IU-KU Symposium on Integrative Molecular Biosciences

PALM OIL RESEARCH IN KU FOR BIOFUEL

By

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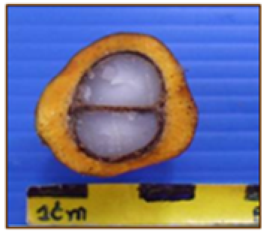
Center of Excellence – Oil Palm was established in 2009

Researchers come from different faculty

The research is divide into three schemes

1. Agronomy and variety improvement
2. Oil extraction and oil quality improvement
3. Value added of oil and biomass

Oil Palm Technology Development for Local Commercial Biodiesel Industry in Newly Planted Area Project



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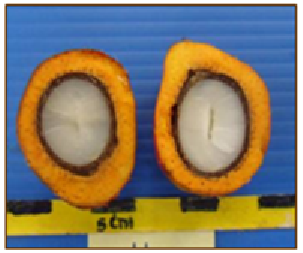

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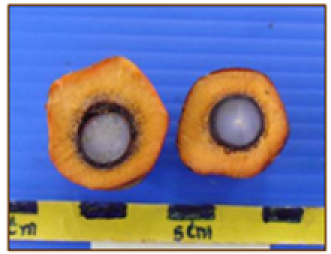

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Raw materials for bioethanol

Oil palm trunk

Oil palm frond

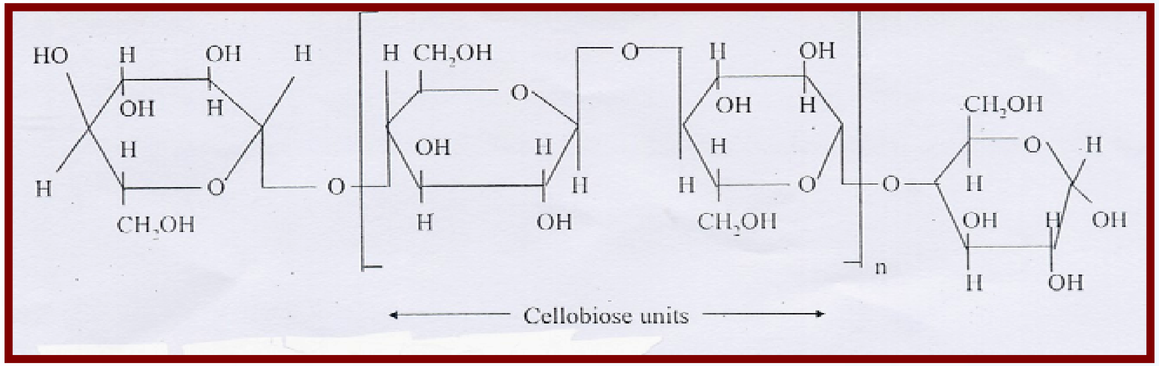
Oil palm empty fruit brunch

	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Glucose (%)	Xylose (%)
Trunk	41.00	34.00	17.00	31.77	18.47
Bunch	40.52	33.72	22.90	31.44	15.62
Frond	35.74	40.41	16.37	-	-

Three main chemical components in biomass

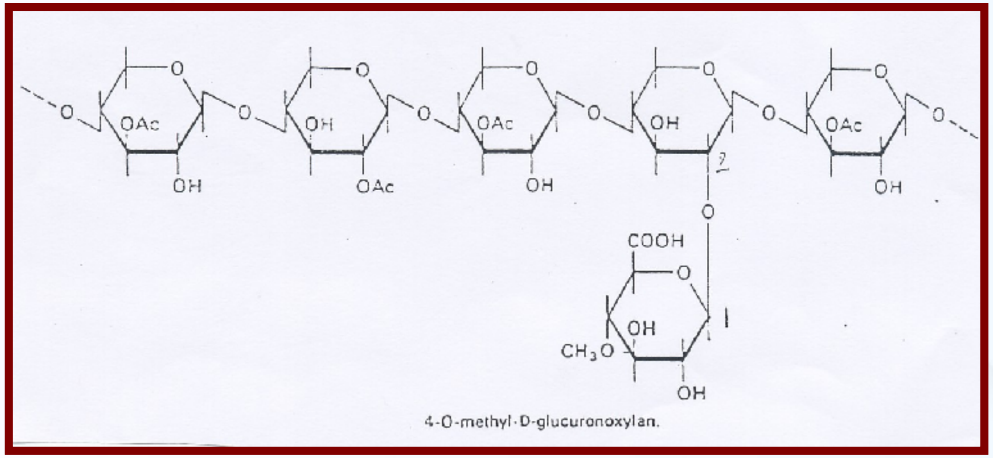
1. Cellulose (40-45%)

- a linear homopolymer of glucose



2. Hemicellulose (20-30%)

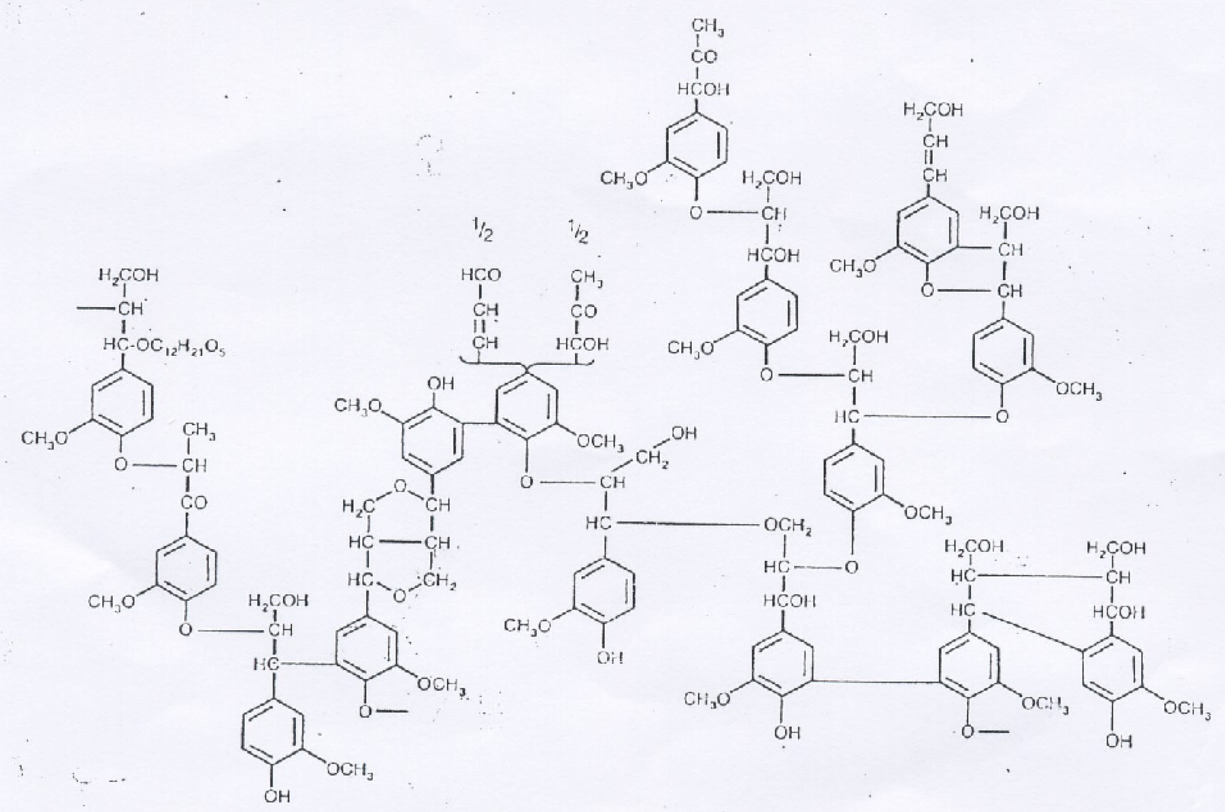
- a branch heteropolymer of monoseccharide sugar



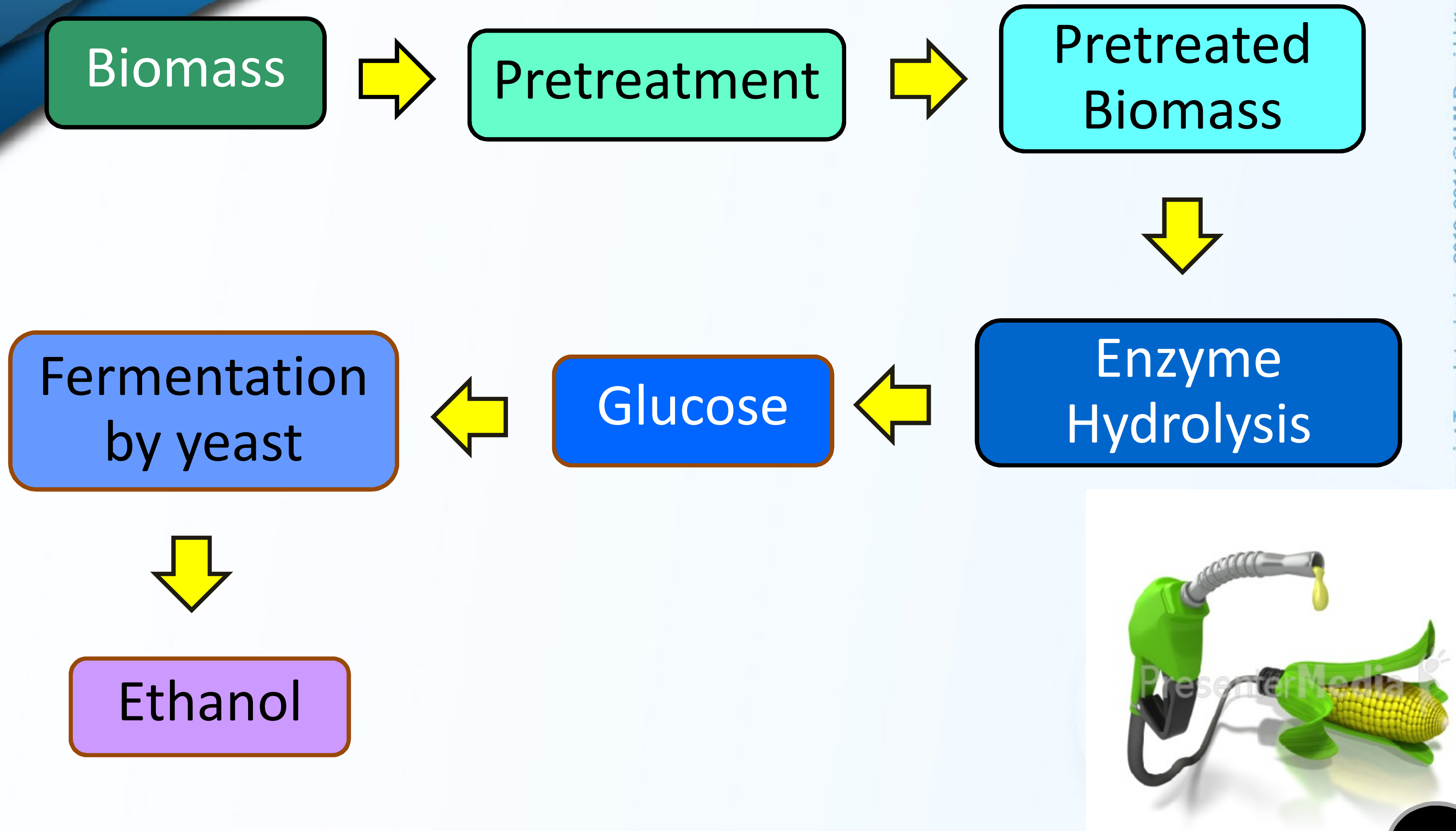
Three main chemical components in biomass

3. Lignin (20-30%)

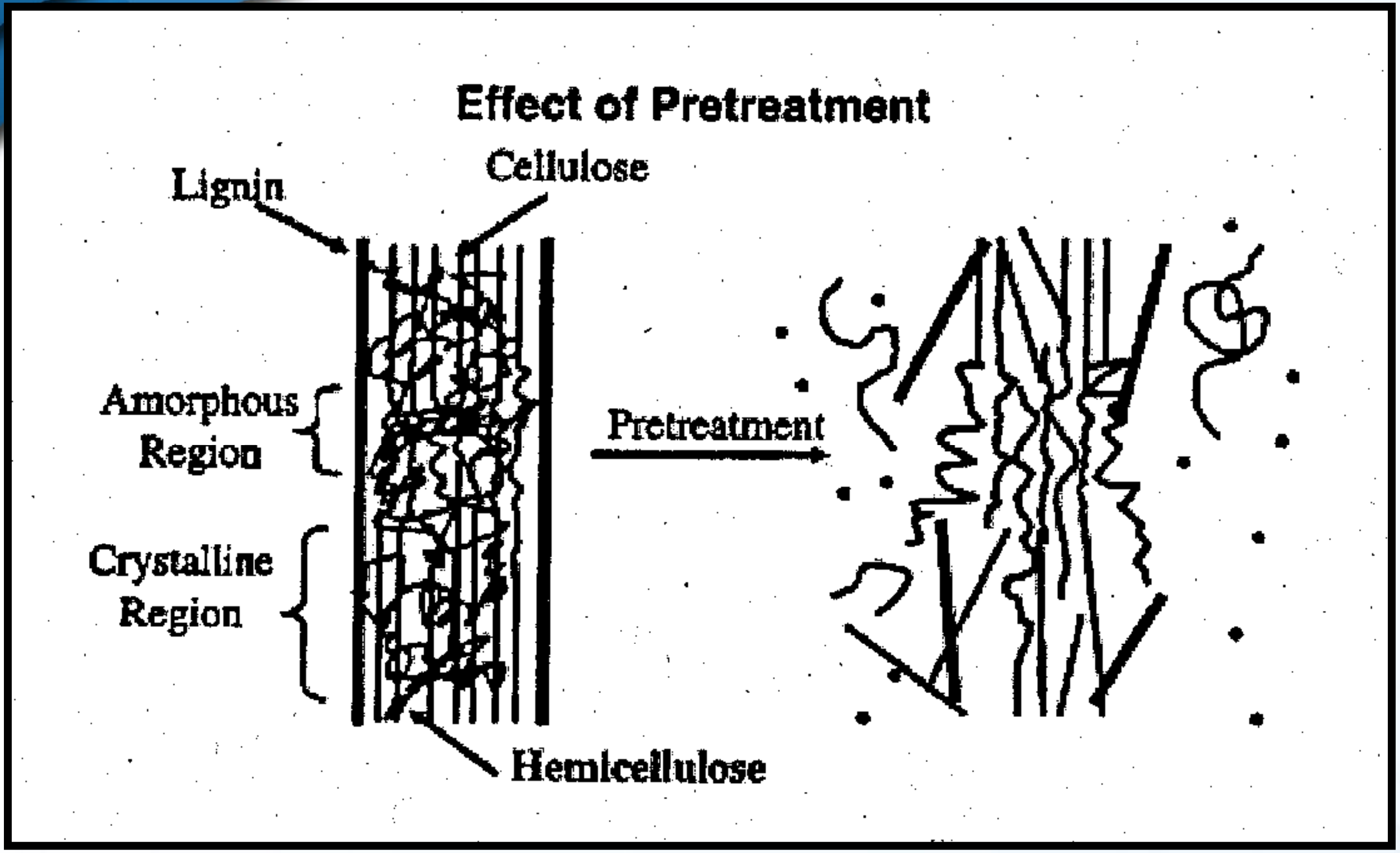
- a phenolic macromolecule that formed by polymerization of coniferyl alcohol sinapyl alcohol and p-coumaryl



Ethanol production from biomass



Pretreatment of biomass



- ❑ Remove lignin and hemicellulose
- ❑ Disordered structure of fiber
- ❑ Minimize loss of carbohydrate

❑ Steam explosion pretreatment use high temperature and high pressure of steam to fractionate hemicellulose from biomass in short period of time

Steam explosion

The possible mechanism reaction occur during steam explosion

Xylan + CH_3COOH ⟶ Xylose + Xylooligosaccharide

Cellulose+ CH_3COOH ⟶ Glucose

Xylose $\xrightarrow{\text{dehydration}}$ Furfural

Glucose $\xrightarrow{\text{dehydration}}$ 5-Hydroxymethylfurfural

Lignin ⟶ Phenolic compound

Agricultural waste
↓
Steam explosion at 180-230 °C
↓
Pulp
↓
Washing with hot water → Xylose + Xylooligosaccharide
↓
Cellulose + Lignin
↓
Enzyme Hydrolysis
↓
Glucose
↓
Fermentation

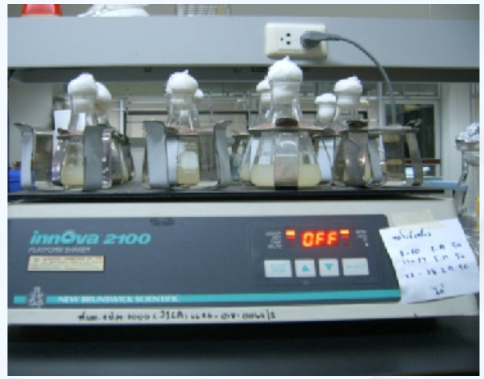
Xylose + Xylooligosaccharide
↓
Xylose
↓
Fermentation
↓
Ethanol

Steam explosion

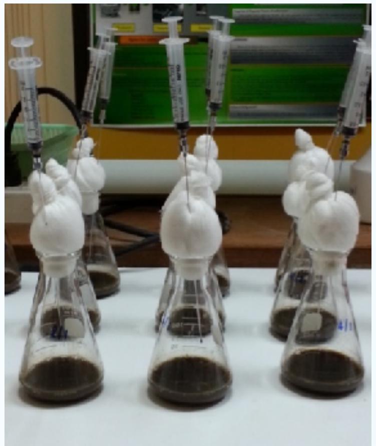
Chip

Steam explosion

Pulp



Enzyme Hydrolysis



Fermentation

Ethanol

The result of %yield on ethanol production

Sample	Yield (%)
Trunk	65
Empty fruit brunch	74
Frond	76

Oil palm frond squeeze juice

Frond

Processing machine

Fiber

Juice

Ethanol production from juice

Oil palm frond

Oil palm frond process

Oil palm frond juice

Filtration to remove sediment

Evaporation to °Brix of sugar

Centrifuge at 5,000 rpm

Ethanol fermentation

Ethanol analysis

Raw materials for biodiesel

Crude palm oil (CPO)
(FFA≈ 10%)

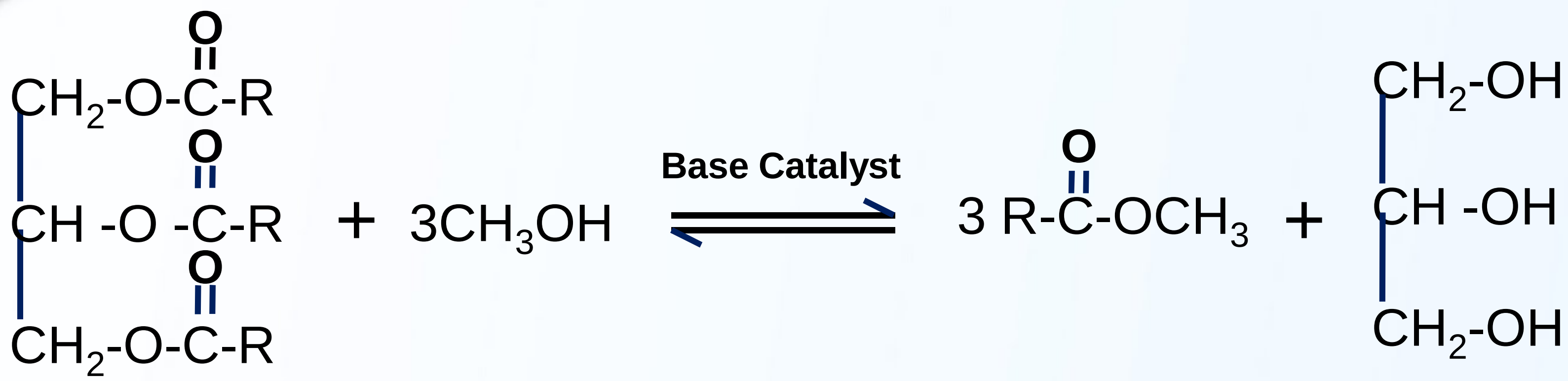
Refined bleach and deodorized palm oil (RBDPO) (FFA≈0.1%)

Palm stearin
(FFA ≈ 0.1%)

Used cooking oil
(FFA≈ 0.5-2%)

Chemical reaction for biodiesel production

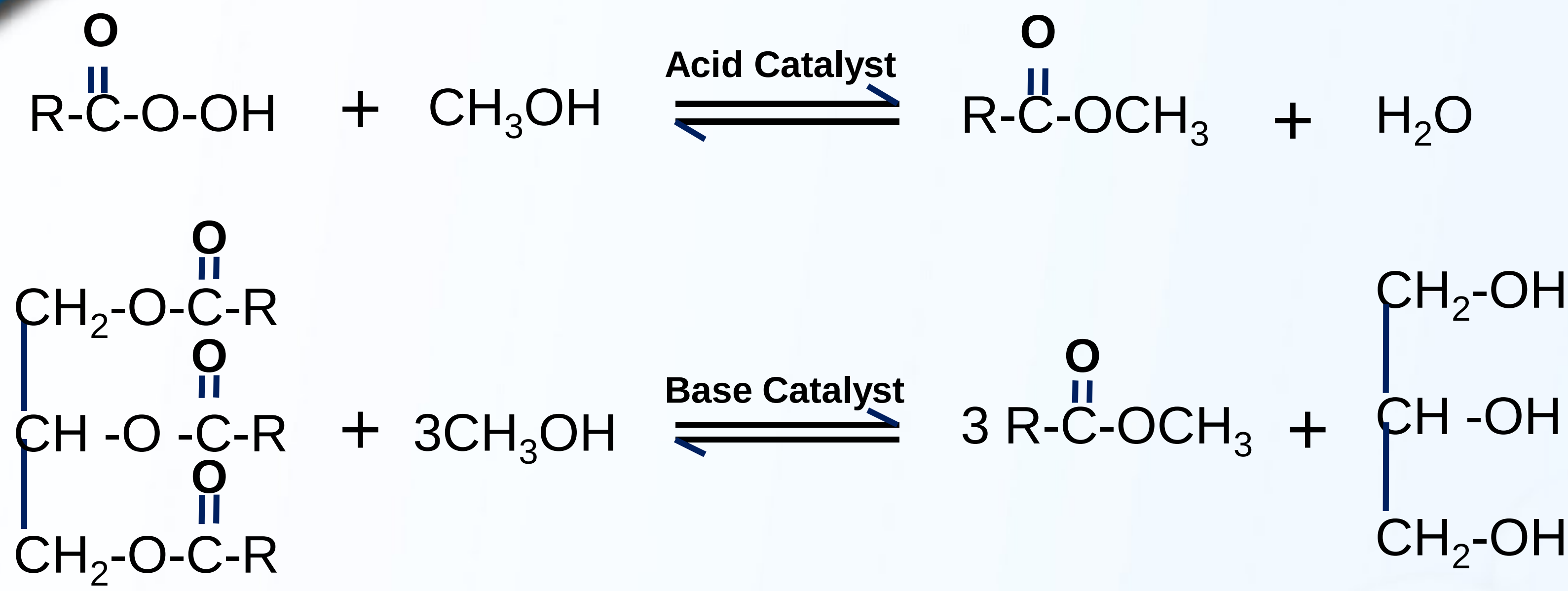
1. Transesterification reaction



- This reaction used with RBDPO, Palm stearin, Used cooking oil (FFA $<$ 2%)

Chemical reaction for biodiesel production

2. Esterification reaction + Transesterification reaction



- These reactions used with CPO, mixed CPO, *Jatropha* curcas oil (FFA> 2%)

Biodiesel production


150 L of biodiesel reactor
from community

150 L of biodiesel reactor
from Kasetsart University

Research on heterogeneous catalyst

Quick lime

- Calcinations
- React with CH_3OH

$Ca(OCH_3)_2$

Calcium methoxide as highly effective catalyst for biodiesel production

Synthesis of catalyst

Quick lime was ground manually using mortar and pestle

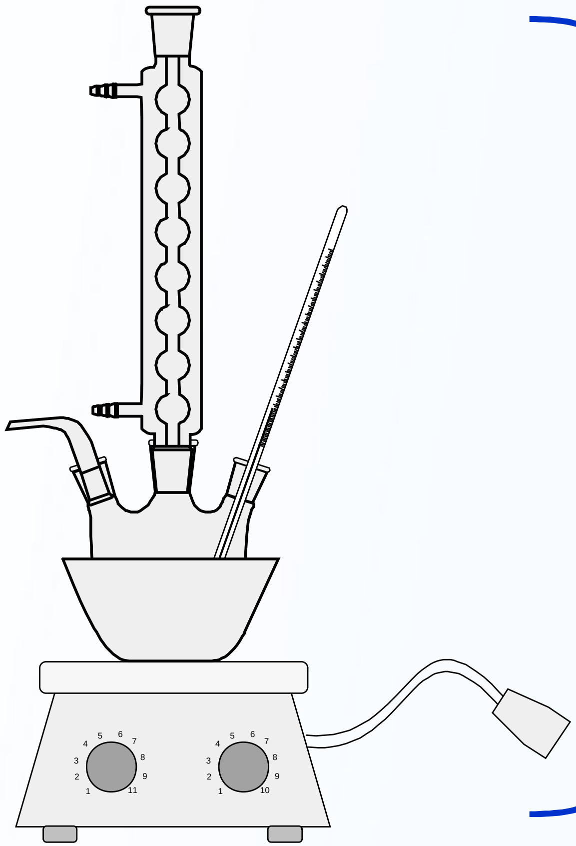
60 mesh screen

quick lime powder

Synthesis of catalyst

Quick lime powder → Calcine at 700 °C for 3.0 h

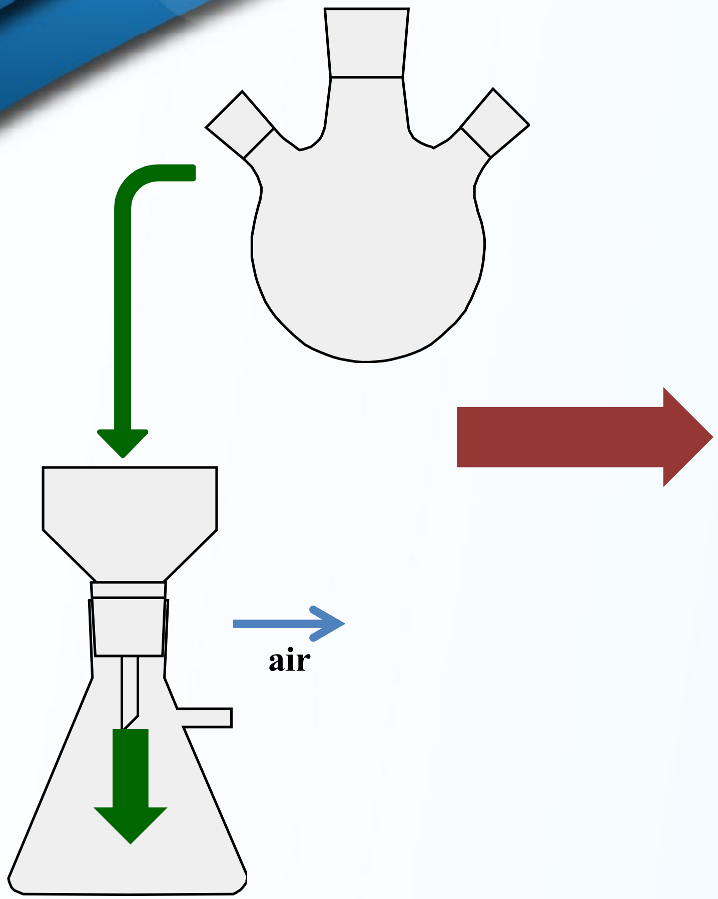
$$CaCO_3(s) \overset{\Delta}{\Rightarrow} CaO(s)$$



5g calcined product was reacted with 150 mL methanol under reflux at 65 °C for 2 h and continuous stirring 1500 rpm

$$CaO + 2CH_3OH \Rightarrow Ca(OCH_3)_2 + H_2O$$

Synthesis of catalyst



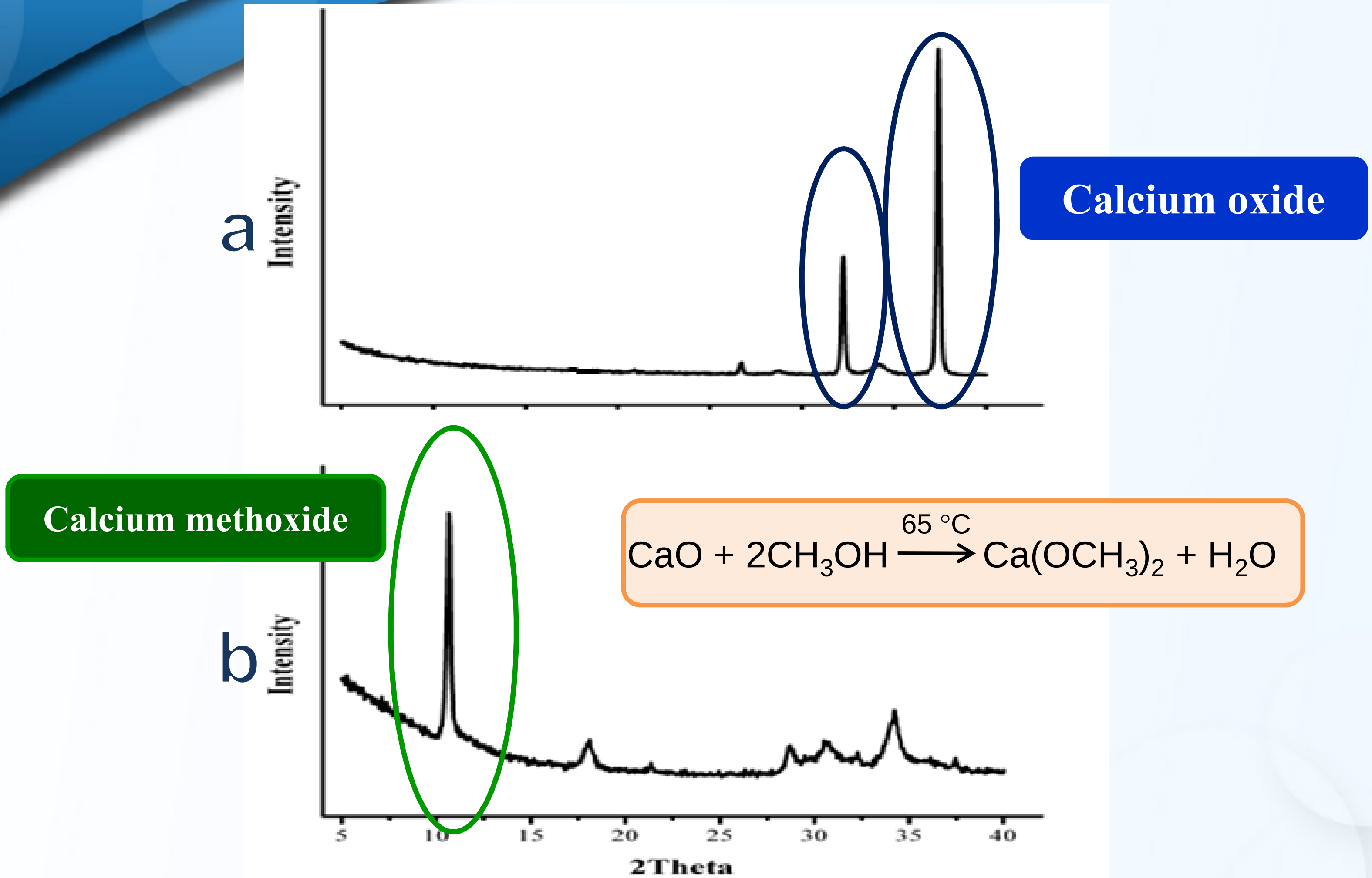
Dried in the oven at

105 °C for 1 h

Catalyst characterization

- X-ray diffraction (XRD)
- Solid state 13C-NMR
- Attenuated total reflection-Fourier transform-infrared (ATR-FTIR)
- Scanning electron microscopy (SEM)
- Energy-dispersive X-ray spectroscopy (EDX)
- BET surface area

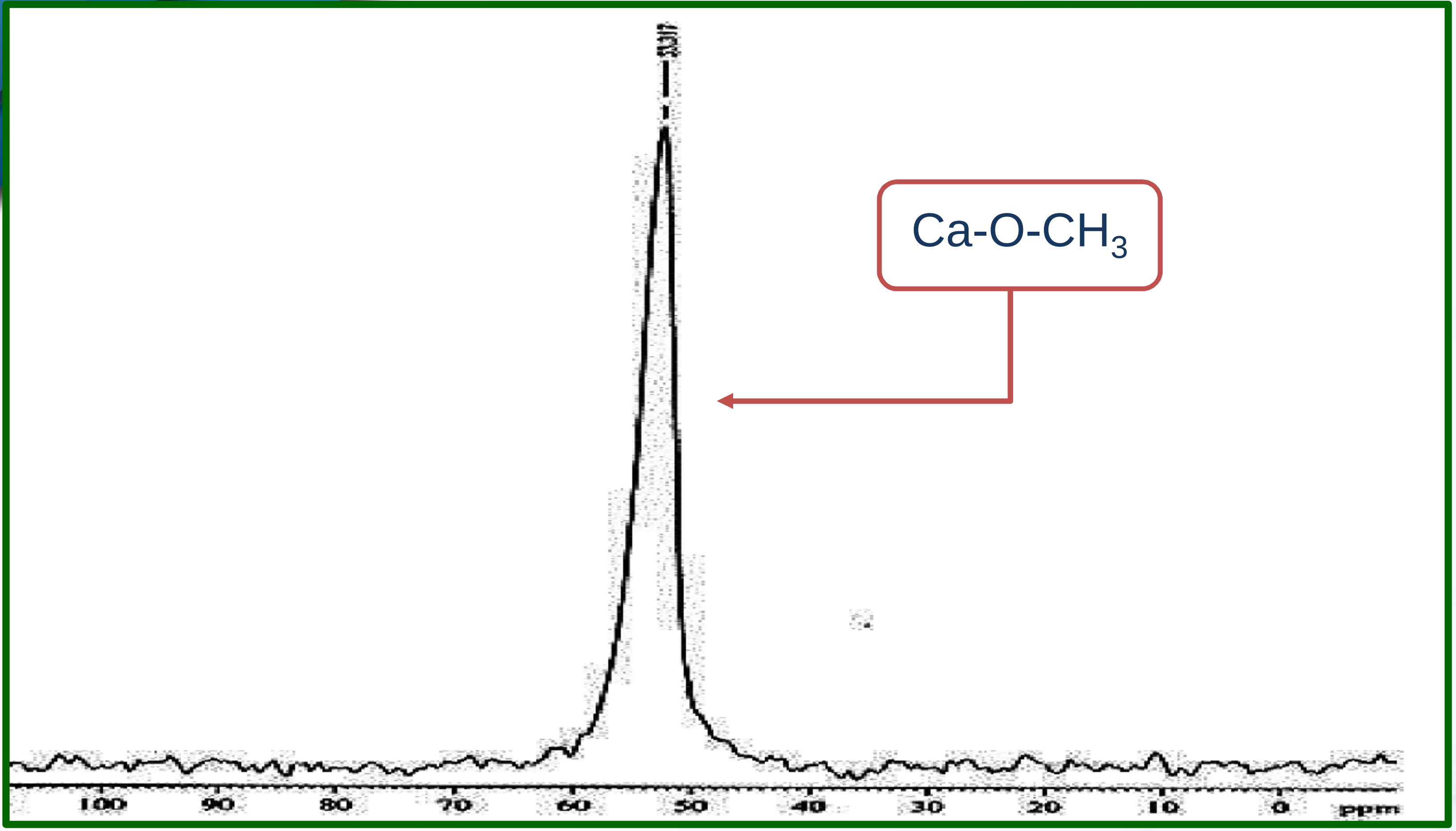
Characterizations of the synthesized catalyst



$$CaO + 2CH_3OH \xrightarrow{65\ ^{\circ}C} Ca(OCH_3)_2 + H_2O$$

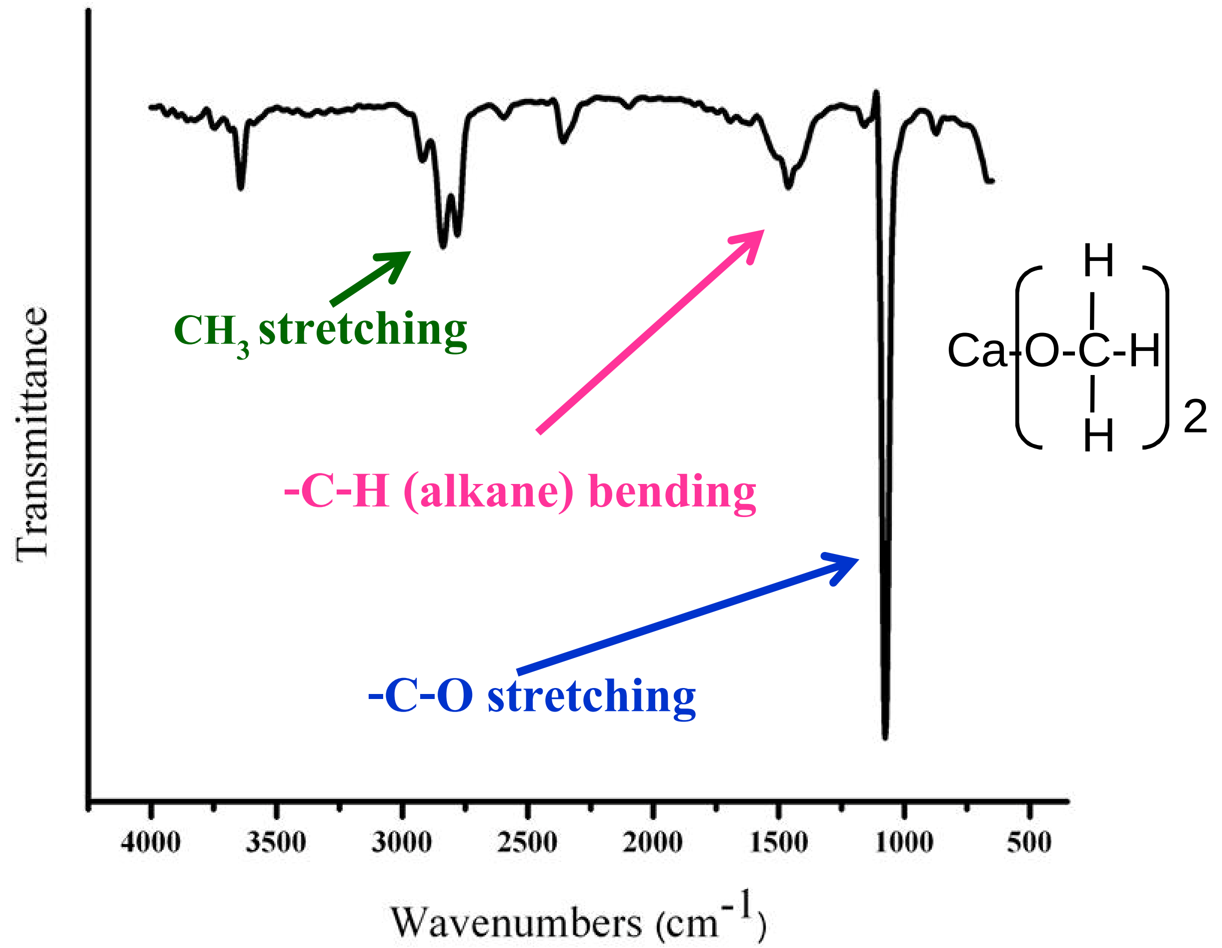
XRD patterns of (a) calcined quick lime; (b) calcium methoxide product

Characterizations of the synthesized catalyst



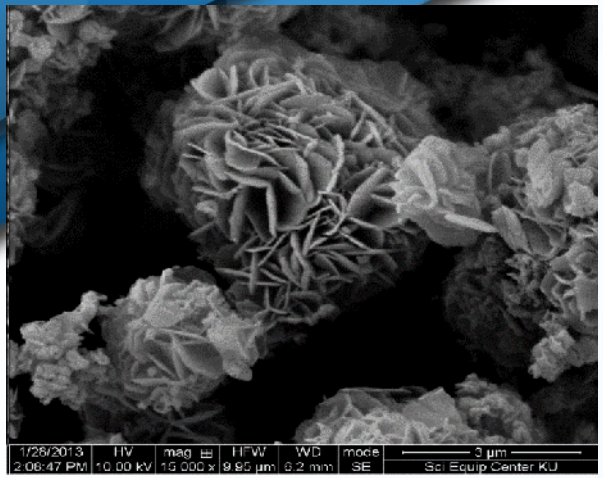
Spectra of solid state ^{13}C-NMR of calcium methoxide

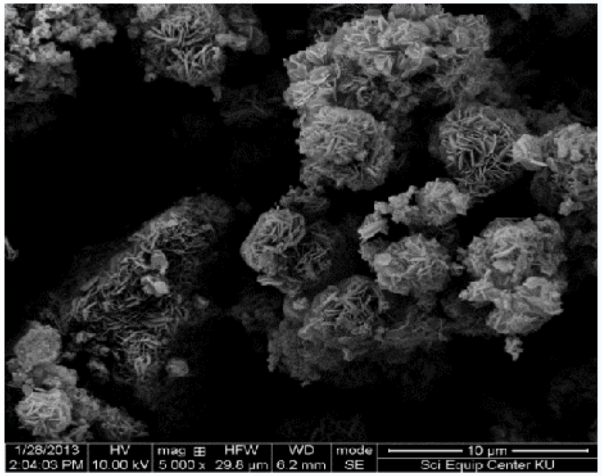
Characterizations of the synthesized catalyst

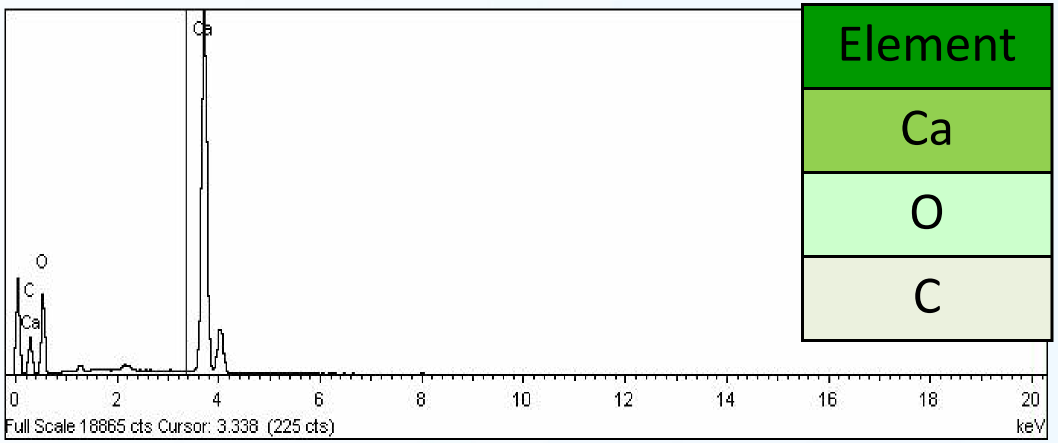


FTIR spectrum of calcium methoxide

Characterizations of the synthesized catalyst





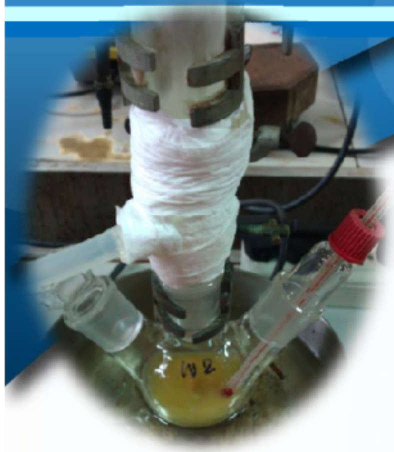


Element
Ca
O
C

Properties	results
BET surface area (m^2/g)	38.46
Total pore volume (cm^3/g)	0.33
Average pore diameter (nm)	34.39

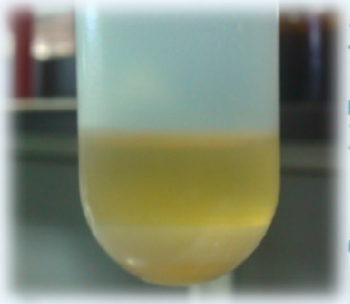
SEM images, EDX spectrum and BET of calcium methoxide

Biodiesel production



RBDPO + $CH_3OH \rightleftharpoons$ Biodiesel + glycerol

The reaction mixture was centrifuged



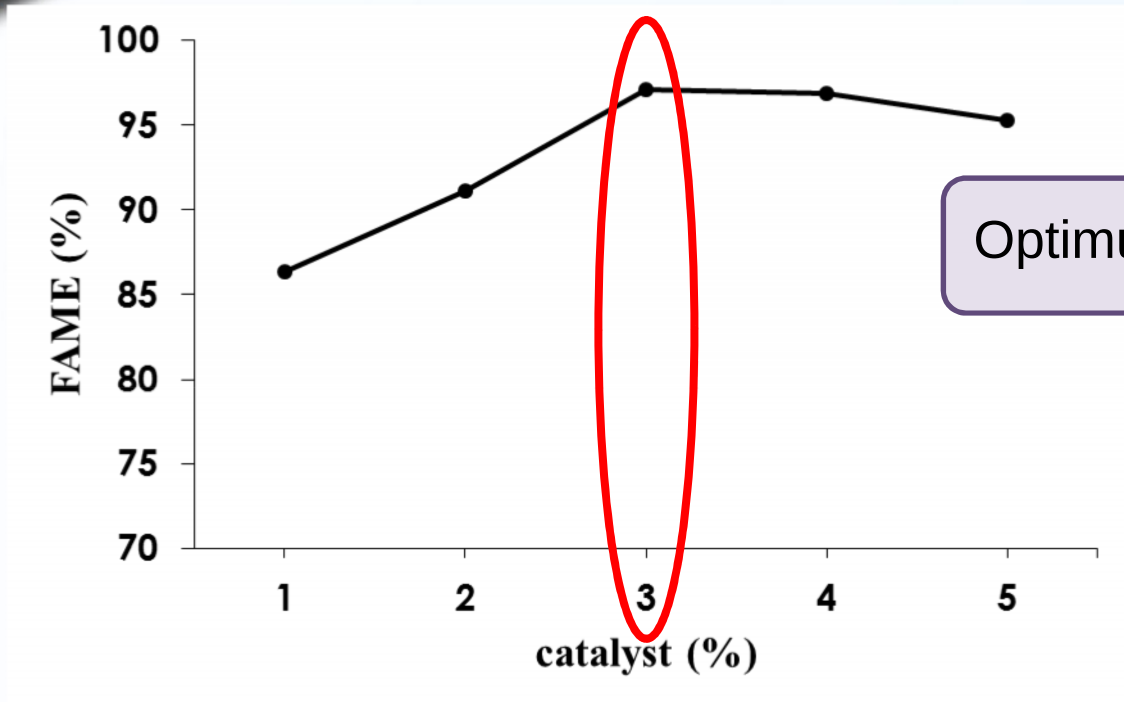
Biodiesel separation from glycerol and catalyst

The FAME (%) in biodiesel was analyzed by gas chromatography (GC)

Variation effects on transesterification

1. Catalyst concentration (1 to 5%wt.)
2. Methanol to oil molar ratio (6:1 to 12:1)
3. Reaction time (1 to 5 h)
   - Constant temperature at 65 °C
   - Constant stirring rate at 750 rpm

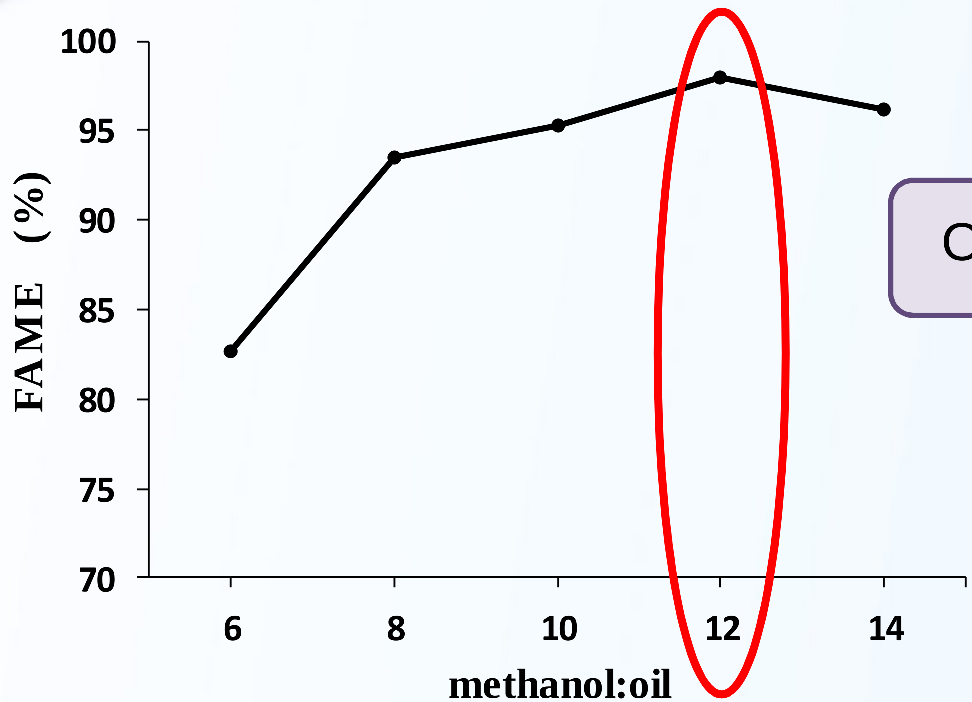
Catalyst concentration



Optimum : 3% wt.

Effect of catalyst concentration on FAME(%), reaction time, 3h ; methanol:oil molar ratio, 12:1 ; reaction temperature, 65 °C.

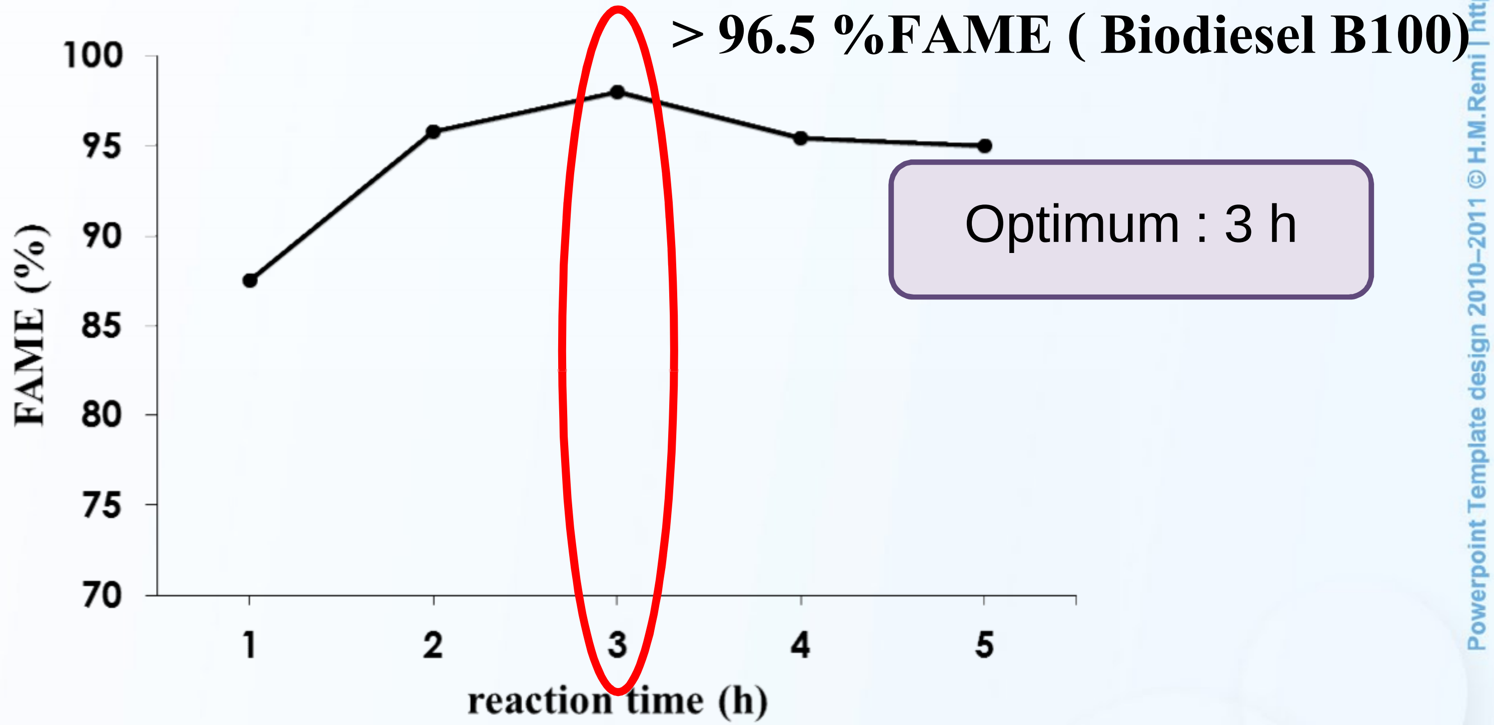
Methanol to oil molar ratio



Optimum : 12:1.

Effect of methanol to oil molar ratio on FAME(%), catalyst concentration, 3% ; reaction time, 3h ; reaction temperature, 65 °C.

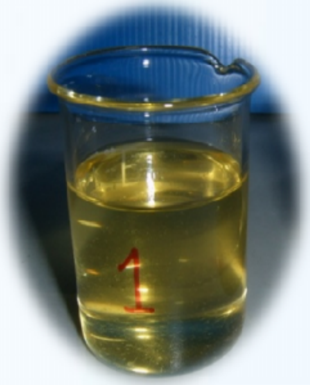
Reaction Time



Effect of reaction time on FAME(%), catalyst concentration, 3% ; methanol:oil molar ratio, 12:1; reaction temperature, 65 °C.

Optimum condition

65 °C, 12:1 methanol to oil molar ratio, 3% wt. catalyst, 3 h reaction time FAME = 97%



BD from solid catalyst

60 °C, 6:1 methanol to oil molar ratio, 1% wt. catalyst, 1 h reaction time FAME = 98%

BD from liquid catalyst

65 °C, 12:1 methanol to oil molar ratio, 3% wt. catalyst, 3 h reaction time FAME = 89.23%

Used cooking oil from solid catalyst

Conclusion

1. Oil palm wastes (Trunk, Frond, Empty fruit bunch, Juice) are potential raw material in ethanol production. It need to further study to improve ethanol yield.

2. Solid catalyst is one of the key of sustainability in palm oil biodiesel production.

THANK YOU VERY MUCH