Biodiesel Production from Used Cooking Oil using Calcined Sodium Silicate Catalyst

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Motivation

Sources: Guo et al, 2012; Aransiola et al., 2012; Sivozhelezova et al, 2009; Papayannakos, 2013; Li et al, 2014; Cheah et al, 2009

- Conversion of waste to useful product such as Biodiesel
- Homogeneous catalysts give very high conversion for biodiesel production but the consumption and recovery of the catalyst constitute a challenge
- Enzymatic conversion is promising but huge cost of enzyme and separation of product pose a challenge
- The use of heterogeneous catalyst has eliminated equipment corrosion and waste water discharge, and appear to be the most promising and sustainable processes
- Need to develop heterogeneous base catalyst for the production of biodiesel with higher tolerance for FFA's content in the feedstock

Research Questions

- What could be the conversion yield of biodiesel obtained from Used (waste) Cooking (UCO) Oil over sodium silicate catalyst?
- What is the effect of reaction time and temperature on the conversion?

Objectives

- Synthesize and characterize sodium silicate catalyst
- Evaluate the FFA content of the UCO sample before the production of biodiesel
- Use the prepared catalyst for biodiesel production from UCO
- Investigate the effect of reaction temperature and reaction time on the conversion

Biodiesel from used cooking oil

Source; Green Cape, 2013

New SA regulation to kick in on the 1st of October 2015

Fuel producers will be required to blend a minimum of 5 percent biodiesel with diesel fuel

Challenges:

- SA UCO market: poor supplier
- Transportation effect of UCO over long distances on the system's sustainability.

Renewable energy of South Africa

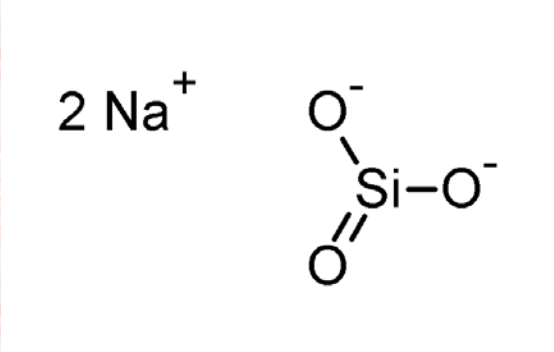
Source; Green Cape, 2013

Status of Biofuel in October 2013

Company Name	Crop / Feedstock	Capacity (million litres/yr)	Location	Licence status
BIOETHANOL				
Mabele Fuels	Sorghum	158	Bothaville, FS	Issued
Ubuhle Renewable Energy	Sugarcane	50	Jozini, KwaZulu Natal	Issued
E10 Petroleum Africa cc	Sugarcane and other crops	4.2	Germiston, Gauteng	Granted
ARENGO 316 (Pty) Ltd	Sorghum and sugar beet	180 (in two phases of 90 each)	Cradock, Eastern Cape	Granted
TOTAL BIOETHANOL CAPACITY		**392.2**		
BIODIESEL				
Rainbow Nation Renewable Fuels	Soya Bean	288	Port Elizabeth, Eastern Cape	Issued
Exol Oil Refinery	Waste Vegetable Oil	12	Krugersdorp, Gauteng	Granted
Phyto Energy	Canola	>500	Port Elizabeth, Eastern Cape	Applying for licence
Basfour 3528 (Pty) Ltd	Waste Vegetable Oil	50	Berlin, Eastern Cape	Granted
TOTAL BIODIESEL CAPACITY		**850**		

Sodium Silicate Catalyst

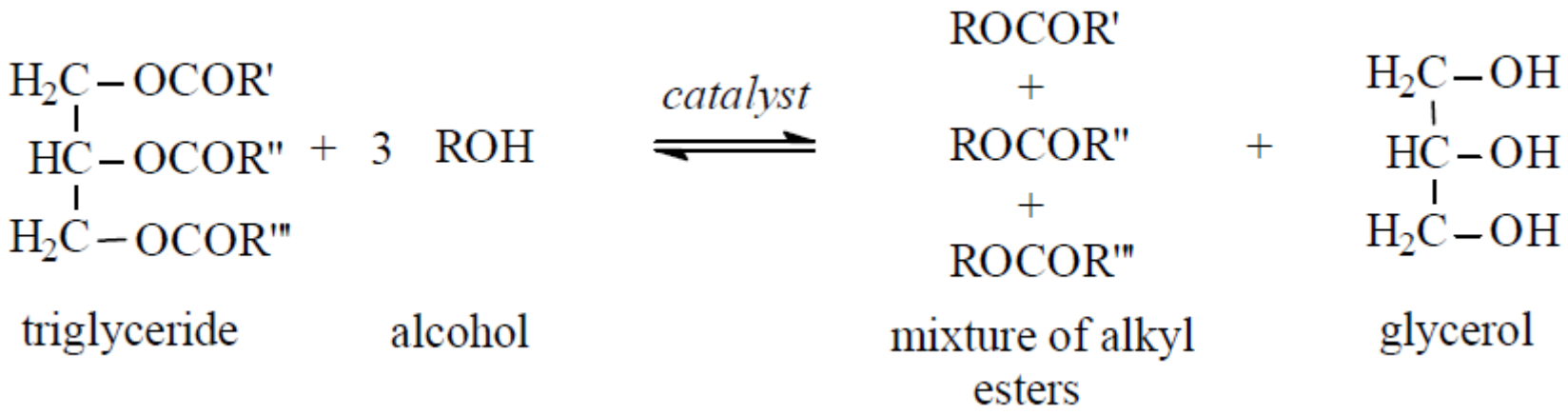
Sources: Dai et al, 2010; Guo et al, 2012



- The use of heterogeneous catalyst showed higher tolerance of FFA
- Sodium silicate as transesterification catalyst has higher catalytic activity after calcination
- Hydrolysis reaction suppresses the formation of soap and decrease water content

Biodiesel production: Transesterification

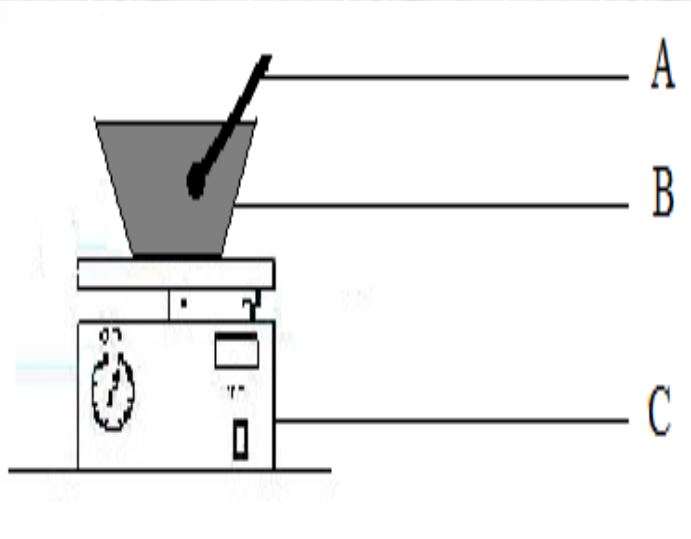
Source: *Schuchardt et al, 1998*



Reaction for transesterification

Experimental Procedure

1. Catalyst preparation



$NaOH + H_2O$ SiO_2

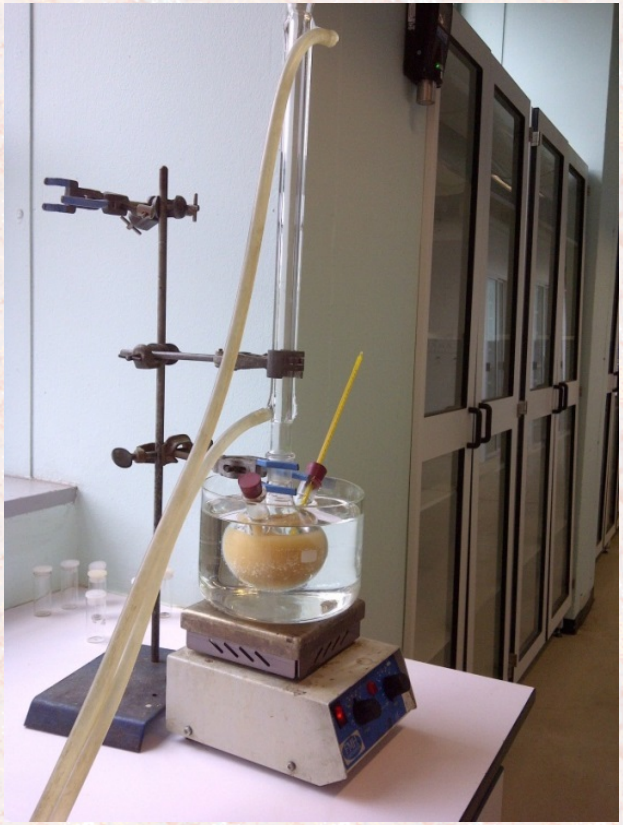
Mixing at constant temperature → Calcination $200/350\ ^0C$

Catalyst Preparation Experimental Set-up

A: spatula used to ensure the uniform mixing of reagents, B:steel bowl used to perform the reaction and C: magnetic heater and stirrer, used to obtain the required reaction temperature.

Experimental Procedure

- Biodiesel production over the catalyst



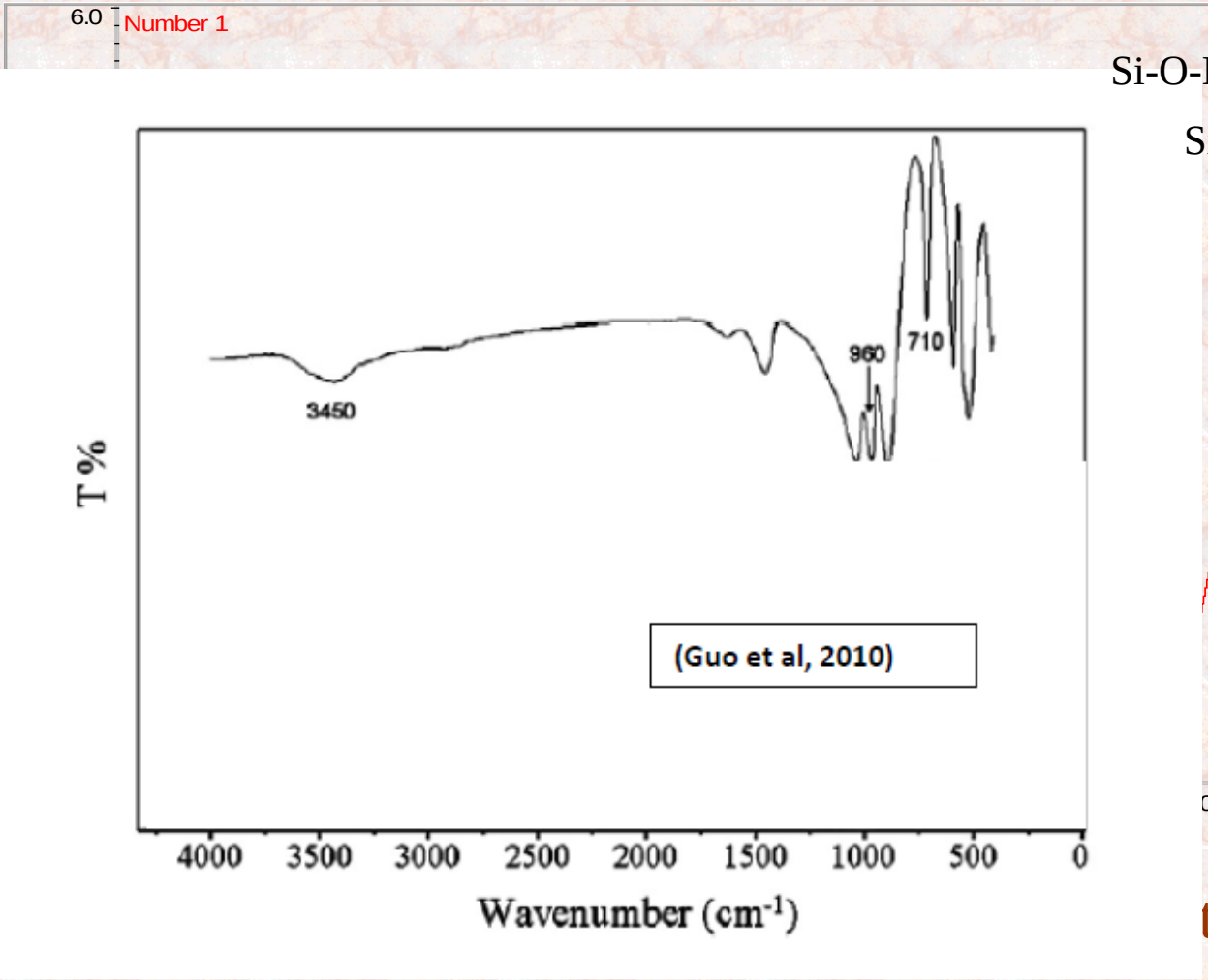
Na_2SiO_3 (2.51 g)
+
Methanol (214.3 ml)

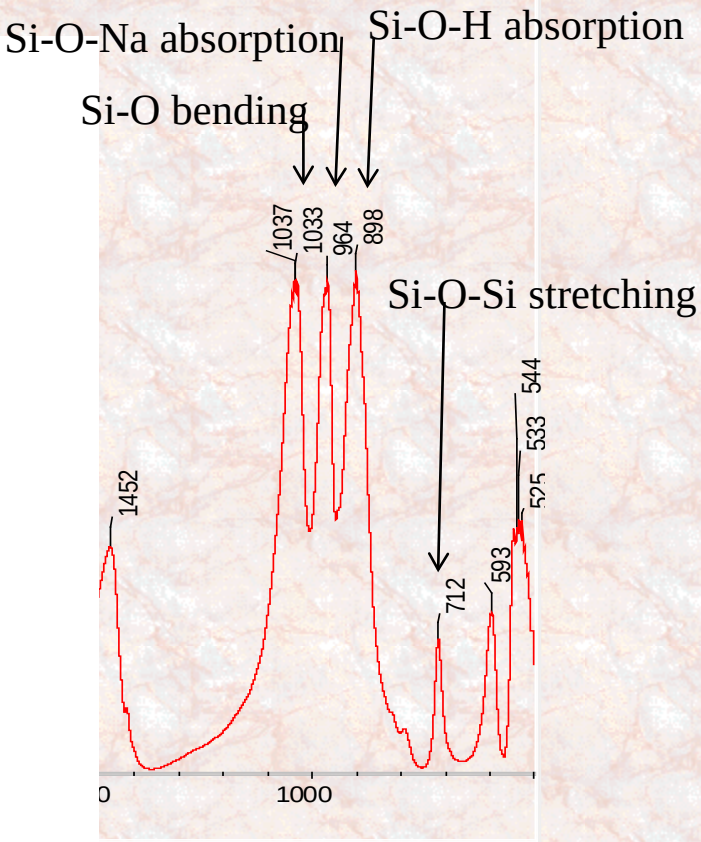
WCO
(35.7 ml)

Reaction at
varied
Temperature (25-70°C)
and time
(0-180 minutes)
Under continuous stirring

The equipment used in the transesterification setup is a Liebig condenser that is connected to a running tap.

Catalyst Characterization





thesized at 41°C

UCO Characterization

- Physico-chemical characteristics of the UCO

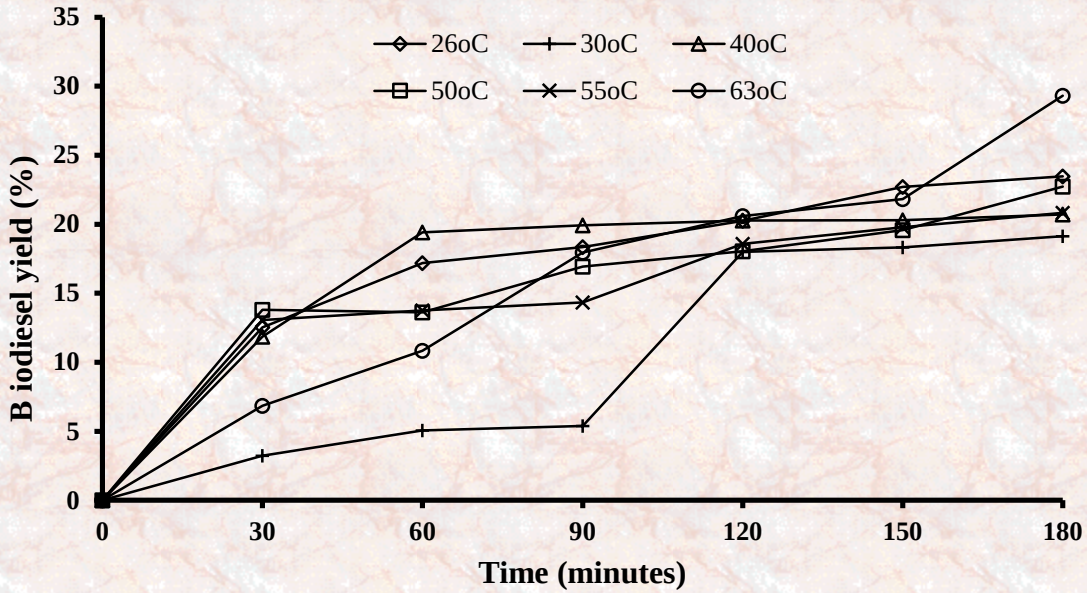
Moisture content (%)	High heating value (MJ/kg)	Melting point (°C)	Specific gravity
<0.05	40	30	0.87

FFA Content of the UCO

The number of titrations conducted along with the volume of titrant used for the solution to reach end-point. (Titration method used by Ding et al (2012))

Titration	Volume used (ml)
1	1.7
2	1.95
3	1.9
4	1.8
Average titration volume (ml)	1.8375 ↔ FFA % = 1.41 % > 1 %
%volume of acid (%)	0.115
Average density of acid used (kg/m^3)	900

Effect of Time & Temperature



Biodiesel yield as function of reaction temperature and reaction time

Effect of Time & Temperature

- Yield of fatty acid methyl esters (FAME) during the reaction increased with time and about 30% FAME was obtained after 180 minutes and at reaction temperature of 63°C.
- The increase in FAME yield at increasing reaction time is consistent with results from previous research efforts on the use of a homogeneous catalyst (NaOH) for the conversion of Jatropha Curcas oil seeds and palm oil to biodiesel (Aransiola et al, 2012 & 2013; Alamu et al, 2008) and on the conversion of WCO to biodiesel over RHC-SO_3H and Ambertyst-15 catalysts (Li et al, 2014).
- Increase in the yield of FAME at increasing reaction time, and reaction temperature could be attributed to the kinetics of the reaction.

Results Compared with Literature

Catalyst	Nature	Reaction T (°C)	Reaction Time (h)	Methanol/oil ratio	BD yield (%)	Ref.
Ambertyst-15	acid	110	3	20:1	~25	Li et al, 2014
RHC-SO_3H	acid	110	3	20:1	42	Li et al, 2014
Na_2SiO_3	base	63	3	6:1	30	This study

Results Compared with Literature

- Based on the same reaction time scale, the yield of FAME obtained in this study was about 5% higher that the FAME yield obtained for Ambertyst-15 catalyst. However, the performance of our catalyst in terms of the yield of FAME is lower than that of RHC-SO_3H catalyst by about 12%.
- The lower reaction temperature and lower methanol-to-oil ratio at which transesterification was conducted in this study could explain the lower performance of our catalyst when compared to RHC-SO3H.
- Since reaction rate increases with increasing temperature, it is expected that increase in reaction temperature beyond 63°C in this study might enhance the yield of FAME beyond 30% while keeping the time and the methanol-to-oil ratio the same.

Conclusions & Recommendations

- Solid sodium silicate catalyst was synthesized and evaluated for biodiesel synthesis from UCO.
- Results show that the calcined Na_2SiO_3 catalyst is able to convert UCO to biodiesel at mild temperature. The results also compare well with literature
- More in-depth studies on the characterization, activity, and the kinetics of the catalyst in transforming UCO to biodiesel to improve the yield of FAME are on-going in our lab.
- At the same time, improvement of the synthesis protocol of the catalyst via optimization study is essential to improving the activity of the catalyst.
- Evaluation of performance stability and optimization of the transesterification operating conditions are essential to achieving optimized process.

Acknowledgments

Wits FEBE Top-slice Grant

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Thank You for Your Attention