anti-melanoma inhibitory and anti-bacterial activity**
- ***Le Duy Khuong,*** **Crysophanol and pachybasin, two anthraquinone derivatives with melanin biosyntheis inhibitory activity from sugarcane bagasse**

Consolidated Bio Processing (CBP)

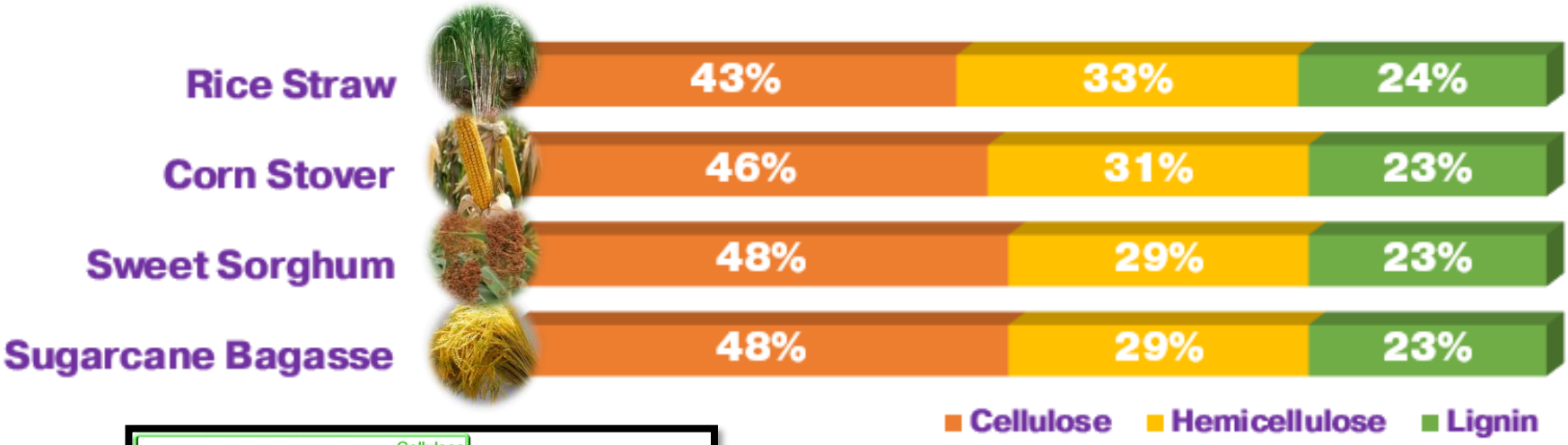
BIOETHANOL

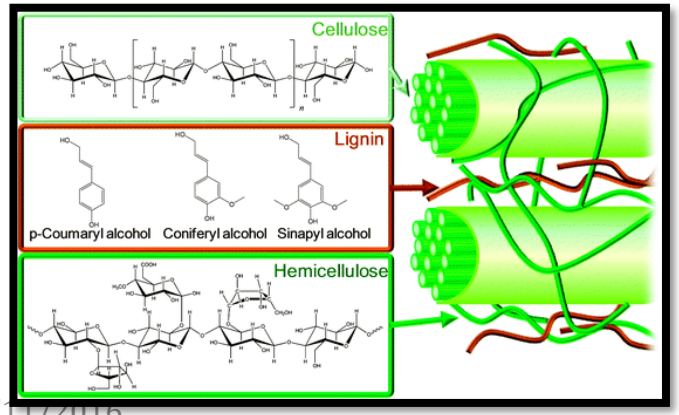


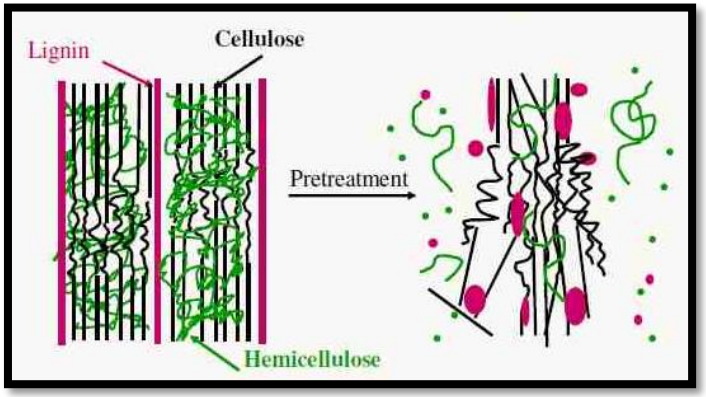
BIOETHANOL
Raw Materials



LIGNOCELLULOSE





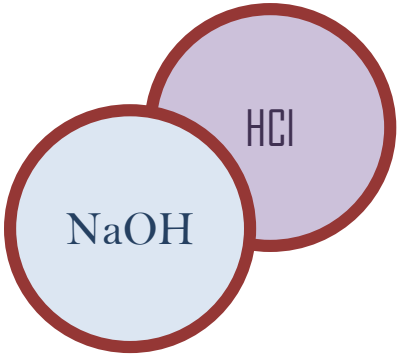


PRETREATMENT

PHYSICAL

BIOLOGICAL

CHEMICAL



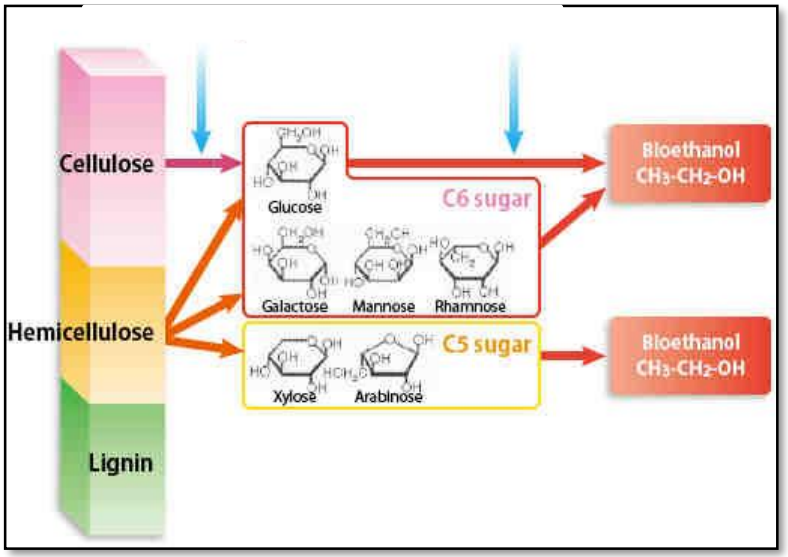
COMBINED

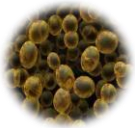
CONSOLIDATED BIOPROCESSING

CBP

Enzymatic hydrolysis

Fermentation





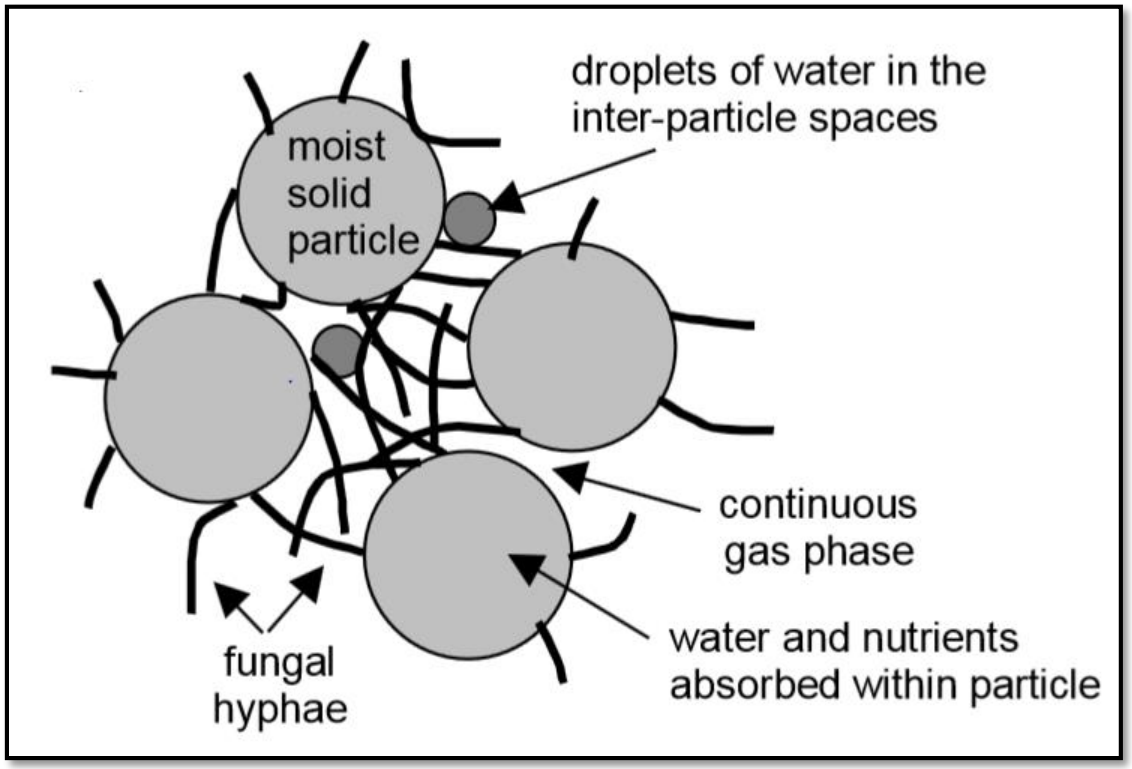
Saccharomyces cerevisiae

Neurospora crassa

Fusarium oxysporum

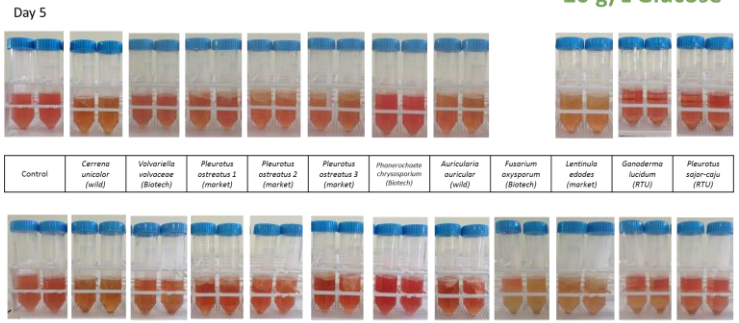
Fusarium moniliforme

HIGH-SOLIDS PROCESSING

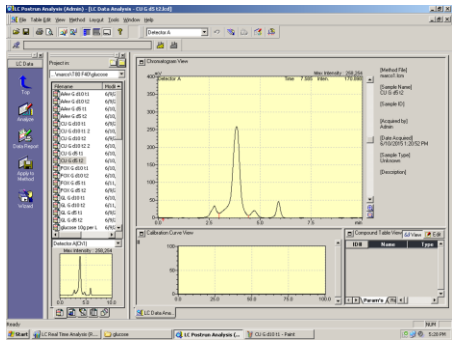


Lignocellulose Fuels: Current Thrust

- Screening of Filamentous Fungi for ability to ferment cellulose to ethanol



Cerrena unicolor (wild)



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BIOETHANOL PRODUCTION VIA CONSOLIDATED BIOPROCESSING UNDER HIGH SOLIDS CONDITIONS OF ALKALI-PRETREATED RICE STRAW USING *Fusarium moniliforme*

Almajoy P. Ilao
John Steven M. Magboo
Ariel Raye V. Rica
Rizalinda L. de Leon Adviser and Head, FETS Laboratory

METHODOLOGY: PRETREATMENT

Rice Straw

Oven drying @ 70°C

Size reduction to Mesh 20-80

Soxhlet extraction for 16 h

Extractives-free Biomass

METHODOLOGY: PRETREATMENT

Extractives-free Biomass (200 g)

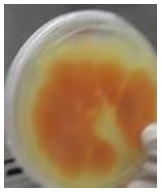
Treatment w/ 400 mL 0.1 M NaOH, 120°C, 1 h

Filtration & washing to pH 6.5

Drying to constant weight

Alkali-pretreated biomass

METHODOLOGY: CULTURE PREPARATION

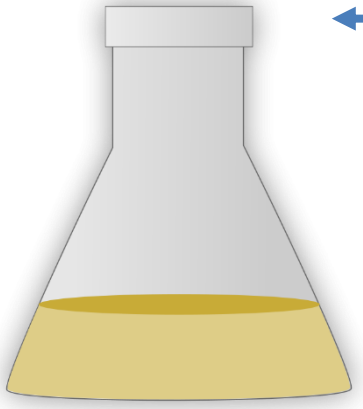


5-mm mycelial discs

7-day old *F. moniliforme* sub-culture

10 mL Mandel's media

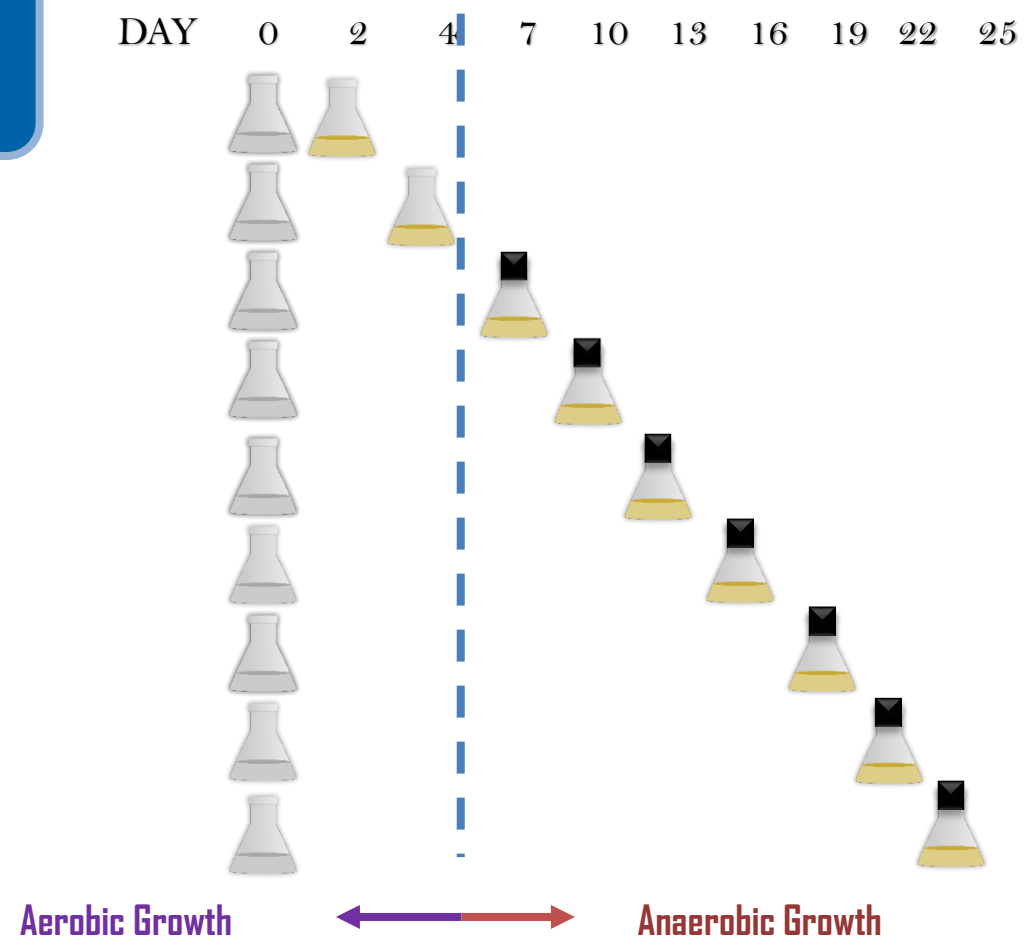
2 g substrate



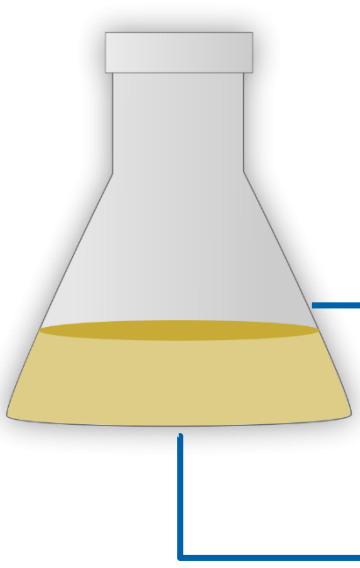
Adjust to pH 7, incubate at 35°C

Component	Amount (g/L)
Glucose	10
Yeast Extract	5
KH_2PO_4	10
$Mg_2SO_4 \cdot 7H_2O$	0.5
$CaCl_2 \cdot 2H_2O$	0.5
$Fe_2SO_4 \cdot H_2O$	0.005
$CoCl_2 \cdot 6H_2O$	0.005
$ZnSO_4 \cdot 7H2O$	0.005
$CuSO_4$	0.005
$MnSO_4$	0.005
Tween 80	1
Resazurin indicator	0.01

METHODOLOGY: FERMENTATION



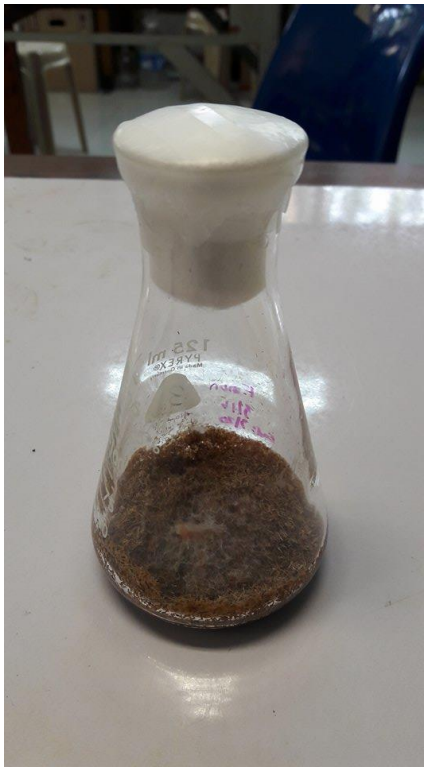
METHODOLOGY: ANALYSIS



Air Space:
Relative Humidity
(Humidity Meter)

Liquid Fraction:
- **Ethanol** (HPLC – water)

Dry Solids:
- **Glucose and Xylose** (HPLC – acetonitrile)
- **Acid-Soluble Lignin** (UV-Vis)
- **Acid-Insoluble Lignin** (Furnace)



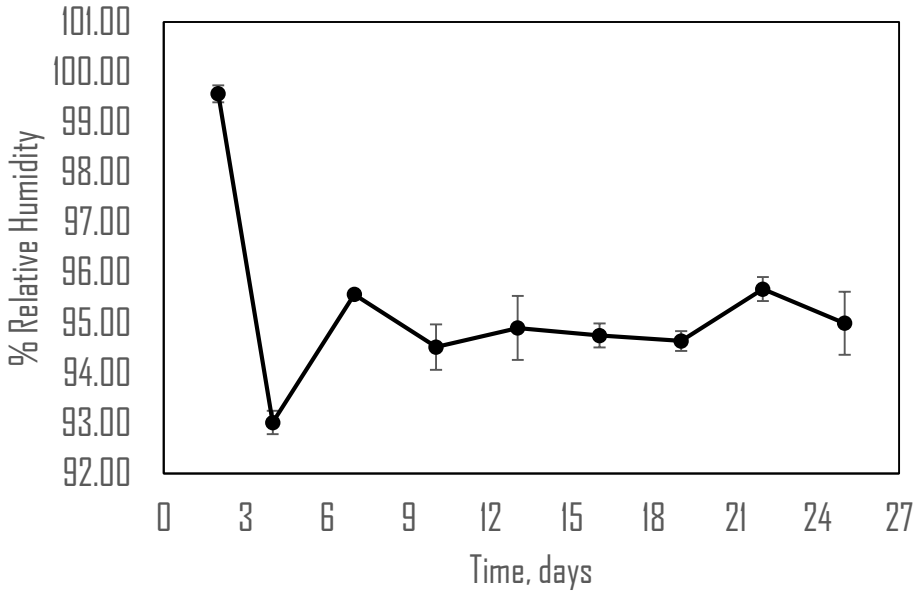
SUMMARY OF RESULTS

Change in Composition of Extractives-free Rice Straw before and after Alkali-Pretreament

	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Treatment with 0.1 *M* NaOH	33.60 ± 4.58	13.83 ± 0.02	15.37 ± 4.41
Untreated	27.58 ± 1.49	10.89 ± 2.51	19.47 ± 1.53

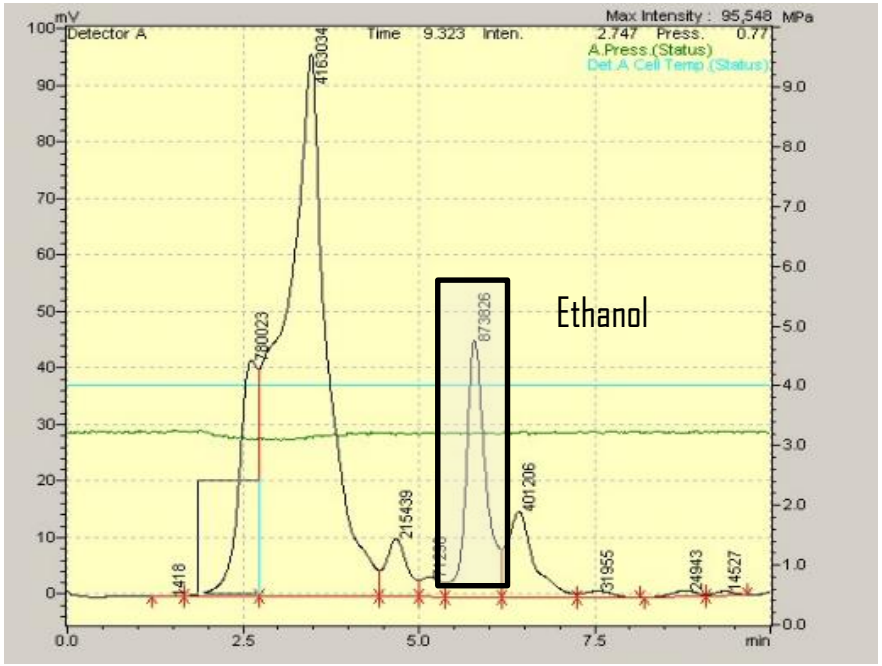
SUMMARY OF RESULTS

Relative humidity in the 125-mL flask space at various fermentation times:



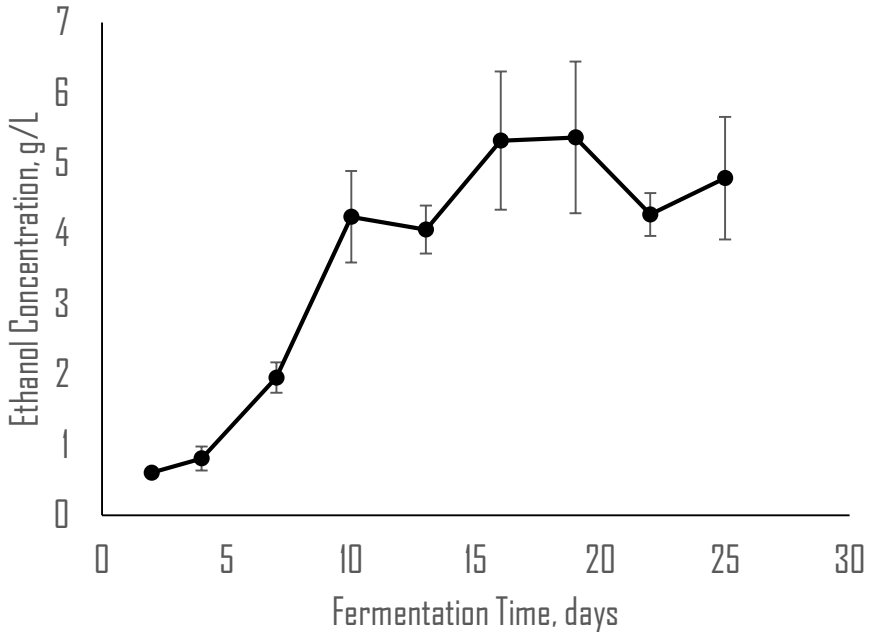
SUMMARY OF RESULTS

HPLC Chromatogram for Ethanol analysis at Day 25:



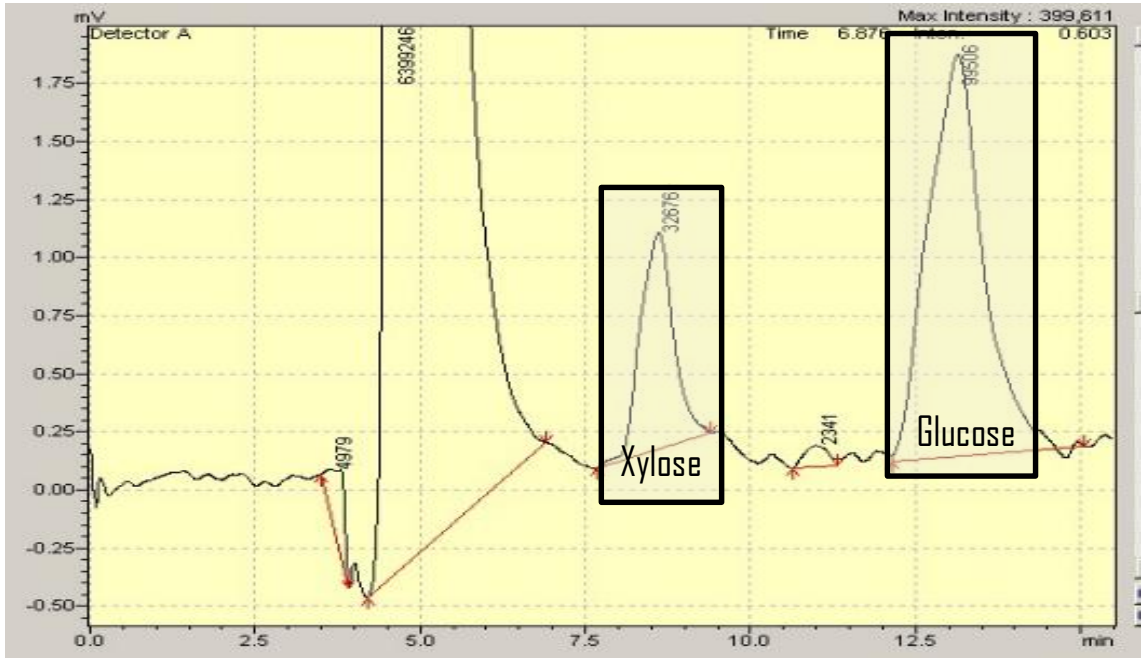
SUMMARY OF RESULTS

Ethanol production by *F. moniliforme* terminated at different fermentation times.



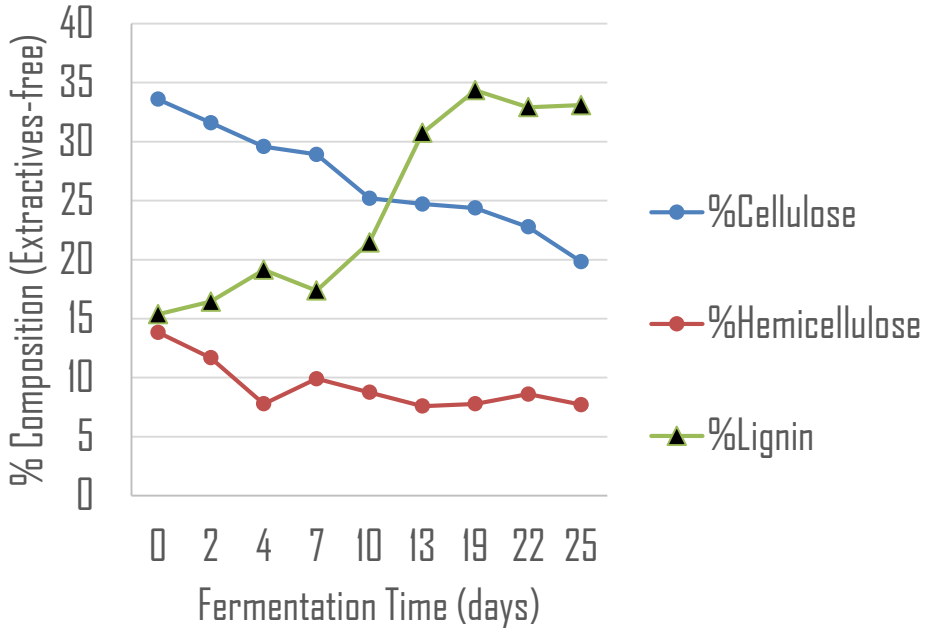
SUMMARY OF RESULTS

HPLC Chromatogram for Carbohydrate analysis at Day 20:



SUMMARY OF RESULTS

Change in biomass composition during fermentation:



CONCLUSIONS

- The filamentous fungus *Fusarium moniliforme* is able to produce bioethanol via consolidated bioprocessing from alkali-pretreated rice straw under solid-state fermentation.
- A maximum ethanol concentration of 5.37 g/L was obtained after 17 days, corresponding to a yield of 26.4 mg ethanol per gram of substrate.
- A decrease in both cellulose and hemicellulose content was observed during the 25-day fermentation.
- *Fusarium moniliforme* is able to ferment both pentose and hexose sugars.

Looking Forward

- Bioreactor Design: e.g. Oscillatory Baffled Reactor (good mixing, low shear, increased mass transfer, linear and predictable scale-up, continuous operation under plug flow conditions)
- Intermittent Feeding

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Suggestions

- Determine changes in protein concentration with time (to follow biomass growth)
- Carbon-balance to determine how much was consumed for biomass production
- Determine enzyme activity
- Composition of Medium – concocted based on requirements per sub-process
- Screening (glucose) greater than theoretical 10 g glucose/L.
- Do you think there might be ethanol inhibition? Do you know tolerance?
- What other components produced? Enzymes? Proteins? Xylitol? Organic acids?
- Viability of the strain? Molecules that could inhibit the growth and the ethanol production?