

**SYNTHESIS OF ZEOLITE-A FROM PUMICE SILICA AND  
ALUMINIUM FOIL AS A CATALYST FOR PYROLYSIS  
OF PALM OIL MILL EFFLUENT (POME)**

**(Skripsi)**

**By**

**QUNTUM RAMADHINA**



**FACULTY OF MATHEMATICS AND NATURAL SCIENCES  
LAMPUNG UNIVERSITY  
BANDAR LAMPUNG  
2023**

## **ABSTRACT**

### **SYNTHESIS OF ZEOLITE-A FROM PUMICE SILICA AND ALUMINIUM FOIL AS A CATALYST FOR PYROLYSIS OF PALM OIL MILL EFFLUENT (POME)**

**By**

**QUNTUM RAMADHINA**

In this research, palm oil mill effluent (POME) was converted into liquid fuel by pyrolysis method using zeolite-A as a catalyst with various calcination temperature, to study the effect of it towards the characteristic of liquid fuel. Zeolite-A was synthesized from pumice silica and food grade aluminium foil with hydrothermal method at 100°C for 72 hours, then calcined at 600, 700, and 800°C for 6 hours. Synthesized zeolite-A was then characterized using XRD and SEM to ensure the formation of zeolite-A. Liquid fuel produced from the catalytic upgrading process using zeolite-A was analyzed using GC-MS to identify the components contained in the sample. The GC-MS results show the most optimum catalyst used for catalytic upgrading in terms of hydrocarbon was zeolite-A 700°C with relative percentage of 84.48%, and the least optimum was zeolite-A 800°C with relative percentage of 81.37%. In terms of hydrocarbon chain in range of bio gasoline, zeolite-A 600°C has the highest relative percentage of 47%, and the least optimum was zeolite-A 700°C with relative percentage of 36%.

**Keywords:** Palm oil mill effluent, liquid fuel, pyrolysis, zeolite-A, synthesized, pumice.

**SYNTHESIS OF ZEOLITE-A FROM PUMICE SILICA AND  
ALUMINIUM FOIL AS A CATALYST FOR PYROLYSIS  
OF PALM OIL MILL EFFLUENT (POME)**

**By**

**QUNTUM RAMADHINA**

**Final Project (Skripsi)**

**As a partial fulfillment of the requirements for the Bachelor of Science  
degree**

**At**

**Chemistry Department  
Faculty of Mathematics and Natural Sciences**



**FACULTY OF MATHEMATICS AND NATURAL SCIENCES  
LAMPUNG UNIVERSITY  
BANDAR LAMPUNG  
2023**

**SINTESIS ZEOLIT-A DARI SILICA BATU APUNG DAN ALUMINIUM  
FOIL SEBAGAI KATALIS PIROLISIS *PALM OIL MILL EFFLUENT*  
(POME)**

Oleh

**QUNTUM RAMADHINA**

Skripsi

Sebagai salah satu syarat untuk memperoleh gelar Sarjana Sains

pada

**Jurusan Kimia**

**Fakultas Matematika dan Ilmu Pengetahuan Alam**



**FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM  
UNIVERSITAS LAMPUNG  
BANDAR LAMPUNG  
2023**

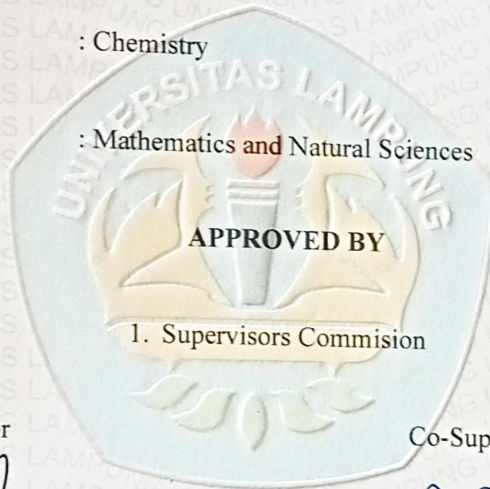
Research Title : **Synthesis of Zeolite-A from Pumice Silica and Aluminium Foil As A Catalyst for Pyrolysis of Palm Oil Mill Effluent (POME)**

Name : **Quntum Ramadhina**

Student ID : 1917011048

Department : Chemistry

Faculty : Mathematics and Natural Sciences



Main Supervisor

**Prof. Wasinton Simanjuntak, Ph.D.**  
NIP. 195907061988111001

Co-Supervisor

**Dr. Ilim, M.S.**  
NIP. 196505251990032002

2. Head of Department

**Mulvono, Ph.D.**  
NIP. 197406112000031002



APPROVAL

1. Examiner Team

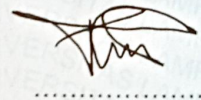
Chief : Prof. Wasinton Simanjuntak, Ph.D.



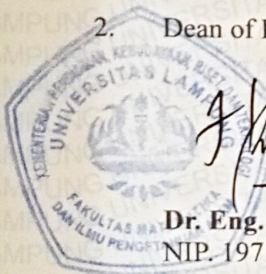
Secretary : Dr. Ilim, M.S.

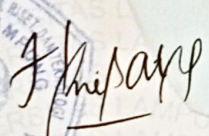


Examiner  
Non Supervisor : Prof. Dr. Sutopo Hadi, S.Si, M.Sc.



2. Dean of Faculty of Mathematics and Natural Sciences



  
Dr. Eng. Heri Satria, S.Si., M.Si.  
NIP. 197110012005011002

Date of the examination: 27<sup>th</sup> of July 2023



## SURAT PERNYATAAN

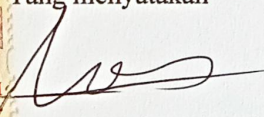
Yang bertanda tangan di bawah ini:

Nama : Quntum Ramadhina  
Nomor Pokok Mahasiswa : 1917011048  
Jurusan : Kimia  
Fakultas : Matematika dan Ilmu Pengetahuan Alam  
Perguruan Tinggi : Universitas Lampung

Menyatakan bahwa skripsi yang berjudul "*Synthesis of Zeolite-A from Pumice Silica and Aluminium Foil As A Catalyst for Pyrolysis of Palm Oil Mill Effluent (POME)*" adalah benar hasil karya sendiri dan tidak pernah menggunakan dan diterima sebagai syarat penyelesaian studi pada universitas lain. Saya tidak keberatan jika data dalam skripsi ini digunakan oleh dosen atau program studi untuk kepentingan publikasi sesuai kesepakatan.

Bandar Lampung, Agustus 2023  
Yang menyatakan



  
Quntum Ramadhina  
1917011048

## **RIWAYAT HIDUP**

Penulis bernama lengkap Quntum Ramadhina, lahir di Tangerang pada 15 Desember 2001 dan merupakan anak ke-2 dari 3 bersaudara, dari pasangan suami istri Bapak Jerry Sonya Putra dan Ibu Tuti Yuliani.

Penulis menyelesaikan pendidikan mulai dari Taman Pendidikan Al-Qur'an (2005 – 2006), SD Negeri Bojongnangka (2006 – 2012), SMP Negeri 2 Kelapa Dua (2013 - 2016), SMA Negeri 23 Kabupaten Tangerang (2016 – 2019), dan mulai tahun 2019 hingga penulisan skripsi ini, penulis melanjutkan ke Perguruan Tinggi Negeri di Jurusan S1 Kimia FMIPA Universitas Lampung melalui jalur SBMPTN.

Selain belajar di bangku kuliah, penulis juga aktif berorganisasi. Organisasi yang pernah diikuti penulis adalah Himpunan Mahasiswa Kimia (HIMAKI) FMIPA Universitas Lampung sebagai Kader Muda Himaki 2019 – 2020, dan anggota Bidang SPIK 2020 – 2021. Penulis juga menjadi anggota riset Merdeka Belajar Kampus Merdeka (MBKM) pada tahun 2022, menjadi Asisten Praktikum Kimia Dasar untuk Mahasiswa Kimia pada tahun 2022, Asisten Praktikum Kimia Fisik 1 untuk mahasiswa kimia pada tahun 2022, dan Asisten Praktikum Kimia Fisik 2 untuk Mahasiswa Kimia pada tahun 2023.



I dedicate this scientific work as a form of dedication and responsibility to:

My Parents

Mr. Jerry Sonya Putra and Mrs. Tuti Yuliani

For giving me an endless support mentally and financially

My Supervisors

Prof. Wasinton Simanjuntak, Ph.D.

Dr. Ilim, M.S.

My Beloved Ones

Aldan Fatu Rahman

For being my support system when things went tough

Best Friends, Friends, and acquaintances

Beloved Alma Mater

University of Lampung

## **MOTTO**

“I don’t chase, I attract. What belongs to me will simply find me”

“When life deals us card, make everything taste like it is salt” – Ariana Grande  
Buttera

## SANWACANA

Puji syukur atas kehadiran Allah SWT karena atas segala rahmat, karunia, serta kasih sayang-Nya penulis dapat menyelesaikan skripsi ini. Sholawat dan salam juga tidak lupa dipanjatkan kepada Baginda Nabi Muhammad SAW, keluarga beserta sahabatnya. Skripsi ini disusun sebagai salah satu persyaratan untuk mendapatkan gelar Sarjana Sains pada Jurusan Kimia FMIPA Unila. Pada kesempatan ini, penulis mengucapkan terima kasih kepada:

1. Orang tua, dan adik yang telah memberi dukungan mental dan finansial, serta doa untuk penulis.
2. Bapak Prof. Wasinton Simanjuntak, Ph.D. selaku pembimbing pertama penelitian atas segala bimbingan, motivasi, nasehat, bantuan, saran, serta kesabaran dan kebaikannya dari awal penelitian hingga penulis dapat menyelesaikan skripsi ini.
3. Ibu Dr. Ilim, M.S. selaku pembimbing kedua penelitian atas motivasi, bimbingan, saran, bantuan, nasehat, dan seluruh kebaikannya hingga penulis dapat menyelesaikan penulisan skripsi.
4. Bapak Prof, Sutopo Hadi, M.Sc., P.hD. selaku pembahas penelitian atas segala saran, kritik, nasehat, serta motivasi yang sangat memotivasi penulis agar menjadi lebih baik.
5. Bapak Diky Hidayat, M.Sc. selaku pembimbing akademik atas saran, bimbingan dan dukungan yang telah diberikan selama penulis melakukan perkuliahan.
6. Bapak Mulyono, P.hD. selaku Ketua Jurusan Kimia FMIPA Universitas Lampung.
7. Segenap staff pengajar dan karyawan khususnya Jurusan Kimia dan FMIPA Universitas Lampung.

8. Teman-teman satu grup penelitian Eki dan Zahra yang telah kebersamai penulis sejak Maret 2022 hingga penulisan skripsi selesai.
  9. Sahabat Polimer Kak Diska, Selvia, Erika, Zahra, Devy, Rifdah, Farich, Dito, Rangga, Thio, Eki , dan Arya yang telah memberikan warna di semester akhir yang berat ini.
  10. M. Fadhil Ramadito yang telah memberikan support secara mental sejak sebelum semhas hingga penulis selesai sidang komprehensif.
  11. Keluarga KKN Desa Pasir Kupa Aca, Silfa, Adel, Adis, Faisal, Nopal, Ebed, Dede, dan Mumtas yang telah memberikan penulis banyak nasehat dan pelajaran.
  12. Kimia angkatan 2022 kelas C yang sudah mewarnai hari-hari penulis.
  13. Keluarga Besar “Bulubabi Pangsit” Ica, Alyaa, Dita, Selvia, dan Nabila yang telah kebersamai penulis sejak maba hingga penulis menyelesaikan penulisan skripsi.
  14. My boyfriend, best friend, support system, Aldan Fatu Rahman who’s been giving me motivation, endless support, love, and spirits since 2019 until this skripsi is finally finished.
  15. Taylor Swift, Niki, Ariana Grande, Lana Del Rey karena telah menciptakan lagu yang sangat membantu dalam melewati waktu-waktu kelam penulis.
- Atas segala kebaikan yang telah diberikan, semoga Tuhan YME membalasnya dengan pahala dan kebaikan yang berlipat ganda. Aamiin. Penulis menyadari bahwa dalam penulisan skripsi ini masih terdapat banyak kekurangan, namun penulis berharap skripsi ini dapat bermanfaat dan berguna, khususnya bagi Jurusan Kimia FMIPA Unila.

Bandarlampung, Agustus 2023

Penulis

**Quntum Ramadhina**



## TABLE OF CONTENTS

	Page
<b>TABLE OF CONTENTS</b> .....	i
<b>LIST OF TABLE</b> .....	iii
<b>LIST OF FIGURES</b> .....	iv
<b>I. INTRODUCTION</b> .....	1
<b>1.1. Background</b> .....	1
<b>1.2. Research Purposes</b> .....	3
<b>1.3. Research Benefits</b> .....	3
<b>II. LITERATURE REVIEW</b> .....	4
<b>2.1. Biomass Pyrolysis</b> .....	4
<b>2.2. Chemical Composition of BCO</b> .....	5
<b>2.3. Zeolite-A</b> .....	6
<b>2.4. Pumice Silica</b> .....	7
<b>2.5. Characterization of Pumice Silica</b> .....	7
2.5.1. X-Ray Diffraction (XRD) .....	7
2.5.2. X-Ray Fluorescence (XRF).....	8
2.5.3. Fourier Transform Infrared Spectroscopy (FTIR) .....	9
<b>2.6. Characterization of Zeolite-A</b> .....	10
2.6.1. X-Ray Diffraction (XRD) .....	10
2.6.2. Scanning Electron Microscopy (SEM) .....	10
<b>2.7. Liquid Fuel Analysis</b> .....	11
<b>III. RESEARCH METHOD</b> .....	13
<b>3.1. Place and Time of Research</b> .....	13
<b>3.2. Tools and Materials</b> .....	13
3.2.1. Tools.....	13
3.2.2. Materials.....	13
<b>3.3. Research Procedures</b> .....	14
3.3.1. Pumice Preparation .....	14
3.3.2. Pumice Extraction .....	14
3.3.3. Synthesis of Zeolite-A.....	14
3.3.4. Zeolite-A Characterization.....	15
3.3.5. Liquid Fuel Manufacture.....	15

3.3.6. Liquid Fuel Analysis .....	16
<b>IV. RESULT AND DISCUSSION .....</b>	<b>17</b>
<b>4.1. Scope of the Study .....</b>	<b>17</b>
<b>4.2. Extraction of Pumice Silica .....</b>	<b>17</b>
<b>4.3. Characterization of Pumice Silica .....</b>	<b>18</b>
4.3.1. X – Ray Diffraction (XRD) .....	18
4.3.2. X – Ray Fluorescence (XRF) .....	19
4.3.3. Fourier Transform Infra Red (FTIR).....	20
<b>4.4. Synthesis of Zeolite-A.....</b>	<b>21</b>
<b>4.5. Characterization of Zeolite-A .....</b>	<b>21</b>
<b>4.6. Catalytic Activity Test of Zeolite-A .....</b>	<b>28</b>
<b>V. CONCLUSIONS AND SUGGESTIONS.....</b>	<b>36</b>
<b>5.1. Conclusions .....</b>	<b>36</b>
<b>5.2. Suggestions.....</b>	<b>36</b>
<b>REFERENCE .....</b>	<b>37</b>
<b>APPENDIX .....</b>	<b>42</b>
<b>Appendix 1.</b> Calculations of Si/Al ratio of Zeolite-A .....	43
<b>Appendix 2.</b> Calculations of Solution Preparation .....	43
<b>Appendix 3.</b> XRD Instrument Conditions .....	44
<b>Appendix 4.</b> Chemical compounds of BCO produced from pyrolysis using various types of catalysts.....	45

## LIST OF TABLE

Table	Page
Chemical composition of BCO produced from different feedstocks with the use of different catalysts .....	5
Chemical composition of pumice.....	9
Data on the effect of NaOH concentration on silica yield .....	17
Chemical composition of pumice silica obtained using 2.5 M NaOH.....	19
Information of [NaOH] solution used for each sample.....	21
Peak resemblance of synthesized zeolite-A and IZA.....	24
Chemical compositions of BCO produced with regular pyrolysis .....	30
Chemical compounds of BCO produced with heat exchanger .....	32
Relative compositions of BCO produced for each sample .....	34
Chemical compounds of BCO produced using zeolite-A calcined at 600°C .....	45
Chemical compounds of BCO produced using zeolite-A calcined at 700°C .....	46
Chemical compounds of BCO produced using zeolite-A calcined at 800°C .....	47

## LIST OF FIGURES

Figure	Page
1. The LTA framework type (Golbad <i>et al.</i> , 2017).....	6
2. Diffractograms of pumice and pumice silica (Mourhly <i>et al.</i> , 2015).....	8
3. FTIR spectrum of pumice (Ersoy <i>et al.</i> , 2010). ....	9
4. Diffractogram of (a) commercial Zeolite-A and synthesized zeolite-A with different calcination time (b) 48 h, (c) 72 h, and (d) 96 h (Simanjuntak <i>et al.</i> , 2021). ....	10
5. Scanning electron microscope (SEM) of zeolite-A (Simanjuntak <i>et al.</i> , 2021). ....	11
6. Diffractograms of pumice silica.....	18
7. Spectrum FTIR of pumice silica .....	20
8. Diffractograms of sample synthesized with: (a) 3.72 M, (b) 2.79 M, (c) 2.23 M, and (D) 1.86 M.....	22
9. The diffractograms comparison of Sample A, B, C, D, with sodalite standard	23
10. Diffractogram of sample synthesized with (E) 1.29 M of NaOH solution ....	23
11. Diffractogram of synthesized zeolite-A compared to IZA standard of zeolite-A.....	24
12. Morphology of sample (E) with magnification of (a) 5000x and (b) 15000x	25
13. (a) SEM images of LTA(72) containing mainly sodalite but also a few cubic zeolite A particles (indicated by an arrow). (b) SEM images of LTA(168). (Greer <i>et al.</i> , 2009) .....	26
14. Diffractograms of sample synthesized with 1.29 M of NaOH solution and calcined with (F) 700°C, and (G) 800°C.....	26
15. Diffractograms of Sample E, F, and G.....	27
16. Morphology of sample (F) with magnification of (a) 5000x and (b) 10000x.	27
17. SEM image of zeolite material from (a) AS01 and (b) AS02 sludge samples after calcination at 700°C for 2 hr (Rozhkovskaya <i>et al.</i> , 2021). ....	28



18. Chromatograms and relative compositions of BCO obtained by regular pyrolysis. ....	29
19. Chromatogram of BCO produced using heat exchanger. ....	31
20. Relative compositions of BCO obtained with heat exchanger.....	32
21. GC chromatograms of catalytic upgrading BCO with zeolite-A calcined at (A) 600, (B) 700, and (C) 800.....	33
22. Comparison of bio gasoline range in hydrocarbon composed.....	34

## I. INTRODUCTION

### 1.1. Background

Sustainability of energy is a global concern, which remain as prime energy sources, not renewable and their natural deposit is continuously depleted due to massive exploration. In addition, fossil fuels are the main sources of greenhouse gases and causing many environmental and health problems associated with global warming. Hence, the development of renewable and more environmental friendly energy sources in order to reduce the reliance on fossil fuels is crucially needed. In this respect, continuously growing interests have been focussed on the development of biomass derived energy sources, generally known as biofuel.

At present, three types of liquid biofuel produced by pyrolysis of biomass, *i.e.* bioethanol, biodiesel, and bio crude oil (BCO) are continuously explored. Bioethanol is a product of fermentation of reducing sugars, such as glucose. The advantages of using bioethanol as biofuel includes; high octane number, higher heat of vaporization, low boiling point, and comparable energy content. However, bioethanol also has disadvantages, such as lower energy density compared to gasoline, corrosive, miscibility with water, and lower vapour pressure .

Biodiesel is a renewable and biodegradable fuel produced from vegetable oils, animal fats, or waste cooking oil. Biodiesel can be obtained by transesterification process using simple alcohol, primarily methanol, to convert glycerides in fats and oils into their corresponding methyl esters, and glycerol. Biodiesel has been used

as practical fuel by mixing with petrochemical fuel at certain portions such as B20 (Bari., 2014), B30 and B40 (Pramudito *et al.*, 2022).

However, biodiesel also has some drawbacks, such as more expensive than petrochemical diesel, not suitable to be used in low temperatures, and clogging in engine.

Bio crude oil (BCO) is a liquid biofuel produced by pyrolysis of biomass. Pyrolysis is a heating process of biomass in a tightly closed reactor at high temperature, leading to degradation of large organic molecules into smaller products, which consist of uncondensed gases, BCO, and residual solid.

From energy source point of view, BCO is the most valuable product of biomass pyrolysis, and therefore this particular product has become a focus of extensive studies. Chemically, BCO is a complex mixture of a large number and different types of organic compounds, such as hydrocarbon, ketone, acid, alcohol, and ester (Simanjuntak *et al.*, 2019). The composition of BCO is determined by several factors, in raw materials and catalysts are the most significant factors. Variation in chemical composition of BCO is evidently reflected by the results of previous studies on pyrolysis of different feedstocks, such as cassava solid waste (Simanjuntak *et al.*, 2019), poultry litter and hardwood (Agblevor *et al.*, 2010), sugar cane bagasse (Simanjuntak *et al.*, 2017), palm oil (Febriyanti *et al.*, 2021), torrefied of cassava root and palm oil (Simanjuntak *et al.*, 2021), and coffee grounds (Bok *et al.*, 2012). Although the formation of common substances should also be acknowledged.

The catalyst is another important element in biomass pyrolysis, not only to lower the temperature, as a general function of catalyst, but also to determine the composition of product. Considering these important roles, various types of catalyst have been developed, such as aluminium metal (Simanjuntak *et al.*, 2017), zeolite-Y (Supriyanto *et al.*, 2018), zeolite ZSM-5 (Yang *et al.*, 2004), zeolite-X (Pandiangan *et al.*, 2017), zeolite-A (Simanjuntak *et al.*, 2021), and mordenite (Li *et al.*, 2009). Among various types of catalysts, zeolite is the most widely used because of the deoxygenation ability, stable at high temperature, and non-toxic.

Due to its advantages, synthetic zeolites have been developed and zeolite-A is one of those included. In this research, zeolite-A was synthesized from pumice silica and food grade aluminium foil as a catalyst of pyrolysis of POME.

## **1.2. Research Purposes**

The purpose of this research is as follows :

1. To obtain amorphous pumice silica extracted with sol – gel method.
2. To obtain zeolite-A from pumice silica and food grade aluminium foil with hydrothermal method.
3. To obtain data about the characteristics of pumice silica including crystallinity, composition, and functional groups.
4. To obtain data about the characteristics of synthesized zeolite-A including crystallinity and surface morphology.
5. To obtain chemical composition of BCO from pyrolysis of POME.

## **1.3. Research Benefits**

The benefit of this research is as follows:

1. To increase the added value of POME as bio gasoline, and pumice as a source of silica for the manufacture of zeolites.
2. To overcome the reliance of fossil fuels by increasing the availability of liquid fuel from biomass.



## II. LITERATURE REVIEW

### 2.1. Biomass Pyrolysis

Pyrolysis is a thermal degradation of large organic molecules in a closed reactor, leading to formation of simpler product in the forms of gas, liquid, and solid residue. In the context of renewable energy sources, liquid product of biomass pyrolysis, which is known as biocrude oil (BCO) is of particular interest since this product has the potential to be treated further into practical fuel, such as bio gasoline, bio avtur, and biodiesel.

Pyrolysis is a non-stoichiometry process, however the reactions involved can be distinguished as primary reaction and secondary reaction. Primary reaction are the initial reaction that occur during pyrolysis and involve the direct decomposition of organic materials. Primary reaction of pyrolysis can be classified into several types, including dehydration, decarboxylation, and depolymerization. Secondary reaction of pyrolysis occur after the primary reactions and involve further transformations of the intermediate products formed during pyrolysis, and includes condensation, cracking, and polymerization (Patwardhan *et al.*, 2011).

Since pyrolysis is thermal process, based on the temperature applied, pyrolysis is divided into three schemes known as slow pyrolysis, fast pyrolysis, and flash pyrolysis. Slow pyrolysis is a gradual heating of organic material at relatively low temperatures and longer residence time. Fast pyrolysis involves rapid heating organic matters at high temperatures, typically in the range of 400 to 600°C. Flash pyrolysis involves rapid heating organic matters at very high temperatures

for an extremely short duration, typically in the range of millisecond or a few seconds resulting in the quick decomposition of the material (Onay and Kockar, 2003).

## 2.2. Chemical Composition of BCO

As previously stated, the main characteristic of BCO is complex composition of large number and various types of organic compounds. Various studies revealed that chemical composition of BCO is strongly determined by two main factors, which are the feedstock and catalyst used, reflected by the results presented on Table 1.

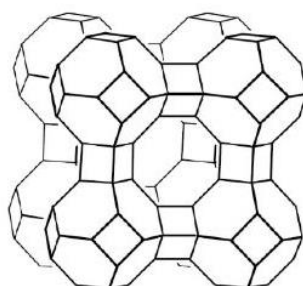
**Table 1.** Chemical composition of BCO produced from different feedstocks with the use of different catalysts

No.	Feedstock	Catalyst	Chemical constituent	Ref
1.	Mixed cassava solid waste and rubber seed oil	Zeolite-A	Hydrocarbon (74%), ketone (13%), ester (6%), alcohol (5%), aldehyde (1%), and acid (1%)	(Simanjuntak <i>et al.</i> , 2019)
2.	Sugarcane bagasse and sludge palm oil	Zeolite-Y	Hydrocarbon (76%), alcohol (13%), ester (8%), and ketone (3%)	(Supriyanto <i>et al.</i> , 2018)
3.	Palm oil	Zeolite-X	Hydrocarbon (77%), acid (16%), and ketone (7%)	(Febriyanti <i>et al.</i> , 2020)
4.	Poplar wood	Pd/CeTiO <sub>2</sub>	Hydrocarbons (0.4%), acid (9.5%), ketone (3%), aldehydes (5.2%), furan (8.4%), sugar (5.3%), phenol (37.2%), and others (8.6%)	(Lu <i>et al.</i> , 2010)
5.	Sugarcane bagasse and rubber seed oil	Zeolite-Y	Hydrocarbon (87.91%), gasoline fraction (42.60%), kerosene fraction (43.59%), and residual fraction (1.72%)	(Simanjuntak <i>et al.</i> , 2019)
6.	Palm oil	Zeolite-Y	Hydrocarbon (88.76%), fraction of bio gasoline (52.55%), and fraction of kerosene (36.21%)	(Pandiangan <i>et al.</i> , 2021)

The results presented on Table 1 indicate that it is necessary to use the right catalyst for specific feedstock in order to optimize the formation of the components of BCO which valuable as fuel. At the same time, using the right catalyst is expected to reduce the formation of unwanted components.

### 2.3. Zeolite-A

Among hundreds of different types of zeolites, zeolite-A is one of the most widely used because of the small aperture of about 4 Å, and high molar ratio of aluminium to silicon (~1), which provides a large number of sites for cation exchange (Ren *et al.*, 2018). Chemical formula of zeolite-A is  $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 4.5\text{H}_2\text{O}$ , with  $\text{Na}_{12}(\text{AlO}_2)_{12} \cdot n\text{H}_2\text{O}$  as unit cell. Zeolite-A has the structure consists of interconnected cages or channels that can selectively adsorb and desorb molecules based on their size and polarity. The outstanding characteristics of zeolite-A, including non – toxic and high thermal stability, making zeolite-A extensively used for waste treatment and suitable for applications such as ion exchange, gas separation, and catalysis. Zeolite-A is usually carried out under hydrothermal conditions with a reactive gel base in an alkaline medium at a temperature of 80-200°C. Hydrothermal conditions can be achieved with conventional methods by using oven, bath, or autoclave as the heat source (Wuntu and Tangkuman, 2008). According to Golbad *et al.*, (2017), the framework of zeolite-A is shown on Figure 1.



**Figure 1.** The LTA framework type (Golbad *et al.*, 2017).

## 2.4. Pumice Silica

Pumice is a porous volcanic rock contains significant proportions for silica ( $\text{SiO}_2$ ) and alumina ( $\text{Al}_2\text{O}_3$ ), and a little amount of metal. Pumice is widely utilized as an alternate feedstocks or mixtures at the industry, for the example is as a source of silica in the manufacture of synthetic zeolite (Mahaddilla and Putra, 2013), because it has the same value and efficiency with high cost adsorbent, such as active carbon and chitosan, and its low in cost is the same as gel silicas. Pumice has percentage of  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  of 48% and 14.9, and Ersoy *et al.* (2010) also stated that pumice is also contains  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  of 70.21% and 13.63% respectively. There are also other components contained, such as  $\text{MgO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{CaO}$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{K}_2\text{O}$ , etc.

There are several ways to obtain pure silica from pumice, one of them is through extraction method. This method is done to separate the solute between two insoluble liquids. Influential parameters affecting extraction process namely are temperature, stirring, solvent solution concentration, and extraction time. Basic principle of extraction is by dissolving polar compounds in polar solvents and non-polar compounds in non-polar solvents (Zhang *et al.*, 2018).

## 2.5. Characterization of Pumice Silica

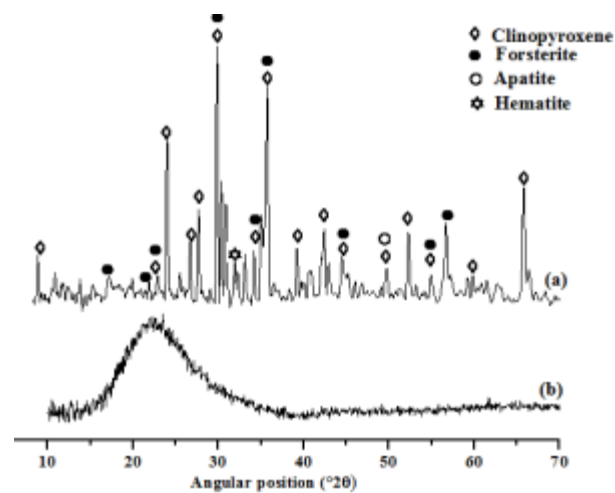
Pumice silica was characterized using XRD to analyze the crystallographic structure of the sample, either amorphous or crystalline. XRF characterization was done to determine the elemental composition of materials, and FTIR characterization was done to identify the functional groups.

### 2.5.1. X-Ray Diffraction (XRD)

The basic principle of XRD characterization is based on the catalyst crystal reflects the X-rays sent from the source and received by the detector. Every compounds consist of arrangement of atoms forming a certain plane. In XRD, the diffraction pattern is defined by the size of the angle formed as a result of the light



beam's diffraction by the crystal in the material. The value of the angle is expressed in  $2\theta$ , where  $\theta$  represents the coming of light, and  $2\theta$  is the angle of incidence with the diffraction angle detected by the detector. Diffraction will only happen if the constructive interference of wave have been formed when the light beam is reflected by the sample material. Meanwhile, the constructive interference will only happen on particular wavelength that comes from particular angle. It means not all wavelengths come from a certain angle will form constructive interference. According to Mourhly *et al.* (2015), the diffractograms of pumice and pumice silica are shown on Figure 2.



**Figure 2.** Diffractograms of pumice and pumice silica (Mourhly *et al.*, 2015).

### 2.5.2. X-Ray Fluorescence (XRF)

XRF characterization is an analytical technique to determine elemental composition. The basic principle of XRF is when a primary X-ray that typically generated in a X-ray tube hits the inner shell electron of the atom and ejects the electron. X-ray analyser determines the chemical components contained in the sample by measuring the fluorescent (or secondary) X-rays emitted from the sample when excited by a primary X-ray source. Sample is then irradiated by high energy X-rays from a controlled X-ray tube. When the atom is exposed to X-rays of sufficient energy, electrons from one of the orbital shells of the atom are released. The atoms will regain stability, filling the vacancy remains in the inner shell orbital with electrons from one of the higher energy shell orbitals of the

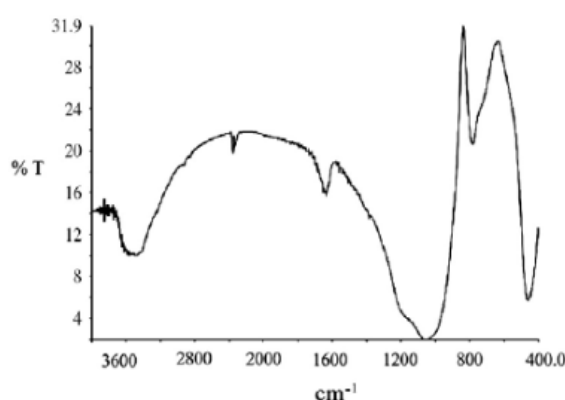
atom. Electrons then descend to a lower energy level by releasing fluorescence X-rays. The energy of this X-rays is equal to the specific energy difference between the two quantum states of the electron. According to Mourhly *et al.* (2015), chemical composition of pumice determined by XRF is shown on Table 2.

**Table 2.** Chemical composition of pumice

Oxide	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	MgO	Na <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	Others
Pumice (%)	14.9	8.34	8.34	8.18	5.70	6.71	1.84	6.33

### 2.5.3. Fourier Transform Infrared Spectroscopy (FTIR)

The Infrared Fourier Transform is equipped with infrared spectroscopy with the Fourier transform for detection and analysis of the spectrum results. Infrared spectroscopy has benefits for identification of organic compounds because of its complex spectrum, a complex spectrum due to consisting too many peaks indicating the presence of a functional group which indicated by the wave number. According to Ersoy *et al.* (2010), the FTIR spectrum of pumice is shown on Figure 3. The analysis of FTIR was carried out by using Perkin Elmer Spectrum BX-2 and having a standard mid-IR DTGS detector. The IR spectrum of pumice silica is shown on Figure 3.



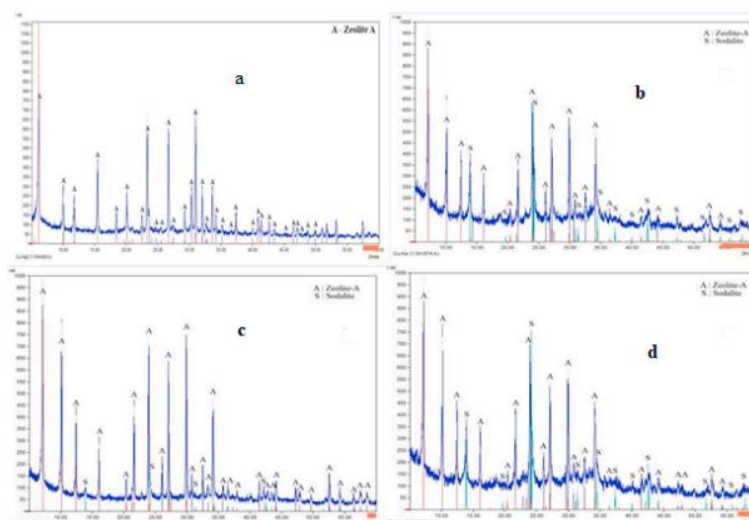
**Figure 3.** FTIR spectrum of pumice (Ersoy *et al.*, 2010).

## 2.6. Characterization of Zeolite-A

Zeolite-A characterization was done using XRD to analyze the crystalline materials of synthesized zeolite-A, and SEM characterization was done to identify the surface morphology of zeolite-A.

### 2.6.1. X-Ray Diffraction (XRD)

XRD is an analytical method utilizes interaction between x-ray with a beam of atoms arranged in a system of crystals. XRD was done to find out the crystal phase and amorph qualitatively and quantitatively, along with its crystallinity percentage from the catalyst. Based on the previous study reported by Simanjuntak *et al.* (2021), diffractograms of zeolite-A are displayed on Figure 4.



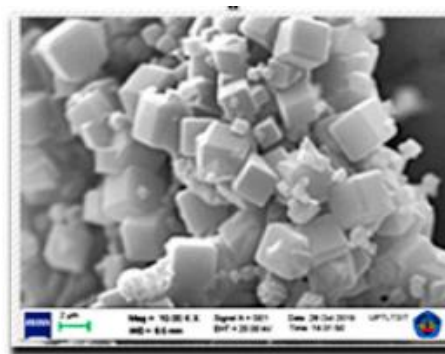
**Figure 4.** Diffractograms of (a) commercial Zeolite-A and synthesized zeolite-A with different calcination time, (b) 48 h, (c) 72 h, and (d) 96 h (Simanjuntak *et al.*, 2021).

### 2.6.2. Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM) is one kind of electron microscope used to observe and analyse the surface morphology of crystals. The working principle of SEM is a source electron from the filament made from tungsten emits a beam of

light. If the electron is reacting with the specimen, it will produce primary and secondary electron.

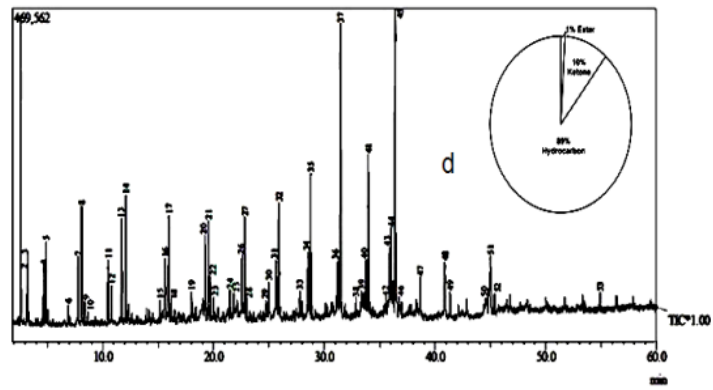
Scanning electron microscopy (SEM), also known as SEM analysis or SEM technique is an effective method in the analysis of organic and inorganic materials at the nanometre to micrometre ( $\mu\text{m}$ ) scale. SEM works at high magnifications of up to 300.000x and even 1.000.000x to produce very precise images of a wide range of materials. Materials that can be used in SEM are organic and solid inorganic materials including metals and polymers. Figure 5 shows the morphology of zeolite-A from the previous study (Simanjuntak *et al.*, 2021).



**Figure 5.** Scanning electron microscope (SEM) of zeolite-A (Simanjuntak *et al.*, 2021).

## 2.7. Liquid Fuel Analysis

Gas Chromatography Mass Spectrometry (GC-MS) is used to identify chemical compounds in a mixture of a sample based on the separation of components in a sample mixture on GC and based on fragmentation of compounds on MS come from the GC separation. Working principle of GC-MS is charged gas molecules will be selected according to its mass and weight, spectrum obtained from converting sample into moving ions, then separated based on mass to charge ratio ( $m/e$ ). Ionization produces fragments which will produce a spectrum. Mass spectrum is a picture between relative abundance with mass to charge ratio ( $m/e$ ). Chromatogram and chemical compositions of liquid fuel reported by the previous study is shown on Figure 6.



**Figure 6.** Chromatogram and Relative Composition of Liquid Fuel (Simanjuntak *et al.*, 2019).

### **III. RESEARCH METHOD**

#### **3.1. Place and Time of Research**

This research has been done at the Polymer Laboratory, Department of Chemistry, Faculty of Mathematics and Natural Sciences, University of Lampung in October 2022 – March 2023. XRD analysis was carried out at ITS Surabaya, SEM analysis was carried out at UPT LTSIT University of Lampung, XRF analysis was carried out at Universitas Negeri Padang, FTIR analysis was carried out at Diponegoro University, and GC-MS analysis was carried out at Gadjah Mada University Yogyakarta and Poltekkes Bandung.

#### **3.2. Tools and Materials**

##### **3.2.1. Tools**

Tools used in this research are included; pyrolysis device, stove, lock and lock container, plate, furnace, teflon, spatula, 300 mesh, plastic jar, analytical balance, filter, pestle and mortar, bucket, oven, hotplate stirrer, magnetic stirrer, glass wares, scanning electron microscope model ZEISS EVO MA 10 for SEM, PANalytical type empyrean diffractometer for XRD, PANalytical Epsilon 3 for X-Ray Fluorescence XRF, Perkin Elmer for FTIR, and QP2010S SHIMADZU for GC-MS.

##### **3.2.2. Materials**

Materials used in this research were included; POME, pumice, food grade aluminium foil, solid NaOH, 3 M of HNO<sub>3</sub> solution, 2.5 M of NaOH solution, 1 M of HCl solution, distilled water, filter paper, universal pH paper, and heat exchanger.

### 3.3. Research Procedures

This research consists following procedures; (1) pumice preparation, (2) pumice extraction, (3) synthesise of zeolite-A, (4) zeolite-A characterization, (5) liquid fuel manufacture, and (6) liquid fuel analysis.

#### 3.3.1. Pumice Preparation

In this research, pumice was washed with water then sun dried for a day, and finally oven dried at 100°C overnight. Cleaned and dried pumice was then mashed into powder using pestle and mortar, and then sieved using 200 mesh to obtain sample with homogeneous size. To remove non-silica components, the pumice powder was soaked in HCl solution 1 M for 24 hours, then rinsed with distilled water to remove acid, and oven dried at 100°C for a night.

#### 3.3.2. Pumice Extraction

To conduct extraction, a mass of 40 g pumice powder was mixed with NaOH solution and the mixture was stirred for 24 hours at 100°C. The sample was filtered and the filtrate was neutralized using 3 M of HNO<sub>3</sub> solution to produce silica gel. The resulting gel was aged for 4 hours then washed with hot water and finally oven dried for a night at 100°C. Solid silica formed was ground then sieved with 200 mesh to obtain silica powder. Silica powder obtained was then characterized by using XRD, XRF, and FTIR.

#### 3.3.3. Synthesis of Zeolite-A

Synthesis of zeolite-A was carried out by dissolving 22.32 g of NaOH pellets in various amount of distilled water; 150, 200, 250, and 430 mL. Then divide the NaOH solution into two, one was to dissolve 13.32 g of aluminium foil to produce sodium aluminate and the other one was to be dissolved with 20 g of pumice silica to prepare sodium silicate. To produce the precursor of zeolite, both mixtures were stirred for 3 hours. Natrium aluminate produced then put in the autoclave for 24 hours then crystallized in the oven for 72 hours at 100°C. Then sample was washed and oven dried at 100°C to produce dry solid. Powder sample prepared



by ground the solid and calcined at various temperatures of 600, 700, and 800°C for 6 hours. Zeolite-A obtained then characterized by using XRD and SEM.

#### 3.3.4. Zeolite-A Characterization

Zeolite-A characterization was done using XRD and SEM. XRD characterization was conducted to identify the crystal phase of the sample, and SEM characterization was conducted to analyze the surface morphology of the sample.

##### 3.3.4.1. X-Ray Diffraction (XRD)

XRD analysis was carried out using PANalytical with Cu anode material, 40 kV energy and 30 mA current, and diffraction angle in the range of 5 – 50° to identify the XRD pattern. XRD data obtained were analyzed using Match!3 software Ver. 2.4.7 build 529 and data were compared to standard data available on International Zeolite Association (IZA).

##### 3.3.4.2. Scanning Electron Microscope (SEM)

SEM analysis was carried out using SEM ZEISS EVO MA 10 with the instrument electron acceleration voltage at 15.00 kV, the window (WD) of 8.5 and 9.5 mm, magnification (Mag) up to 35.000 times.

#### 3.3.5. Liquid Fuel Manufacture

In this research, pyrolysis was conducted in 5 variables, which are regular pyrolysis, using heat exchanger, and using various calcined temperature of zeolite-A (Sample E – G). Regular pyrolysis and pyrolysis using heat exchanger have the same method, but the addition of silica sand as heat exchanger was mandatory for pyrolysis using heat exchanger. An amount of 500 mL of POME was pyrolyzed in a laboratory scale up to 3 hours with low heat.

About 20 minutes after the preheating, the first drop of BCO was dripped and collected in a glass bottle. Pyrolysis was done for about 3 hours or until no BCO was dripping and 209 mL of BCO was produced. BCO produced then filtered by using filter paper to separate it from impurities, then kept overnight in a separatory funnel to separate the organic and inorganic phase. Afterwards, the

organic phase of BCO was characterized with GC-MS to identify the components contained in the sample.

BCO produced with catalytic upgrading was carried out by using 5 g of synthesized zeolite-A into 100 mL of POME BCO and put into the pyrolysis reactor. Catalytic upgrading pyrolysis was taken up to 30 minutes and liquid fuel obtained were put into the separatory funnel to separate the organic phase (BCO) and inorganic phase. BCO was characterized using GC-MS to analyse the chemical components in the sample.

#### 3.3.6. Liquid Fuel Analysis

Liquid fuel characterization was carried out by using the GC-MS type QP2010S Shimadzu to identify the components in the sample with column type Rtx 5 (30 m length; ID 0.25 mm; film thickness: 0.25  $\mu$ m; carrier gas: Helium; EI 70 Ex). The injector temperature was 310°C with split mode, the detector temperature was 250°C, the oven column temperature was 40°C, the flow rate at a pressure of 13 kPa and a total flow of 80 mL.min<sup>-1</sup>. The standard used for the characterization of liquid fuel is by using the GC-MS standard.

## V. CONCLUSIONS AND SUGGESTIONS

### 5.1. Conclusions

Based on the experimental results, it can be concluded that:

1. Amorphous pumice silica has been successfully extracted with 2.5 M of NaOH solution.
2. Zeolite-A has been successfully synthesized using 1.29 M of NaOH solution with hydrothermal method by an addition of food grade aluminium foil with Si/Al ratio 1.
3. BCO produced with zeolite-A 700 has the highest hydrocarbon contained in the sample with relative percentage 84%, while BCO produced with heat exchanger has the least amount with relative percentage of 67.86%.
4. BCO produced with regular pyrolysis has the highest bio gasoline content with relative percentage 54% and BCO produced with heat exchanger has the least amount with relative percentage of 25%.

### 4.2. Suggestions

Based on the results obtained, the following studies are suggested.

1. To use lower concentration of NaOH to form zeolite-A with higher crystalline phase.
2. Further investigation for catalytic upgrading of the BCO to increase the biogasoline content.

## REFERENCES

- Agblevor, F. A., Beis, S., Kim, S. S., Tarrant, R., Mante, N. O. 2010. "Bio Crude Oils from the Fast Pyrolysis of Poultry Litter and Hardwood". *Waste Management*. 30 (2): 298 – 307.
- Bari, S., 2014. "Performance, Combustion, and Emission Tests of A Metro-Bus Running on Biodiesel-ULSD Blended (B20) Fuel." *Journal Applied Energy*. 124: 35 – 43.
- Bok, J. P., Choi, H. S., Choi, Y. S., Park, H. C., Kim, S. J. "Fast Pyrolysis of Coffee Grounds: Characteristics of Product Yields and Bio Crude Oil Quality." *Journal of Energy*. 47 (1): 17 – 24.
- Cruz, T. J. T., Melo, M. I. S., Pergher, S. 2020. "Optimization of Parameters and Methodology for the Synthesis of LTA – Type Zeolite Using Light Coal Ash." *Applied Sciences Journal*. 10: 1 – 11.
- Ersoy, B., Sariisik, A., Dikmen, S., and Sariisik. G. 2010. "Characterization of Acidic Pumice and Determination of Its Electrokinetic Properties in Water." *Powder Technology*. 197 (1): 129-135.
- Febriyanti, T. D., Simanjuntak, W., Pandiangan, K. D. 2021. "Pyrolytic Conversion of Palm Oil Into Liquid Fuel Using Protonated Zeolite-X Prepared from Rice Husk Silica and Aluminum Foil as Catalyst." *Journal of Physics: Conference Series*. 1751: 1-10.
- Golbad, S., Khoshnoud, P., and Abu-Zahra, N. 2017. "Synthesis of 4A Zeolite and Characterization of Calcium- and Silver-Exchanged Forms." *Journal of Minerals and Materials Characterization and Engineering*. 5: 237 - 251.

- Greer, H., Wheatlet, P. S., Ashbrook, S. E., Morris, R. E., and Zhou, W. 2009. "Early Stage Reversed Crystal Growth of Zeolite – A and Its Phase Transformation to Sodalite." *Journal of The American Chemical Society*. 131 (49): 17986 – 17992.
- Lu, Q., Zhang, Y., Tang, Z., Li, W., Zhu, X. 2010. "Catalytic upgrading of biomass fast pyrolysis vapors with titania and zirconia/titania based catalysts." *Journal of Fuel*. 89 (8): 2096 – 2103.
- Lin, J., Siddiqui, J.A. & Ottenbrite, M. 2001. "Surface Modification of Inorganic Oxide Particles with Silane Coupling Agent and Organic Dyes." *Polymer Advance Technology*. 12 (5): 285–292.
- Mahaddilla, F. M., and Putra, A. 2013. "Pemanfaatan Batu Apung sebagai Sumber Silika dalam Pembuatan Zeolit Sintetis." *Jurnal Fisika Unand*. 2 (4): 262 - 268.
- Mourhly, A., Khachani, M., Hamidi, A. E., Kacimi, M., Halim, M., Arsalane, S. 2015. "The Synthesis and Characterization of Low – Cost Mesoporous Silica SiO<sub>2</sub> from Local Pumice Rock." *Journal of Nanomaterials and Nanotechnology*. 5 (35): 1 – 7.
- Onay, O., Kockar, O. M. 2003. "Slow, Fast, and Flash Pyrolysis of Rapeseed." *Journal of Renewable Energy*. 28 (15): 2417 – 2433.
- Pandiangan, K. D., and Simanjuntak, W. 2013. "Transesterification Of Coconut Oil Using Dimethyl Carbonate And Tio<sub>2</sub>/SiO<sub>2</sub> Heterogeneous Catalyst." *Indonesian Journal of Chemistry*. 13 (1): 47-52.
- Pandiangan, K. D., Arief, S., Jamarun, N., and Simanjuntak, W. 2017. "Synthesis of Zeolite-X from Rice Husk Silica and Aluminum Metal as a Catalyst for Transesterification of Palm Oil." *Journal of Materials and Environmental Sciences*. 8 (5): 1797-1802.
- Pandiangan, K. D., Simanjuntak, W., and Pratiwi, E., and Rilyanti, M. 2019. "Characteristics and catalytic activity of zeolite-Asynthesized from rice husk silica and aluminium metal by sol-gel method." *Journal of Physics: Conference Series*. 1338: 1 - 13.

- Patwardhan, P. R., Dalluge, D. L., Shanks, B. H., Brown, R. C. 2011. "Distinguishing Primary and Secondary Reactions of Cellulose Pyrolysis." *Bioresource Technology*. 102 (8): 5265 – 5269.
- Pramudito, Y., Wirahadi, D., Faturrahman, N. A., Supriadi, F., Bethari, S. A., Rulianto, D., Widodo, S., Respatiningsih, C. Y., Aisyah, L., Yuliarita, E. 2022. "Comparison Performance CI Engine of Using High-Speed Diesel Fuel-Biodiesel Blend (B30) and (B40) on Diesel Engine Dyno Test." *Earth and Environmental Science*. 1034: 83-96.
- Ren, X., Xiao, L., Qu, R., Liu, S., Ye, D., Song, H., Wu, W., Zheng, C., Wu, X., and Gao, X. 2018. "Synthesis and Characterization of A Single Phase Zeolite A Using Coal Fly Ash." *Journal of Zhejiang University*. 8: 42200-42209.
- Rios, C. A., Williams, C. D., Maple, M. J. 2007. "Synthesis of Zeolites and Zeotypes by Hydrothermal Transformation of Kaolinite and Meta kaolinite." *Journal of Wolverhampton*. 5 (1): 15 – 26.
- Rios, C. A., Williams, C. D., Roberts, C. L. 2008. "Removal of Heavy Metals from Acid Mine Drainage (AMD) using Coal Fly Ash, Natural Clinker and Synthetic Zeolites." *Journal of Hazardous Materials*. 156 (1 – 3): 3 – 35.
- Rios, C. A., Williams, C. D., and Fullen, M. A. 2009. "Nucleation and Growth History of Zeolite LTA Synthesized from Kaolinite by Two Different Methods." *Applied Clay Science Journal*. 42 (3 – 4): 446 – 454.
- Rios, C. A., Williams, C. D., and Oscar, C. 2013. "Nucleation and Growth Process of Sodalite and Cancrinite from Kaolinite – Rich Clay under Low – Temperature Hydrothermal Conditions." *Journal of Material Research*. 16 (2): 424 – 438.
- Rozhkovskaya, A., Rajapakse, J., and Millar, G. J. 2021. "Optimisation of Zeolite LTA Synthesis from Alum Sludge and the Influence of the Sludge Source." *Journal of Environmental Sciences*. 99: 130 – 142.
- Simanjuntak, A., Simanjuntak, W., Pandiangan, K. D., and Sembiring, Z. 2019. "The Effect of Sugarcane Bagasse to Rubber Seed Oil Ratios on the

Chemical Composition of Liquid Fuels Produced by Zeolite-Y Catalyzed Pyrolysis." *Journal of Physics: Conference Series*. 1338: 1-8.

- Simanjuntak, W., Pandiangan, K. D., Sembiring, Z., Sihombing, I. P. 2021. "Biogasoline Production by Zeolite-A Catalyzed Co-pyrolysis of Torrefied Cassava Root and Palm Oil." *Journal of Physics: Conference Series*. 1751: 1-10.
- Simanjuntak, W., Pandiangan, K. D., Sembiring, Z., Simanjuntak, A. 2019. "Liquid Fuel Production by Zeolite-A Catalyzed Pyrolysis of Mixed Cassava Solid Waste and Rubber Seed Oil." *Oriental Journal of Chemistry*. 35 (1): 71-76.
- Simanjuntak, W., Satria, H., and Utami, N. 2014. "Production Of Reducing Sugar From Cassava Solid Waste Bysimultaneous Ultrasonication And Acid Hydrolysis." *Indonesian Journal of Chemistry*. 14 (3): 233-238.
- Simanjuntak, W., Sembiring, S., and Sebayang, K. 2012. "Effect Of Pyrolysis Temperatures On Composition And Electrical Conductivity Of Carbosil Prepared From Rice Husk." *Indonesian Journal of Chemistry*. 12 (2): 119-125.
- Simanjuntak, W., Sembiring, S., Simanjuntak, A., Pratiwi, E., and Syani, F. 2017. "Hydrocarbon Rich Liquid Fuel Produced by Co-pyrolysis of Sugarcane Bagasse and Rubber Seed Oil Using Aluminosilicates Derived from Rice Husk Silica and Aluminum Metal as Catalyst." *Oriental Journal Of Chemistry*. 33 (6): 3218 - 3224.
- Srivastava, K., Shringi, N., Devra, V., and Rani, A. 2013. "Pure Silica Extraction from Perlite: Its Characterization and Affecting Factors." *Journal of Matter Science*. 2: 2936 – 2942.
- Suka, I. G., Simanjuntak, W., Sembiring, S., Trisnawati, E. 2008. "Karakteristik Silika Sekam Padi dari Provinsi Lampung yang Diperoleh dengan Metode Ekstraksi." *Jurnal MIPA*. 37 (1): 47 – 52.
- Supriyanto, R., Simanjuntak, W., Pandiangan, K. D., Situmeang, R., And Ahmadhani, M. Y. 2018. "Chemical Composition of Liquid Fuel Produced by Co-pyrolysis of Sugarcane Bagasse and Sludge Palm Oil Using Zeolite-Y as Catalyst." *Oriental Journal of Chemistry*. 34 (3): 1533-1540.



- Ulfa, Z. M., Manurung, P., and Karo, P. K. 2019. "Pengaruh Variasi Konsentrasi NaOH Optimum pada Pembuatan Nanosilikat dari Batu Apung." *Journal Teori dan Aplikasi Fisika*. 8 (1): 56 – 67.
- Ummah, S., Prasetyo, A., Barroroh, H. 201. "Kajian Penambahan Abu Sekam Padi dari Berbagai Suhu Pengabuan terhadap Plastisitas Kaolin." *Alchemy Journal*. 1 (2): 53 – 103.
- Wuntu, A. D., and Tangkuman, H. D. 2008. "Derajat Kristalisasi sebagai Fungsi Waktu Ageing dan Waktu Kristalisasi pada Sintesis Zeolite – A dengan Radiasi Gelombang Mikro." *Journal of Chemistry Program*. 1 (1): 19 – 24.
- Yang, Z. X., Xia, Y. D., and Mokaya, R. 2004. "Zeolite ZSM-5 with Unique Supermicropores Synthesized Using Mesoporous Carbon as a Template." *Journal of Advanced Materials*. 16 (8): 727 – 732.
- Zhang, Q. W., Lin, L. G., and Ye, W. C. 2018. "Techniques for Extraction and Isolation of Natural Products." *Chinese Medicine Journal*. 13 (20): 2 – 6.
- Zuwanna, I., Riza, M., and Aprilia, S. 2021. "The Impact of Solvent Concentration on the Characteristic of Silica from Rice Husk Ash Using Sol Gel Method." *Materials and Science and Engineering*. 1087: 1 – 7.