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Study on the Reaction Parameters on Transesterification of Rubber Seed Oil Using MgO/zeolite-A Catalyst

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Abstract

In this research, transesterification of rubber seed oil (RSO) with methanol in the presence of MgO/zeolite-A composites with different MgO loads as catalysts was investigated. In addition, the effect of different reaction parameters including oil to methanol ratio, the amount of catalyst, and transesterification time were also investigated. Zeolite-A was prepared from rice husk silica (RHS) and food-grade aluminum foil and confirmed using XRD and SEM/EDS techniques. The MgO/zeolite-A composites with different MgO loads were prepared by impregnating the zeolite with Mg $(NO_3)_2$ solution of different concentrations. The composites were then characterized using XRF, XRD, and SEM, and finally applied as a catalyst in transesterification of RSO at varied experimental conditions. The XRF results indicated that the zeolite has been successfully impregnated, and the content of MgO varied depending on the concentration of magnesium nitrate solution used for impregnation process. Zeolite-A and also MgO/zeolite-A composites were confirmed by XRD investigations, supported by SEM analysis with indicated the shape of cubic particle, a characteristic feature of zeolite-A, and rod like structure which is most likely the MgO particle. The results of transesterification experiments revealed the appreciable activities of the composites and the effect of reaction parameters on the conversion of the RSO, with the highest conversion of 89 % achieved using 12.5 % catalyst relative to the mass of RSO, with MgO 4.43 %/zeolite-A catalyst, oil to methanol ratio of 1:10, and a transesterification time of 6.0 h. Analysis of the transesterification products using GC-MS confirmed that fatty acids composing the RSO were converted into corresponding methyl esters.

Keywords: Zeolite-A, MgO/zeolite-A, Catalyst, Transesterification, Rubber seed oil

Introduction

The progressive increasing demand for liquid fuel in the light of depletion of fossil sources, together with growing concern about environmental impact arising from fossil fuel use, has placed the development of biofuels as a research interest around the globe. Biodiesel is one of the biofuels that has been commercially produced and mixed with petrodiesel. The development of this particular renewable liquid fuel is supported by the availability of raw materials, both vegetable oils and animal fats, as well as increasingly well-established processing technology.

Chemically, biodiesel is the product of transesterification reaction, in which raw material is reacted with alcohol primarily methanol or ethanol to convert fatty acids in the raw material into methyl esters or ethyl esters [1]. In practice, biodiesel has been derived from an array of raw materials, most vegetable oils such as coconut oil [2,3], palm oil [4,5], and soybean oil [6].

In an attempt to reduce competition with the food industry, the use of non-edible vegetable oils [7], or waste oils as alternative raw materials is continuously studied [8]. Many kinds of non-vegetable oil are available in large quantities and can be obtained easily at a low cost. Considering their potential, different types of non-edible oil have been studied, such as rubber seed oil, cotton oil, rapeseed oil [9], and Jatropha seed oil [10].

Of various non-edible vegetable oils available in Indonesia, rubber seed oil (RSO) is an interesting raw material. In addition to availability, a typical sample of rubber seed from rubber plantations in Indonesia was found to contain oil up to 46 % [11], which is in agreement with 40 - 50 % reported by others [12,13]. In a previous study [14], a particular RSO sample was reported to compose of around 18.9 % saturated fatty acids and 80.5 % unsaturated fatty acids (oleic acid 24.16 %, linoleic acid 37.28 %, and linolenic acid 19.12 %).

Besides raw materials, another crucial need for biodiesel production is catalyst. In this regard, heterogeneous catalysts have attracted growing attention since their use is more advantageous than those of conventional homogeneous catalysts. At present, the most widely explored type of heterogeneous catalyst is a composite catalyst, which consists of metal oxides supported on porous solids. Of particular interest is the use of zeolite as solid support for different metal oxides, one of them is MgO [15,16].

Magnesium oxide (MgO) is an interesting metal oxide as an active site for composite catalysts for different catalytic reactions, including transesterification of different raw materials for biodiesel production. This oxide is known to have basic characteristics, with a basicity of from 3.13 - 4.58 ηmol/m^2 depending on the calcination temperature [17], therefore it can increase the surface basicity of the catalysts. Mohadesi *et al.* [18] reported the use of MgO supported on silica in transesterification of refined corn oil with methanol. MgO nano use as catalyst for biodiesel production from waste coconut oil and fish oil [19], Pandiangan *et al.* [3] reported the use MgO as a catalyst for coconut oil transesterification, and production of biodiesel from waste cooking oil using mesoporous MgO-SnO_2 nanocomposite has been reported by Velmurugan and Warrier [20].

Figure 1 is the proposed reaction mechanism of RSO with the use of MgO, based on the reaction mechanism of triglyceride transesterification using CaO as catalyst proposed in previous study by Mazaheri *et al.* [21].

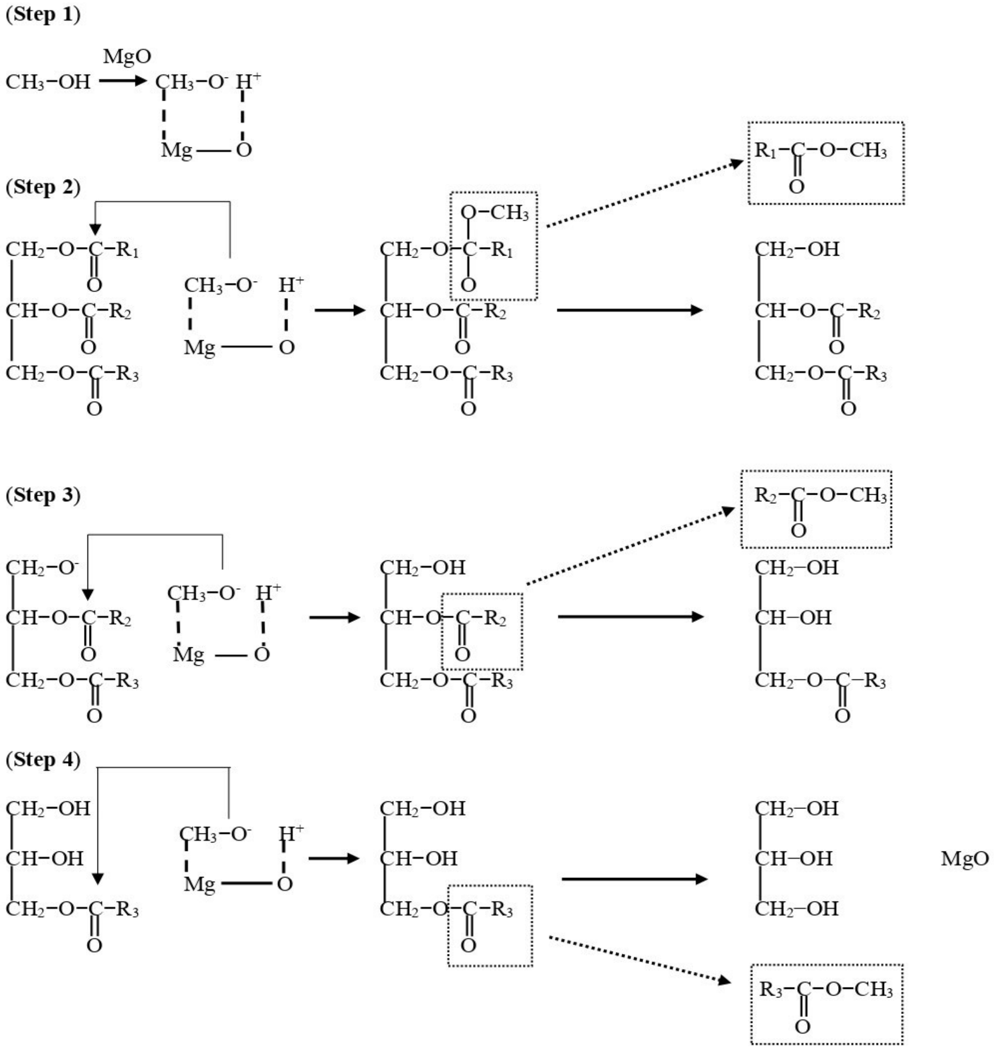


Figure 1 Reaction mechanism of triglyceride transesterification using MgO catalyst.

Transesterification is a multivariable reaction, where the conversion rate of the oil into methyl esters is influenced by several reaction parameters including the ratio of oil to methanol, the amount of catalyst used, reaction temperature, and reaction time [18]. As an example, da Conceição *et al.* [22] reported that the optimum yield of biodiesel from transesterification of jupati oil (*Raphia taedigera* Mart.) with an acid catalyst was achieved with the oil to methanol ratio of 1:10. In another work [23] transesterification of Jatropha oil was investigated using MgO/MCM-22 with different MgO loads as catalyst to evaluate the effect of MgO load, ratio of oil to methanol, reaction temperature, and reaction time. It was reported that the optimum conversion of 98 % was achieved using the catalyst with the MgO load of 20 %, with a ratio of oil to methanol of 1:15, reaction temperature of 70 °C, reaction time of 100 min, with a 3 % amount of catalyst.

In this study, MgO/zeolite-A composites with different MgO loads were prepared by impregnating zeolite-A synthesized from rice husk silica (RHS) and food grade aluminium foil (FGAF), with magnesium nitrate solution of different concentrations. In this study, rice husk was chosen as a source of silica for several reasons. The first reason is the availability of rice husk in Indonesia as rice growing country where Lampung Province is one of the main producers. In addition, silica content of rice husk rice is considerably high, in the range of 16 - 20 % with a purity of 95 - 98 % [24]. Rice husk silica is recognized as an amorphous material and soluble in an alkaline solvent, therefore it is suitable as a raw material for the fabrication of synthetic zeolite. As a precursor of aluminum oxide (Al_2O_3), food grade aluminium foil (FGAF) was chosen instead of aluminium compounds commonly used, since this element is readily dissolved in an alkaline solution, as the case with RHS. In addition, FGAF is practically pure and therefore contributes no impurities to the synthesized zeolite, is cheaper than aluminum compounds, and is readily available. In the context of raw materials used for preparation of synthetic zeolites, the use of aluminium foil is the main novelty of this research, since the use of this metallic aluminium for preparing synthetic zeolite is a relatively new practice. Successful application of this metallic aluminum in production of zeolite-A has been reported in our previous study [25].

The zeolite-A was then impregnated with magnesium nitrate solution of different concentrations to obtain the MgO/zeolite-A composites with varied MgO loads. The produced composites were then tested as catalysts for transesterification of RSO and methanol, with the main purpose to investigate the effect of MgO loads on catalytic performance of the composites to convert the RSO into fatty acids methyl ester (FAME).

Materials and methods

Experimental

Rice husks sample was collected from a local source (Bandar Lampung, Indonesia), NaOH, HNO_3, and methanol from Sigma-Aldrich, Mg $(NO_3)_2.6H_2O$ from Merck, and food-grade aluminum foil (FGAF) with the purity of 99.9 % was purchased from local supplier. Rubber seeds were collected from a rubber plantation in the Mesuji region, Lampung. Rubber seed oil (RSO) was extracted using a pressing machine type HJ-P05 (Jingdezhen Huiju Technologies Co). Instruments used for characterizations are PANalytical type Empyrean X-Ray Diffraction (XRD) unit, CarlZeiss/Evo MA 10 Scanning Electron Microscope-Energy (SEM), PANanalytical Epsilon 3 X-Ray Fluorescence (XRF), and GCMS-QP2010 SE SHIMADZU.

Experimental outline

In this study, a series of experiments were conducted as depicted in the outline shown in **Figure 2**.

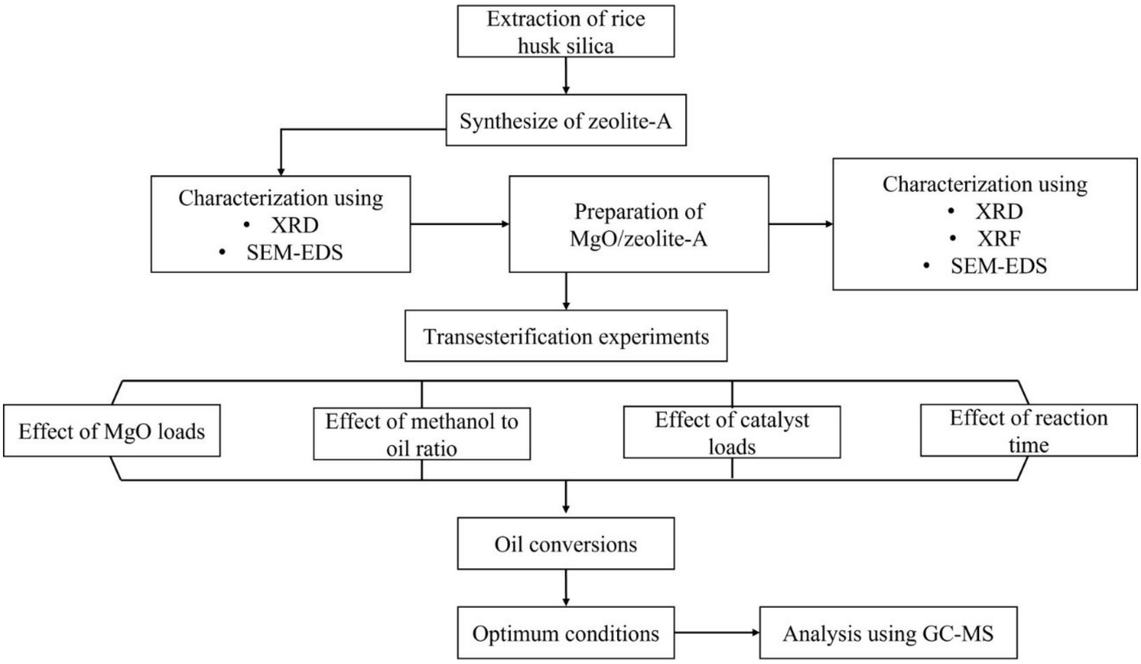


Figure 2 The outline of the experiments carried out in present work.

Extraction of silica

Rice husks were soaked in hot water for 30 min and then filtered and washed repeatedly with hot water to remove natural impurities and water dissolved organic components. The husk was sun dried and soaked in 1.0 M HNO_3 solution for 24 h, rinsed with distilled water to remove the acid, and finally dried. To extract the silica, 50 g of the husk was mixed with 500 mL of 1.5 % NaOH solution, and the mixture was heated to boil and left for 30 min. The mixture was filtered using common filter paper and the filtrate which contains silica was neutralized with 10 % HNO_3 to obtain silica gel. The silica gel was washed using hot distilled water and then oven-dried at 100 °C for 12 h. Finally, the silica was ground and sieved using a 200-mesh sieve to obtain silica powder with relatively homogeneous size.

Synthesis of zeolite-A

Zeolite-A was prepared by adopting the method in the previous study [25]. Sodium silicate solution was prepared by dissolving 60 grams of rice husk silica in sodium hydroxide solvent (prepared by dissolving 40 g of NaOH in 200 mL of distilled water). A mass of 27 g of food-grade aluminum foil previously cut into small pieces was dissolved in sodium silicate solution. The mixture was then transferred into a Teflon-lined autoclave, and the autoclave was tightly sealed and placed in an oven at 110 °C for a crystallization process for 96 h. The solid was rinsed with distilled water and then dried in an oven at 80 °C for 12 h, ground into powder, and finally calcined at a temperature of 550 °C for 6 h.

To prepare MgO/zeolite-A composite with different MgO loads of 2, 4, 6 and 8 %, a series of magnesium solutions were prepared by dissolving specified mass of $Mg(NO_3)_2.6H_2O$ in 50 mL of distilled water, as shown in **Table 1**.

Table 1 Mass of $Mg(NO_3)_2.6H_2O$ dissolved for preparation of composite with different MgO loads.

No.	**Mass of $Mg(NO_3)_2.6H_2O$ (g) dissolved**	**Theoretical MgO load of composite (%)**
1	1.28	2
2	2.56	4
3	3.84	6
4	5.12	8

Impregnation experiment was undertaken by mixing 10 g of zeolite-A with the magnesium solution and the mixture was magnetically stirred at 70 °C for 6 h and then allowed to stand at room temperature for 24 h. The mixture was subsequently filtered and the impregnated zeolite was dried in an oven at 100 °C for 8 h. Finally, the sample was calcined at a temperature of 550 °C for 6 h.

XRF analysis

To determine the composition, the zeolite-A and MgO/zeolite-A were analyzed using XRF method, with particular purpose to determine the MgO content of the MgO/zeolite-A composites. Characterization was carried out using PANalytical Epsilon 3 XRF spectrometer, operated with a voltage of 30 kV and a current of 300 μA.

XRD characterization

XRD characterization was carried out using PANalytical type Empyrean X-Ray Diffraction (XRD) unit with Cu anode material, 40 kV energy, and 30 mA current, and the diffractogram was recorded in the diffraction angle (2θ) range of 10 - 60 °C. The XRD data obtained were analyzed using Match! 3 software Ver. 2.4.7 build 529 and compared to the data for standard zeolite-A available in International Zeolite Association (IZA) database.

SEM/EDS characterization

SEM/EDS characterization was carried out using SEM ZEISS EVO MA 10 instrument, operated with the electron acceleration voltage at 15.00 kV, the window width (WD) of 9.5 mm.

Transesterification of experiment

Rubber seeds were collected from a rubber plantation in the Mesuji region, Lampung. The RSO was extracted using a pressing machine type HJ-P05 (Jingdezhen Huiju Technologies Co). To study the effect of reaction parameters, a series of transesterification experiments were conducted using 10 mL of RSO with varied volumes of methanol, the amounts of catalyst, and reaction times. After the completion of the experiment, the product was filtered into a separating funnel and allowed to separate between biodiesel and unreacted oil. The unreacted methanol was evaporated and biodiesel was analyzed using GC-MS equipped with MS Library System NIST62, and Wiley 7 database for identification of biodiesel components. Conversion of the RSO into FAMEs was calculated using the following equation [24]:

$$\%\, conversion = \frac{V_i - V_f}{V_i} \times 100$$

where V_i is the initial volume of oil (mL) and V_f is the volume of unreacted oil (mL).

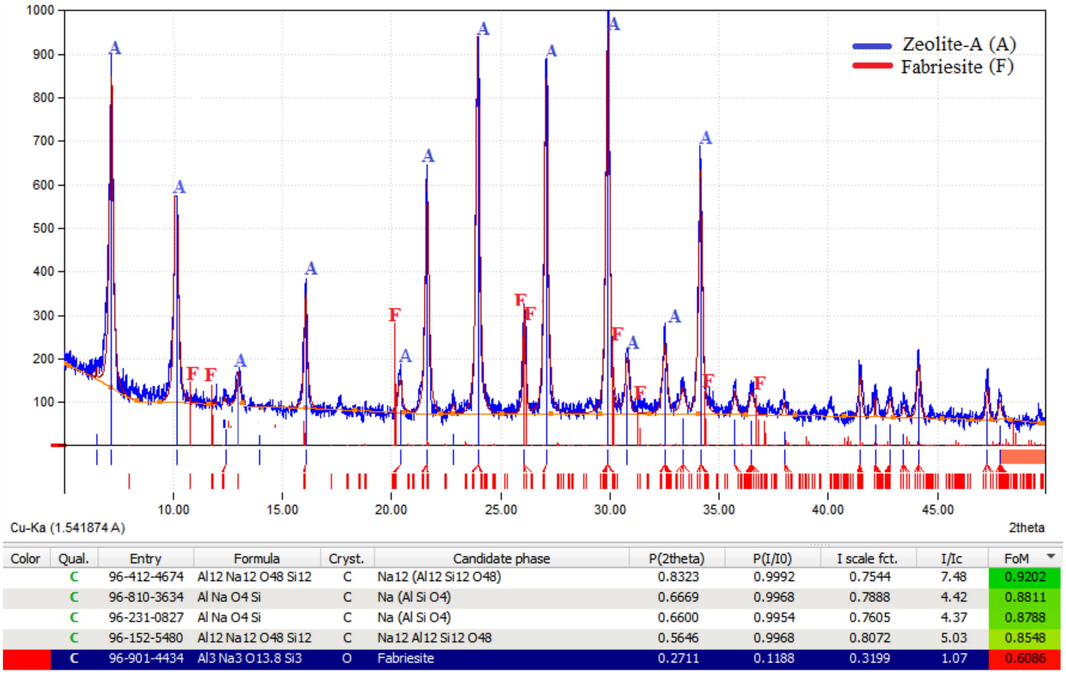
GC-MS analysis of the transesterification product

GC-MS analysis of the transesterification product was carried out using a GCMS-QP2010 SE SHIMADZU instrument. The GC column used was a 30 m long HP SMS column with internal diameter of 0.32 mm, and the instrument was operated at 70 EV in the EI mode. Helium was used as carrier gas and nitrogen as a make-up gas to achieve a flow rate of 60 mL min^{-1}. Component identification was conducted with the aid of MS Library System NIST62 and Wiley 7 databases.

Results and discussion

XRD characterization of synthesized zeolite-A

The XRD diffractogram of synthesized sample and the phases identified using Match software is presented in **Figure 3**.



Color	Qual.	Entry	Formula	Cryst.	Candidate phase	P(2theta)	P(I/I0)	I scale fct.	I/Ic	FoM
	C	96-412-4674	Al12 Na12 O48 Si12	C	Na12 (Al12 Si12 O48)	0.8323	0.9992	0.7544	7.48	0.9202
	C	96-810-3634	Al Na O4 Si	C	Na (Al Si O4)	0.6669	0.9968	0.7888	4.42	0.8811
	C	96-231-0827	Al Na O4 Si	C	Na (Al Si O4)	0.6600	0.9954	0.7605	4.37	0.8788
	C	96-152-5480	Al12 Na12 O48 Si12	C	Na12 Al12 Si12 O48	0.5646	0.9968	0.8072	5.03	0.8548
🟥	C	96-901-4434	Al3 Na3 O13.8 Si3	O	Fabriesite	0.2711	0.1188	0.3199	1.07	0.6086

Figure 3 XRD diffractogram of synthesized zeolite-A and IZA standard zeolite-A.

As can be seen, the diffractogram of the synthesized sample is characterized by the existence of sharp diffraction peaks, justifying the sample as crystalline material, although the existence of an amorphous phase should also be acknowledged, as indicated by the presence of small bumps distributed in a wide range of 2θ at entire diffractogram. With the aid of Match software, zeolite-A was identified as the main crystalline phase, and Fabriesite ($Na_3Al_3Si_3O_{12}.2H_2O$) as a minor phase. For further confirmation of the zeolite-A formation, the diffractogram of the synthesized sample was compared with that of standard zeolite-A available in International Zeolite Association (IZA) database, as shown in **Figure 4**.

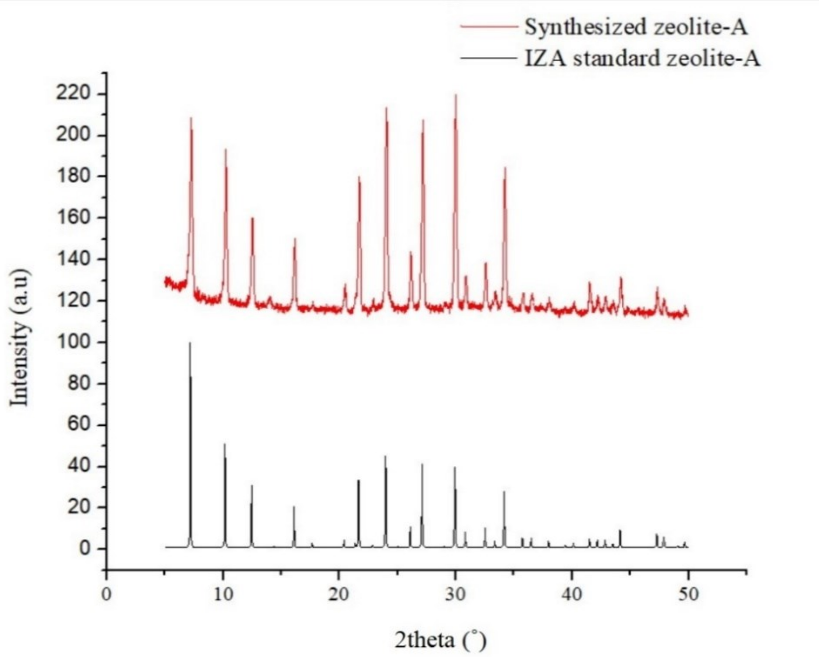


Figure 4 XRD diffractogram of synthesized zeolite-A and IZA standard zeolite-A.

As can be observed in **Figure 4**, the XRD pattern of the sample synthesized is very similar to that of IZA standard zeolite-A, suggesting that FGAF is a promising alternative raw material to replace the more expensive alumina precursors generally applied for fabrication of synthetic zeolites. The XRD data of the synthesized zeolite-A and standard zeolite-A are presented in **Table 2**.

Table 2 Comparison of the XRD data of IZA standard zeolite-A and synthesized zeolite-A.

IZA standard zeolite-A		Synthesized zeolite-A	
2θ (°)	**Relative intensity (%)**	**2θ (°)**	**Relative intensity (%)**
7.198	100	7.284	76.42
10.187	48.73	10.233	67.76
12.475	23.44	12.579	34.68
16.132	21.02	16.168	33.11
21.692	10.59	21.701	60.57
24.015	14.44	24.087	86.79
29.976	11.65	30.015	100.00
34.235	9.15	34.240	64.19

As displayed by the data presented in **Table 2**, eight the most prominent peaks characterizing standard zeolite-A are found in the samples synthesized, although the relative intensities of the peaks are not exactly the same. This difference in relative intensity is most likely due to existence of an amorphous phase in the sample investigated, while the standard zeolite-A is treated as a perfectly pure crystalline material.

SEM characterization of synthesized zeolite-A

SEM micrograph of the synthesized zeolite-A is shown in **Figure 5**, showing the surface morphology of the sample.

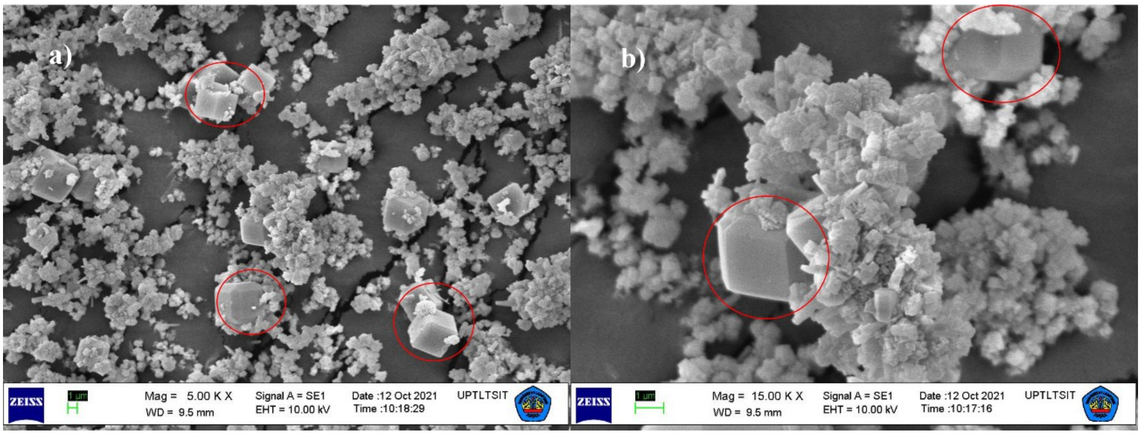


Figure 5 Micrograph of zeolite-A with 5,000× and 15,000× magnification.

The evident presence of cube-shaped particles in the micrograph justifies the formation of zeolite-A structure as has been reported in previous studies [25]. The irregular shape of the particles can also be seen in **Figure 5** which indicates the existence of an amorphous phase in the sample, as also indicated by the XRD diffractogram of the sample shown in **Figure 4**.

XRF analysis of MgO/zeolite-A composite

To evaluate the formation of MgO/zeolite-A composites and the MgO loads of the composites, the samples were analyzed using XRF, and the results are shown in **Table 3**.

Table 3 MgO content of MgO/Zeolite-A prepared using magnesium nitrate solution with different concentrations.

Mass of $Mg(NO_3)_2.6H_2O$ (g) (Dissolved in 50 mL solution)	MgO load of the composite (%)	
	Theoretical	Actual
0	0	0.31
1.28	2	1.88
2.56	4	3.21
3.84	6	4.43
5.12	8	3.06

As can be seen in **Table 1**, the formation of composite was achieved resulting in the formation of the samples with different MgO contents, depending on the concentration of magnesium nitrate solutions used to carry out impregnation. In **Table 1**, it can be seen that in the sample prepared without impregnation, the presence of MgO (0.31 %) was observed. The MgO content of this particular sample is believed to originate from the RHS used as has been reported in our previous study [24]. The data also indicate that the MgO content of the composites increases with increased concentration of magnesium solution up to 0.3 M but decreases with the use of magnesium solution of 0.4 M. Overall, it can be seen that the amounts of Mg in the MgO/zeolite are less than the theoretical amounts produced from magnesium nitrate solutions used, suggesting that not all of the magnesium ions were adsorbed by the zeolite. The composites were then characterized using XRD, producing the diffractograms shown in **Figure 6**.

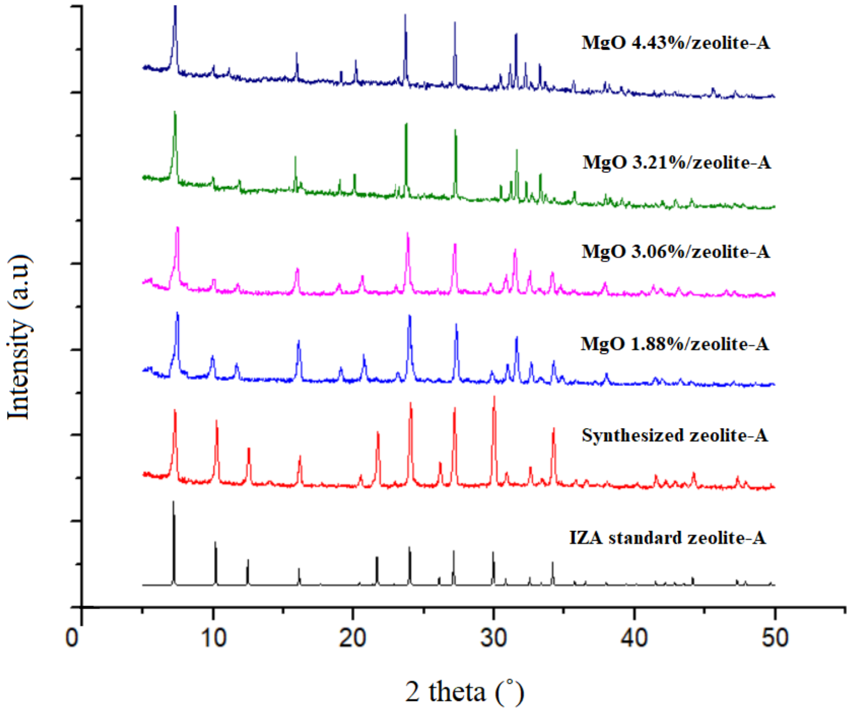


Figure 6 Diffractogram of zeolite-A and composite MgO/zeolite-A.

As can be seen in **Figure 6**, no significant difference between the diffractogram of zeolite-A and those of MgO/zeolite-A composites, implying that impregnation has no significant effect on the structure of the zeolite-A synthesized, except the existence of extra peak at 2θ of 31°. This extra peak is most likely associated with $Mg(OH)_2$, which was not converted into MgO [26]. To investigate the effect of MgO incorporation on surface morphology, SEM micrograph of the zeolite-A and those of composites with different MgO loads are presented in **Figure 7**.

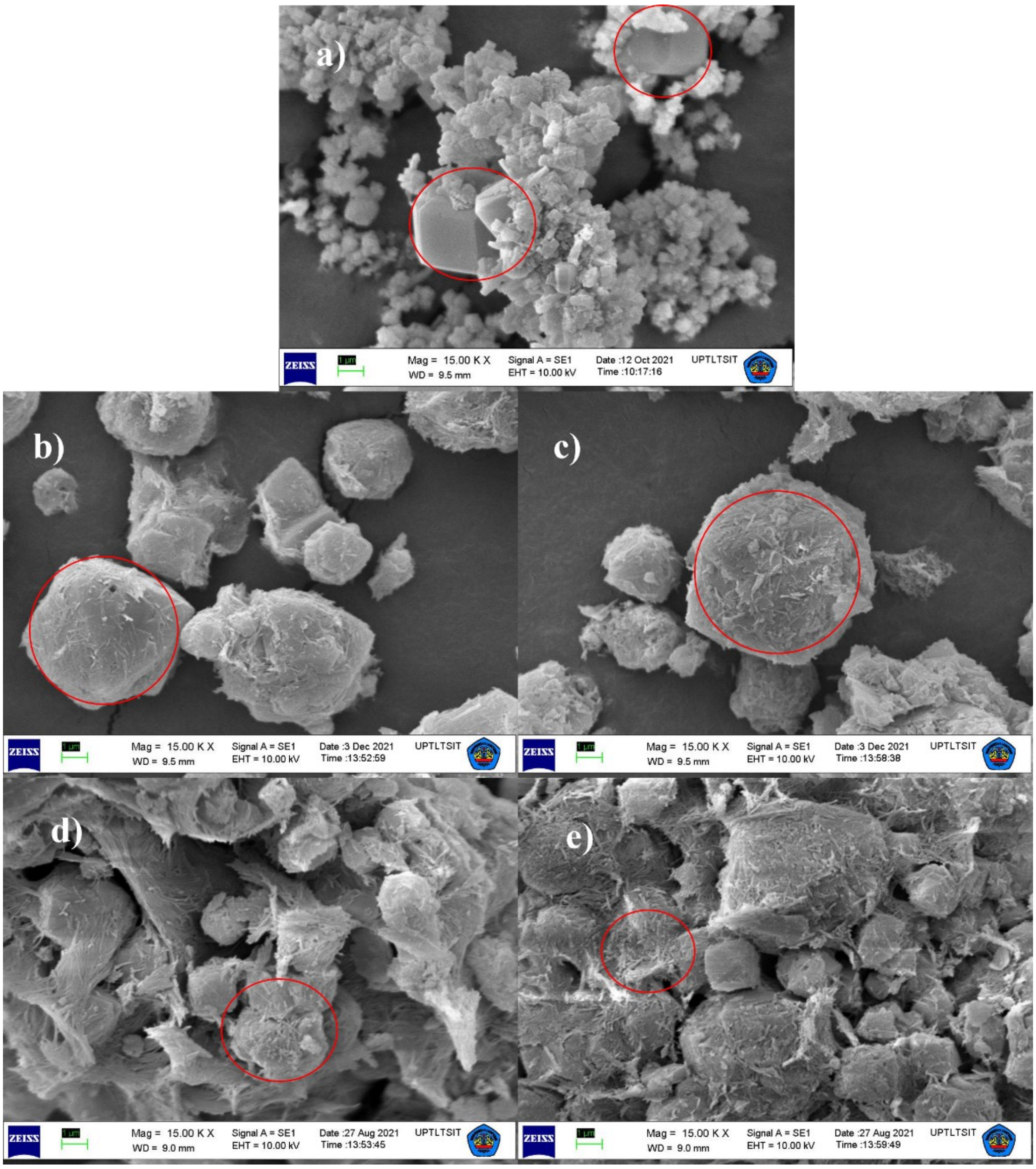


Figure 7 Micrographs of the samples investigated. (a): Synthesized zeolite-A, (b): Composite with MgO load of 1.88 %, (c): Composite with MgO load of 3.06 %, (d): Composite with MgO load of 3.21 %, and (e): Composite with MgO load of 4.43 %.

As can be seen in **Figure 7**, the micrographs of the samples display considerable differences between zeolite-A and the composites, in which the surface of the composites is characterized by the existence of rod-like structures covering the surface, as marked with red color circle on the micrographs, presumably the MgO layer. To confirm the existence of the MgO on the surface of the samples, as suggested by the SEM micrographs in **Figure 7**, three samples were selected and characterized using EDS. The results are presented in **Table 4**.

Table 4 EDS results of the selected catalysts.

No	**Sample**	**Element (Atomic%)**				
		Na	**Si**	**Al**	**O**	**Mg**
1	Zeolite-A	7.08	33.76	11.73	47.43	0.00
2	MgO 1.88 %/zeolite-A	4.72	33.50	13.37	46.87	1.55
3	MgO 4.43 %/zeolit-A	4.82	32.10	13.01	45.74	4.33

As demonstrated by the data in **Table 4** no elemental Mg was detected in zeolite-A sample, while in both composites the presence of elemental Mg was well detected.

Transesterification experiments

As previously mentioned, a series of transesterification experiments were conducted to study the effect of several working variables. The first series of experiments was aimed to study the effect of MgO loads of composite. For this purpose, the experiments were carried out at a fixed amount of catalyst of 10 % of the mass of the oil, ratio of methanol to oil of 6:1, reaction temperature of 70 °C, and reaction time of 6 h. The experimental results are presented in **Figure 8**.

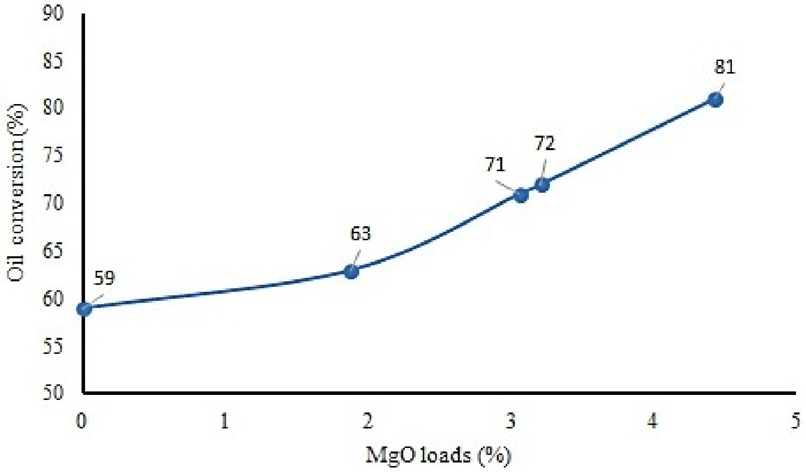


Figure 8 Conversion of rubber seed oil using catalyst with different MgO loads.

As displayed by the experimental results in **Figure 8**, the effect of MgO on the catalytic activity of the catalysts is quite evident, which is in agreement with the existence of MgO as a recognized high catalytic activity oxide. As can be seen in **Figure 8**, the highest percentage of conversion (81 %) was achieved using the MgO 4.43 %/zeolite-A as catalyst, and therefore this particular catalyst was used for the rest of transesterification experiments. As a comparison, in previous work by Rahimi *et al.* [27] , it was reported that application MgO supported on Fe_2O_3-SiO_2 as catalyst for transesterification of camelina seed oil, resulted in an optimum oil conversion of 94.6 % using 4.9 % catalyst load.

To investigate the effect of methanol to oil ratio, experiments with different ratios were conducted, keeping the other variables constant. The experimental results obtained are presented in **Figure 9**.

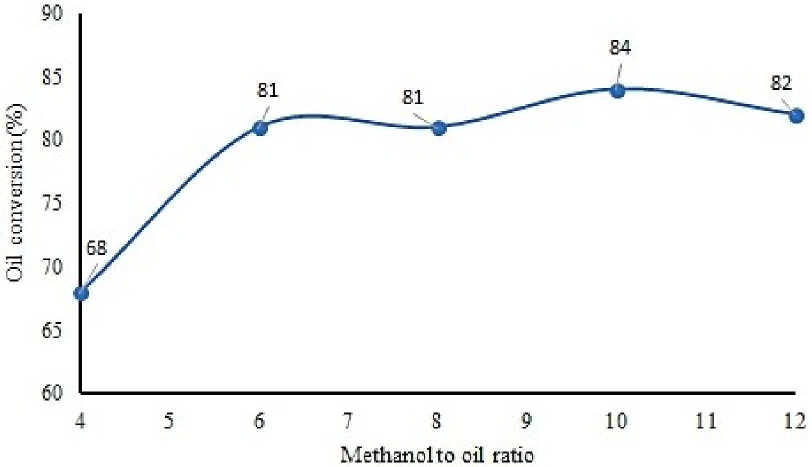


Figure 9 Experimental results with different oil to methanol ratios

As displayed by the results in **Figure 9**, increased ratio of methanol to oil from 4 to 6 led to significant increase in the oil conversion, however further increase of the ratios up to 12, no significant increase in oil conversion. Despite this insignificant difference, it can be seen that the highest conversion was achieved using the methanol to oil ratio of 10, and therefore tis ratio was used for the rest of the experiments. The use of methanol more than stoichiometric equivalence is required since transesterification of vegetable oil is a reversible reaction, therefore the excessive methanol is needed to push the reaction toward product. As a comparison Qu *et al*. [28] utilized MgO/ZSM-5 catalysts in the transesterification of Spirulina platensis algae oil and reported the highest conversion of the oil (92.1 %) was obtained with the alcohol to oil ratio of 15:1.

The results obtained from the experiments with different amounts of catalyst are presented in **Figure 10**, showing progressive increased in oil conversion following an increased amount of catalyst used from 5 % up to 12.5 % followed by slightly decrease with the use of 15 % catalyst. In this respect, it was concluded that the optimum quantity of catalyst is 12.5 %. In this study, the use of 5 % catalyst as a minimum load was based on previous studies by others which reported that the use 5 % catalyst the minimum load [29-31]. The need to use catalyst load higher than 5 % is also reflected by the results obtained in this current study, in which the percentage of conversion achieved using 5 % catalyst is only 77 % and the highest conversion of 89 % was achieved with the use of 12.5 % catalyst. This optimum catalyst load found in this study is in agreement with the optimum load (12 %) reported by others [31].

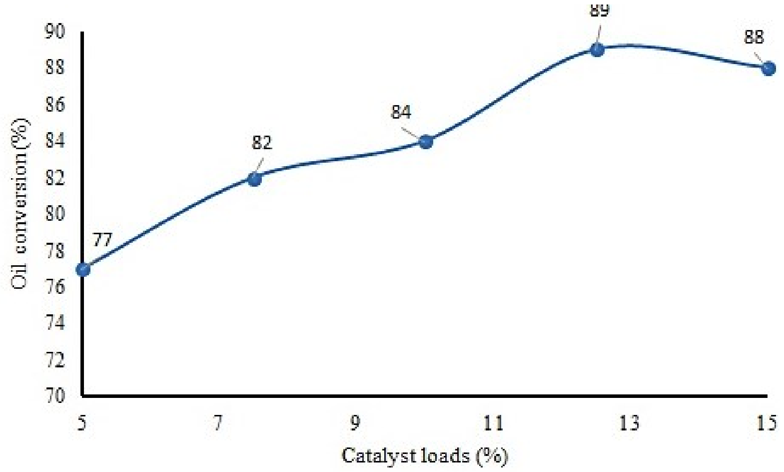


Figure 10 Experimental results using different amounts of catalyst.

The last experiments carried out to study the effect of reaction times produced the data presented in **Figure 11**.

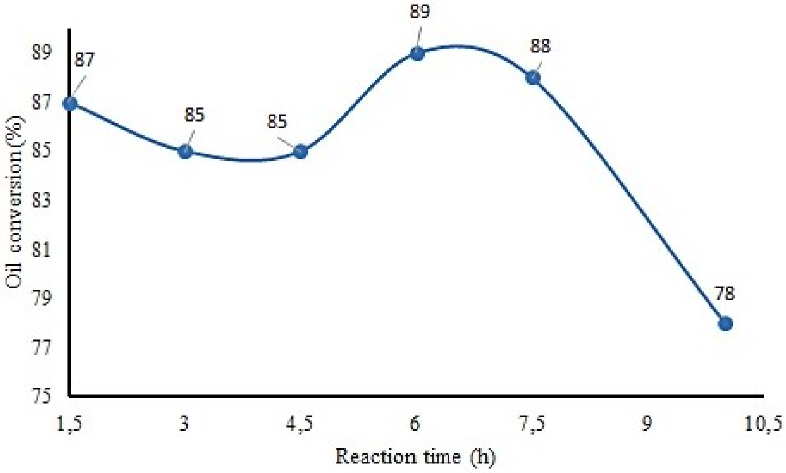


Figure 11 The results were obtained from experiments with different reaction times.

Figure 11 displays that shortening the reaction time to less than 6 h led to a smaller percentage of conversion, and the same is true for the experiments with longer times. In this respect, it was concluded that 6 h is the optimum reaction time. The optimum reaction time of 6 h was also reported by Pandiangan *et al.* [32] on the transesterification reaction of rubber seed oil using a CaO-MgO/SiO_2 catalyst.

The results from all experiments conducted demonstrate that each of the reaction parameters variables investigated affects the transesterification reaction of the RSO, and each of them has the optimum value. The overall results indicate that the highest percentage of conversion (89 %) was achieved from the experiment conducted under the combination of optimum values of reaction parameters applied.

Analysis of fatty methylesters

To confirm that the fatty acids composing the RSO were converted into their corresponding methyl esters, the products of the transesterification experiments were analyzed using GC-MS. The representative GC chromatogram is shown in **Figure 12** and the list of methyl esters identified with the aid of MS Library software is presented in **Table 5**.

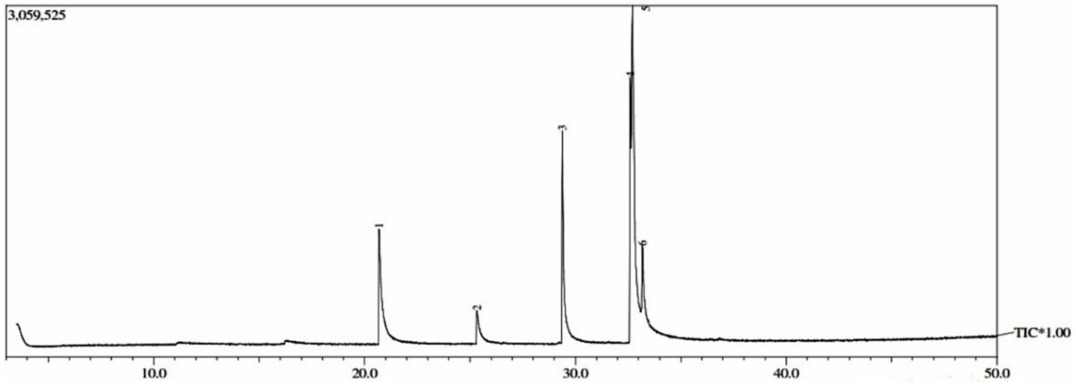


Figure 12 An example of GC chromatogram of RSO transesterification product.

Table 5 The chemical composition of the RSO transesterification product is shown in **Figure 12**.

Peak number	Retention time (min)	Molecular formula	Compound name	Relative percentage (%)
1	20.690	$C_{13}H_{26}O_2$	Methyl laurate	11.29
2	25.332	$C_{15}H_{30}O_2$	Methyl myristate	3.32
3	29.383	$C_{17}H_{34}O_2$	Methyl palmitate	15.66
4	32.601	$C_{19}H_{34}O_2$	Methyl oleate	15.81
5	32.709	$C_{19}H_{36}O_2$	Methyl linoleate	47.81
6	33.179	$C_{19}H_{38}O_2$	Methyl stearate	6.11

As can be observed in **Table 5**, 6 compounds based on the GC chromatogram in **Figure 12** are methyl esters of the fatty acids composing RSO generally reported [32]. In this respect, the results in **Table 5** justify the successful conversion of the oil into biodiesel.

Conclusions

The results obtained demonstrated that zeolite-A can be synthesized using FGAF as a substitute for more expensive raw materials commonly used. It was also found that MgO/zeolite-A composites with different MgO loads were successfully produced as evidenced by characterization using XRF and supported by SEM, and the existence of the MgO on the surface of the samples was justified by the results of EDS analysis. The composites were found to exhibit improved catalytic activity compared to the original zeolite-A. Experimental evaluation of kinetic variables revealed that the optimum percentage of conversion of RSO into biodiesel was achieved using the MgO 4.43 %/zeolite-A, methanol to oil - ratio of 10:1, in the presence of 12.5 % catalyst, and reaction time of 6 h. The result obtained also indicated that the RSO is a potential alternative raw material for biodiesel production, although the need for further study should be acknowledged.

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