

Research Article

Jordanian Dolomite as Potential Catalyst in the Transesterification of *Jatropha* Oil

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- Thermal activation
- Transesterification

Abstract

Jordanian Dolomite was investigated as a heterogeneous catalyst in biodiesel production from *Jatropha* oil. In order to study the thermal activation process of dolomite, dolomite samples were thermally treated for two hours at 100, 200, 300, 400 500, 600, 700 and 800°C as well as for various time intervals at 800°C. Structural and compositional changes were characterized by x-ray diffraction (XRD) and infra-red spectroscopy (IR). No changes could be observed by heating up to 500°C but heating to 600°C causes the magnesium carbonate ($MgCO_3$) to decompose into magnesium oxide while the fraction of calcite ($CaCO_3$) grows at the expense of dolomite. The resulting system showed however a rather low activity (~20% transesterification) as a catalyst in the transesterification of *Jatropha* oil. Highly active catalysts could be produced by heating the dolomite up to 800°C for at least half an hour where the degree of transesterification exceeded 96% at 60°C and a methanol-to-oil molar ratio of 6; the minimum activated dolomite-to-oil mass ratio that gives such a high yield was 1:50 (2%). This high activity was found to correlate with the decomposition of $CaCO_3$ into CaO. Activated dolomite was however found to be non-recyclable as the used catalyst gave when reused a degree of transesterification not higher than 2% suggesting the homogenous nature of the actual catalyst. Nevertheless, activated dolomite can be regarded as a cheaper replacement for the conventionally used potassium hydroxide catalyst.

INTRODUCTION

From the year 2000 to the year 2013, the annual global production of biodiesel grew by 47-fold [1]. It reached 31 billion liter in 2015 and is expected to rise to 41.4 billion liter by 2025 [2], which reflects the importance of biodiesel as an alternative renewable energy resource especially in the transportation sector. In addition to its renewability, biodiesel is biodegradable, non-toxic and has a large blending capacity with other energy resources [3]. Moreover, it is characterized by low SO_2 emissions [4]. The major drawback of biodiesel is its high production cost in comparison to petroleum diesel [5]. Biodiesel is produced mostly via transesterification of vegetable oils; biodiesel prices are thus closely linked to those of the vegetable oil feedstocks [2]; food-fuel competition is expected to drive the oil prices high and doubts arise with respect to the sustainable use of these raw materials in long term [6]. To avoid competition with food, biodiesel should be produced from drought/salt tolerant non-food plants that can be grown on low quality arid lands and irrigated by low quality water. With this respect, *Jatropha* is promising as non-food alternative [1]; its oil is inedible and

Jatropha trees can withstand dryness and very poor soil and can also grow in saline conditions [7]. In 2005, *Jatropha curcas* seeds were introduced in Jordan from India and grown under saline water irrigation and under reclaimed wastewater for research purposes on biodiesel production [8]. The cultivation of *Jatropha* trees in wasteland and the associated biodiesel production as well as its marketing would thus generate employment and improve the socio-economic conditions in a country such as Jordan.

The transesterification of triglycerides (oils or fats) for biodiesel production can be catalyzed by both acid and base catalysts [9], as well as by biocatalysts (enzymes) [10]. Homogenous base catalysts (potassium or sodium hydroxide or methoxide) are in general preferred because the process proceeds rather fast at low temperatures and pressures without intermediate stages [11]. The process is highly effective when the free fatty acid (FFA) content is less than 1%; higher acidity leads to soap formation which hinders the separation process and decreases the conversion [11]. In such a case, a pretreatment (preesterification) is necessary to decrease the oil feedstock

acidity [12]. Replacing the homogeneous catalyst with a heterogeneous one simplifies the purification process and turns it into a benign one as no caustic wastes are discharged into the environment [13].

With this respect, many heterogenous transesterification catalysts have been developed, among which dolomite attracted attention in virtue of its basic properties. Dolomite is a natural mineral consisting mainly of the carbonates of Ca^{2+} and Mg^{2+} . It undergoes thermal decomposition yielding the basic earth alkaline oxides MgO and CaO. MgO [14,15], CaO [16,17] as well as Ca-Mg mixed oxides [18,19] have been investigated as basic solid catalysts. Dolomite arises here as an interesting alternative because of its cheap prices. Ngamcharussrivichai et al., showed that dolomite activated at 800°C could supply highly active mixed oxide that achieves in 3 hours of reaction a 98.0% transesterification at 6% catalyst loading with 30:1 methanol-to-oil molar ratio [20]. Maximum efficiency of dolomite as a transesterification catalyst was reported to be obtained after activation at 850°C [21], but in other studies, the thermal decomposition of dolomite was found to be complete at 815°C [22]. Thermally activated dolomite has been studied as a heterogeneous catalyst for producing biodiesel from canola oil [21], palm kernel oil [23], palm oil [24], sunflower oil [4], and olive oil [25]. This work aims at investigating the catalytic performance of Jordanian dolomite in the transesterification of *Jatropha* oil cultivated in Jordan; the relation between the thermal activation process and the catalytic activity will be addressed. Moreover, the dolomite catalysts will be tested in the so-called extractive transesterification in which oil is extracted from the seeds and transesterified in one step, attempting thereby to improve the cost efficiency of the process of biodiesel production.

MATERIALS AND METHODS

Jatropha oil extraction and analysis

Jatropha fruits were obtained from the National Center for Agricultural Research and Extension (NCARE) in Jordan. The seeds, which constitute ~ 60% of the fruit mass, were finely ground by means of a standard kitchen grinder. n-hexane was then added with the ratio of 1 L hexane/1 Kg seeds. The obtained slurry was mixed at 2500 rpm for 1 hr at room temperature. The liquid phase was then separated by means of suction filtration; hexane was consequently removed from the liquid phase by evaporation under reduced pressure in a rotary evaporator (Büchi Rota evaporator R110). The remaining *Jatropha* oil was found to constitute about 25% w/w of the seeds. The acid value of the oil was determined according to the standard method [26], based on titrating the free fatty acids present in oil by ethanolic KOH solution using phenolphthalein as an indicator. The oil sample was dissolved in a 1:1-solvent mixture of 96% ethanol and diethyl ether. All other oil characteristics were measured in the Scientific Royal Society in Jordan according to standard methods.

Dolomite

Natural dolomite rock was analyzed with respect to its composition by means of x-ray fluorescence (XRF), Minipal PW 4030, and was found to contain 6% Fe in addition to Ca (66%)

Table 1: Fatty acid profile of *Jatropha* oil.

Fatty acid composition	%
C14:0	0.08
C16:0	13.23
C16:1	0.90
C17:0	0.09
C17:1	0.06
C18:0	4.47
C18:1	33.50
C18:2	47.13
C18:3	0.26
C20:0	0.16
C20:1	0.06
C22:0	0.02
C24:0	0.04

and Mg (28%). Due to the weak intensity of Mg in XRF, the mineral was analyzed with respect to its Mg and Ca content by means of Atomic Absorption Spectroscopy (Nova 300, Analytik Jena) and was found to have a Ca: Mg ratio of 1:0.41 which is very close to the XRF results. The dolomite rock was crushed and finely ground, then subjected to different thermal treatments. These include two hours of heating under flowing oxygen (Arab Company) at 100°C, 200°C, 300°C, 400°C and 500°C or under atmospheric air at 600°C, 700°C and 800°C. The thermal treatment at 800°C was also conducted under atmospheric air for different time intervals (12 h, 8 h, 6 h, 4h, 2 h, 1 h, 30 min and 5 min). The prepared catalysts were designated D-T-xh where “x” represents the period of thermal treatment in hours and “T” stands for the temperature in °C at which the thermal treatment has been carried out. All dolomite systems were analyzed with respect to their structure by means of x-ray diffraction (XRD) using a Phillips-PW 1729 device with a Fe-K α tube ($\lambda=1.937 \text{ \AA}$). FTIR spectroscopy (Bruker Tensor 27 FTIR) was applied to determine the various functional groups in the investigated systems.

Preesterification

Homogeneously acid-catalyzed preesterification reactions were carried out at constant temperature (60°C). 25 g of oil were loaded into a 100 ml round bottom flask. Concentrated sulfuric acid (1.2% w/w acid/oil ratio) and dry methanol (25% w/w methanol/oil ratio) were then added and the mixture was allowed to reflux (~60°C) for three hours. The product mixture was washed with water to remove unreacted methanol as well as sulfuric acid and then dried with anhydrous Na_2SO_4 (BDH Chemicals ltd.).

Transesterification

Homogeneously base catalyzed transesterification was carried out for 3 h at 60°C using KOH as a catalyst. 40 g of preesterified oil were loaded into a 250 ml round bottom flask, heated to the designated temperature, then methanol (6:1 methanol/oil mole ratio) and KOH (1.2% w/w KOH/Methanol ratio) were added. The mixture was refluxed with stirring for three hours. The reaction was followed by measuring the $^1\text{H-NMR}$ spectrum (Bruker Avance-III 300) of the organic layer after washing with water and drying up with anhydrous Na_2SO_4 since $^1\text{H-NMR}$ can be very effective in monitoring the substitution of glycerin by methanol

Table 2: Some Characteristics of *Jatropha* oil.

Insoluble impurities in hexane	0.01 %
Acidity as oleic acid	0.45%
Acid value	0.86 mg KOH/ g oil
Peroxide number	0.7 meq O ₂ /kg oil
Iodine number	110.1 g I ₂ / 100 g oil
Saponification value	189.9 mg KOH/ g oil
Unsaponifiable matter	7.23 g/ kg oil
Unsaponifiable matter (after preesterification)	7.63 g/ kg oil

Table 3: Extractive transesterification of *Jatropha* seed mill with Dolomite-800-2h
 Reactions conditions: 10.0 g seed mill, 75 mL methanol, 100 mL chloroform, T = 60°C

	Catalyst mass (g)	Conversion%
Procedure A	0.5	14.1
	1.00	51.8
	2.00	58.6
Procedure B	1.00	65.0
	2.00	88.3
	2.00 (re-used)	1.1

during the transesterification reaction as the glyceride multiplets in the range $\delta=4.0-4.4$ ppm are replaced by a sharp singlet at $\delta=3.65$ ppm corresponding to the protons of the ester methyl group. To eliminate the effect of oil concentration in the analyzed samples, the intensity of the ester methyl resonance relative to that of terminal CH₃ groups of the alkyl chain just below $\delta=1$ ppm is considered because the latter does not undergo any change during the preesterification or transesterification reactions.

In the case of the dolomite catalyzed transesterification, KOH was replaced by 0.50 g of the solid base.

Extractive transesterification

In this method, both extraction of the oil from the seeds and its subsequent transesterification are carried out simultaneously in one step. Two procedures were tested. In the first one, 10 grams of finely ground *Jatropha* seeds were loaded into a 250 ml round bottom flask and mixed with 4.0 g catalyst (D-800-2h), 75 ml methanol and 100 ml chloroform. The mixture underwent refluxing for 10 hours; the *Jatropha* powder was separated by filtration and the solvent was removed from the filtrate using a rota-evaporator. The organic phase was analyzed by ¹H-NMR spectroscopy.

In the second procedure, 10 grams of finely ground *Jatropha* seeds were loaded into a 250 ml round bottom flask and mixed with 100 ml chloroform. The mixture was left under reflux (~60°C) with stirring for two hours. The resulting mixture was filtered and the liquid phase was then loaded into a 250 ml round bottom flask and mixed with 4.0 g catalyst (D-800-2h) and 75 ml methanol. The mixture underwent further refluxing for 3 hours. The solvent was then evaporated under reduced pressure using a rotary evaporator. Analysis was carried out by means of ¹H-NMR spectroscopy.

RESULTS AND DISCUSSION

Oil characteristics

The fatty acid profile of hexane extracted raw *Jatropha* oil is listed in Table 1. The *Jatropha* oil consists mainly of C18 fatty acids (~85%), the majority of which is unsaturated either with one double bond (~34%) or two double bonds (~47%). The oil contains also significant amounts of saturated C16 fatty acid with a percentage of ~13%. Further characteristics of the *Jatropha* oil are found in Table 2.

X-ray Diffraction (XRD)

Figure 1 (a-f) shows the x-ray diffraction patterns of thermally untreated dolomite, D-100-2h, D-300-2h, D-400-2h, D-500-2h and D-600-2h. All patterns are characterized by very sharp lines indicating the high crystallinity of the investigated rock samples. For phase identification purposes, the diffraction lines were compared with the stick patterns of some reference materials (drop lines in Figure 1): Dolomite, CaMg(CO₃)₂ (JCPDS 00-036-0426), calcite, CaCO₃ (JCPDS 00-005-0586), MgO (JCPDS 00-004-0829) and MgCO₃ (JCPDS 00-008-0479). For the purpose of clarity, the drop lines of the last two reference materials are not shown in Figure 1. Comparison with the stick patterns of the above mentioned reference materials shows that the rock sample is indeed dolomite containing small amounts of calcite. Increasing the thermal treatment temperature up to 500°C has no significant effect on the x-ray diffraction patterns, but increasing the temperature to 600°C induced drastic changes. Obviously the dolomite lines almost disappear by the thermal treatment at 600°C and the calcite diffraction lines become more pronounced. In addition, diffraction lines characteristic of MgO are now developed at 54.8° and 81.1° consistent with the decomposition of magnesium carbonate into magnesium oxide and CO₂ (assigned by # in Figure 1d and 1f). Amorphous magnesium carbonate in mixed Mg-Ca carbonate systems has been reported to decompose between 410-490°C [27]. Amorphous carbonate is however metastable with respect to crystalline carbonate [27]. In agreement with our observations, decarbonation of crystalline magnesium carbonate was reported to take place at 550°C [28]. Figure 2 shows the X-ray diffraction patterns of a) D-800-0.5h and b) D-800-2h. No dolomite structure can be recognized, this is in agreement with the results shown in the previous figure that the dolomite phase has disappeared upon thermal treatment at 600°C. The major phases that can be identified in Figure 2 are MgO, CaO and calcite. Apparently, calcium carbonate underwent decarbonation but it didn't disappear completely at this temperature. This is because the practical decomposition temperature of CaCO₃ is above 800°C [27]. It can be seen however that the degree of decarbonation after two hours of heating at 800°C is larger than that after half an hour as indicated by the larger CaO-to-MgO intensity ratio of the lines at 47.7° and 55.0°, respectively.

FTIR-spectroscopy

Figure 3 shows the FTIR spectra of the dolomite samples thermally treated for two hours at various temperatures (D-100-2h, D-200-2h, D-300-2h, D-400-2h, D-500-2h, D-600-2h, D-700-2h and D-800-2h). Carbonate characteristic bands can be

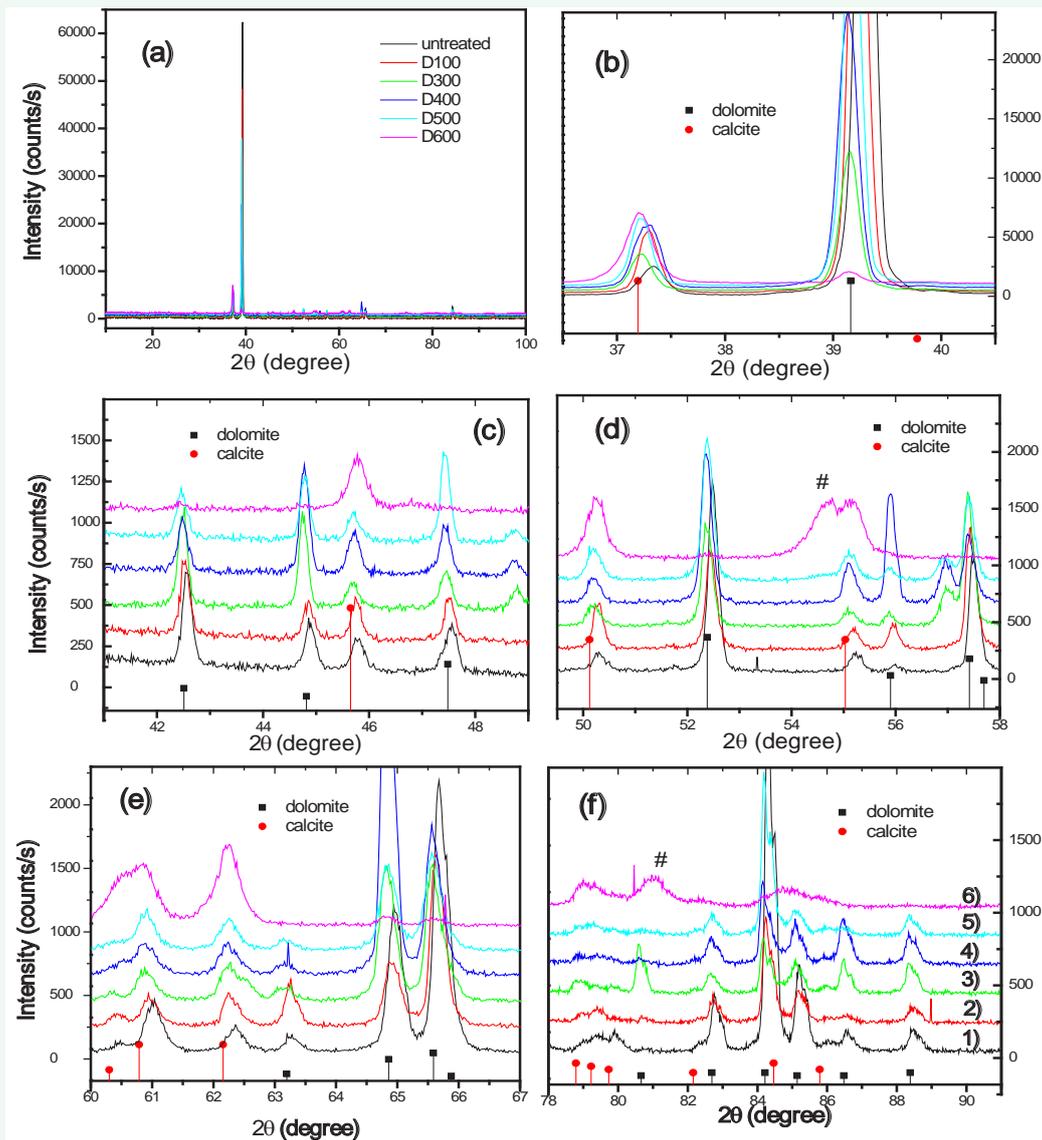


Figure 1 (a-f): X-ray diffraction patterns of dolomite samples 1) Untreated, 2) D-100-2h, 3) D-300-2h, 4) D-400-2h, 5) D-500-2h and 6) D-600-2h.

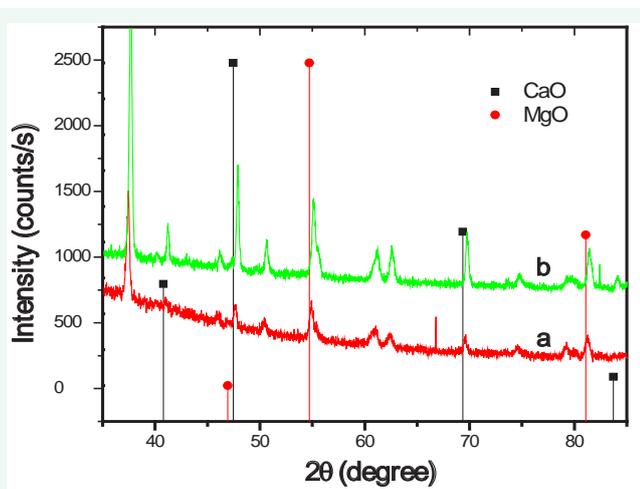


Figure 2 X-ray diffraction patterns of a) D-800-0.5h and b) D-800-2h.

recognized in Figure 3. These bands include the ν_3 asymmetric stretching vibration of the carbonate species at $\sim 1430\text{ cm}^{-1}$, the sharp ν_2 bending vibration at $\sim 880\text{ cm}^{-1}$, a weak ν_1 symmetric stretching vibration at $\sim 1030\text{ cm}^{-1}$ and a sharp band that appears as a doublet at 729 cm^{-1} and 713 cm^{-1} . In addition, the O-H stretching vibration can be observed as a broad band centered around 3450 cm^{-1} corresponding to crystal water and hydrogen bonded OH groups. The O-H bending vibration absorbs at $\sim 1640\text{ cm}^{-1}$.

Upon thermal treatment at 600°C and 700°C , drastic changes in the IR spectrum can be observed. First of all, the sharp band at 728 cm^{-1} disappears while that at 715 cm^{-1} persists. It was reported that the band around 710 cm^{-1} belongs to calcite [27]. Accordingly, it seems plausible to conclude that the band at 725 cm^{-1} belongs to the carbonate species in MgCO_3 since the XRD results show that the magnesium carbonate undergoes decomposition by thermal treatment at 600°C . Also, the shoulder

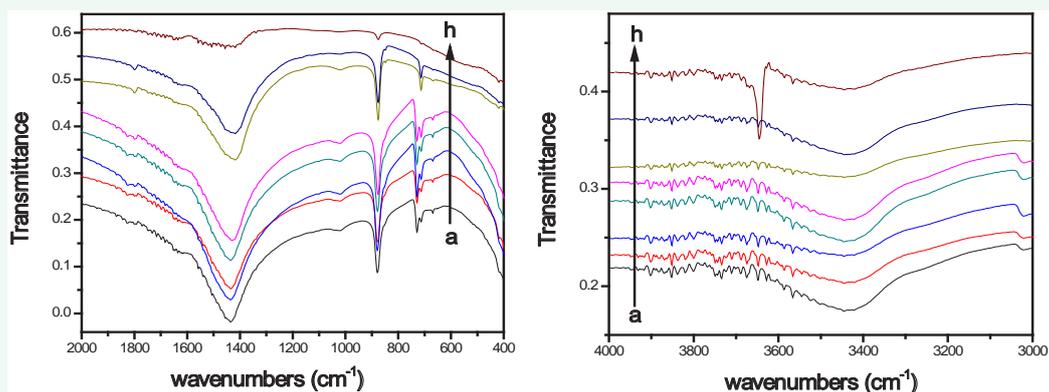


Figure 3 FTIR spectra of dolomite samples treated for two hours at various temperatures: a) D-100-2h, b) D-200-2h, c) D-300-2h, d) D-400-2h, e) D-500-2h, f) D-600-2h, g) D-700-2h and h) D-800-2h.

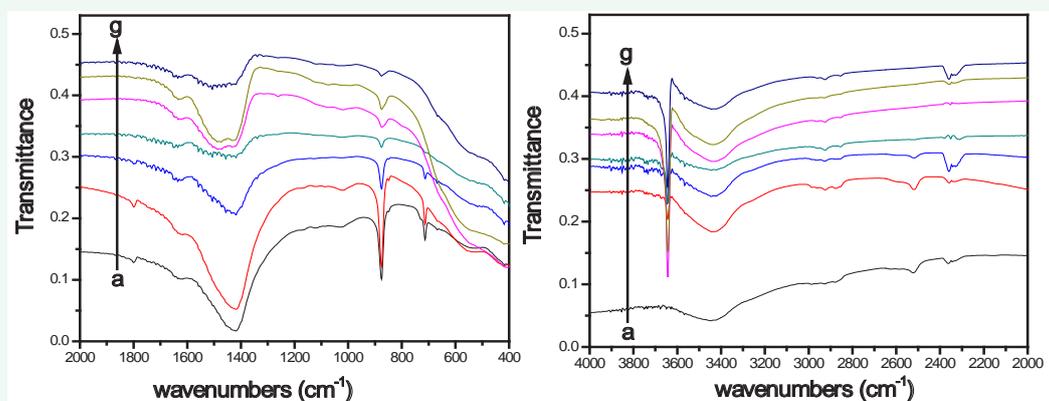


Figure 4 FTIR spectra of dolomite samples treated for different periods of time at 800°C: a) D-800-5min, b) D-800-0.5h, c) D-800-1h, d) D-800-2h, e) D-800-4h, f) D-800-8h and g) D-800-12h.

at lower wave numbers to the 880 cm^{-1} band is observed to disappear by heating up to 600°C which can also be attributed to the decomposition of MgCO_3 .

Figure 4 shows the IR spectra of the dolomite samples thermally treated at 800°C for various time intervals. It can be seen that thermal treatment at 800°C leads almost to the disappearance of the carbonate characteristic vibrational modes indicating that at this temperature also calcite (CaCO_3) undergoes decomposition which is in agreement with literature reports [27]. The disappearance of the carbonate characteristic vibrational bands is accompanied by the appearance of a sharp band at 3645 cm^{-1} which can be assigned to free hydroxide groups. This also is consistent with the decomposition of calcium carbonate into strong basic calcium oxide which upon cooling in the oven under open atmosphere (unavoidable since the samples were heated under open atmosphere) may absorb water vapor leading to the formation of free hydroxide groups.

Figure 4 shows that at least one hour treatment at 800°C is necessary to appreciably decarbonate the sample, but 30 minutes of heating at 800°C does indeed produce CaO as evidenced by the presence of the sharp band at 3645 cm^{-1} corresponding to the isolated hydroxide groups. It can also be seen that the band

corresponding to the ν_3 asymmetric stretching vibration of the carbonate species (1430 cm^{-1}) becomes sharper after 4 hours of heating at 800°C which is reflected in the appearance of two bands centered at 1485 cm^{-1} and 1425 cm^{-1} , a behavior which is well known in literature and is attributed to better crystallinity of the system [27,28].

Transesterification

Transesterification was conducted after the acid value of raw *Jatropha* oil was decreased via preesterification to 0.30 mg KOH /g oil. Figure 5 represents the degree of transesterification achieved using dolomite treated for two hours at various temperatures. Obviously, heating up to 800°C is necessary to activate the dolomite (achieving thereby a 96% conversion). This high activity correlates well with the formation of CaO but not MgO that forms by heating up to 600°C. In a previous study of the catalytic activity of the $\text{Mg}(\text{OH})_2$ -MgO system in the transesterification of *Jatropha* oil [29], the presence of some $\text{Mg}(\text{OH})_2$ in the $\text{Mg}(\text{OH})_2$ -MgO system was necessary to achieve conversions as high as 70%. Thermal treatment at 500°C of the $\text{Mg}(\text{OH})_2$ -MgO system was found to decrease significantly the amount of $\text{Mg}(\text{OH})_2$ in the system leading to a drop in the conversion down to about 40% [29]. It is therefore believed that the low activity of the dolomite-

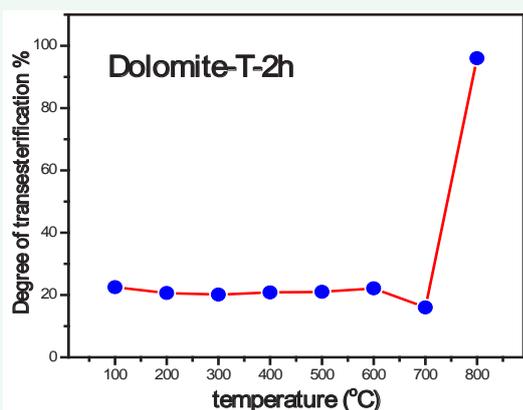


Figure 5 Degree of transesterification achieved by dolomite treated for 2 hours at various temperatures in the production of fatty acid methyl esters (FAME) from preesterified *Jatropha* oil. Reaction conditions: T=60°C, methanol-to-oil molar ratio = 6:1, mass of oil = 5.0 g and mass of catalyst mass = 0.50 g.

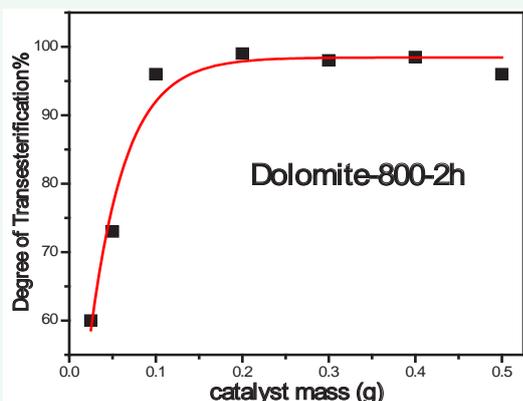


Figure 6 Degree of transesterification achieved by Dolomite-800-2h in the production of FAME from preesterified *Jatropha* oil as a function of applied catalyst mass. Reaction conditions: T = 60°C, methanol-to-oil molar ratio = 6:1, and the mass of oil = 5.0 g.

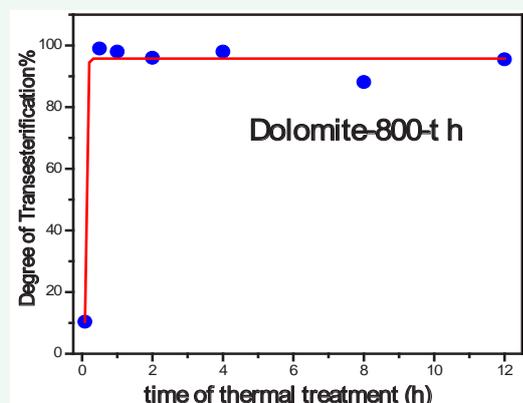


Figure 7 Degree of transesterification achieved by dolomite thermally treated at 800°C for various periods of time in the production of FAME from preesterified *Jatropha* oil. Reaction conditions: T = 60°C, methanol-to-oil molar ratio = 6:1, the mass of oil = 5.0 g and mass of catalyst mass = 0.50 g.

600-2h catalyst despite the presence of MgO results from the lack of the Mg(OH)₂ phase, in addition to having the MgO phase more or less surrounded by the calcite phase that prevents or at least limits its interaction with the reacting molecules. The better activity of the CaO containing system compared with MgO might be also correlated with the stronger basicity of CaO as well as its higher solubility in methanol leading to higher amounts homogeneously active catalytic species in solution.

In an attempt to optimize the mass of the Dolomite-800-2h catalyst needed to achieve almost complete transesterification of fatty acid triglycerides into the corresponding methyl esters experiments were carried out at 60°C using preesterified *Jatropha* oil as a starting material with methanol-to-oil molar ratio of 6:1. In these experiments, the mass of oil was 5.0 g and the catalyst mass was varied between 0.025 g and 0.50 g. The results are depicted in Figure 6 where it can be recognized that a catalyst mass of 0.10 g of D-800-2h is sufficient to almost completely transesterify (96-98%) 5.0 g of preesterified *Jatropha* oil (the catalyst-to-oil mass ratio is thus 50:1). Higher catalyst-to-oil ratios are not only wasted amount of catalyst, they may also lead to adverse effects such as increased saponification causing separation difficulties and loss of desired product.

Regarding the question arising about the minimum time needed for the thermal treatment at 800°C to produce highly active catalysts, dolomite samples treated at 800°C for various periods of time were tested with respect to their activity in converting fatty acid triglycerides into the corresponding methyl esters (Figure 7). It can be seen that at least a 30 min-treatment at 800°C is necessary to transform the dolomite into a highly active catalyst. Longer times of thermal treatment bring no significant enhancement of the catalytic behavior indicating that the major chemical changes in the catalyst system take place already in the first half hour of thermal treatment.

At this point it is important to address the question of catalyst recyclability, a crucial issue when it comes to applied heterogeneous catalysts. Actually, the real nature of the dolomite catalysts used in this work is not clear. It is possible that the transesterification reaction indeed takes place at the surface of the solid catalyst (i.e. it acts heterogeneously) but it is also possible that part of the catalyst dissolves in the reaction solution and acts homogeneously. In the latter case, the catalyst is lost in solution and is thus non-recyclable. To test the recyclability of the D-800-2h dolomite catalyst, the catalyst used in the transesterification reaction was re-used after being washed with hexane to catalyze the transesterification of a second batch of preesterified oil under the same conditions. The conversion (degree of transesterification) was found to drop from 98.5% in the first run to only 1.5% in the second. The catalyst is thus non-recyclable and its catalytic activity is obviously due to the dissolution of CaO into solution. This leaves the residue inactive as it has lost its active constituents. This conclusion is supported by solubility measurements of D-800-2h in methanol by means of titration with EDTA using Eriochrom Schwarz T as an indicator, in which the metal ions concentration in methanol was found to be 0.018 M.

Although thermally activated dolomite was found to be non-recyclable, dolomite can still be used as an alternative to

KOH in the conventionally applied homogeneously catalyzed transesterification of oils, especially in the countries where dolomite is available with low cost. Indeed, in their economic assessment of batch biodiesel production processes, Sakai et al. reported that the process involving CaO as a catalyst and hot water purification was cheaper than the corresponding one in which KOH is used instead [30].

Extractive transesterification

Extractive transesterification refers to the process in which oil is extracted from the seeds and transesterified in one step. The importance of this process lies in the fact, that the major disadvantage of biodiesel production is its relatively high cost for which two factors are responsible: the first factor is the need to extract and separate the oil from the seeds before transesterifying it in a second reactor. The second one is the application of a homogeneous catalyst that requires extensive washing and separation procedures. Until now, all commercial plants for biodiesel production are based on the conventional homogeneously catalyzed two-step process. The introduction of extractive transesterification will definitely improve the cost efficiency of the process of biodiesel production, the reason why a lot of research efforts are being carried out on this subject.

In the experimental part, two procedures for the extractive transesterification were described. In procedure A, all reaction participants (seed mill, methanol, catalyst and solvent) were cooked in one pot in one step. In procedure B, the seed mill was refluxed with the solvent to extract the oil. The seed mill residue was then removed by filtration, methanol and catalyst were then added allowing the transesterification reaction to proceed. Procedure B has thereby the advantage of avoiding any contamination or poisoning of the solid catalyst by the seed mill. Table 3 represents the results obtained for both procedures applying dolomite-800-2h.

From Table 3 the following conclusions can be drawn:

1. In both procedures, the larger the catalyst mass applied in the process, the larger is the achieved conversion. This indicates that the system did not reach equilibrium since catalysis is a kinetic phenomenon.
2. For the same catalyst mass, procedure B gives higher yields than procedure A. This indicates that seed mill indeed poisons or deactivates partially the solid catalyst.
3. Used catalysts are almost inactive in the transesterification reaction in agreement with the results of recyclability test discussed above, pointing out the homogeneous nature of the actual catalyst.

CONCLUSIONS

Dolomite must be thermally activated for at least 30 min at 800°C in order to show high activity (>96% conversion) in the transesterification of *Jatropha* oil at 60°C (methanol-to-oil molar ratio = 6). This high activity correlates with the formation of CaO due to the thermal decomposition of CaCO₃. Minimum catalyst-to-oil mass ratio necessary to give such a yield is 1:50 (2%); the catalyst however is not recyclable and achieves less than 2% transesterification when reused. Nevertheless, activated

dolomite can be regarded as a cheaper replacement for the conventionally used potassium hydroxide catalyst.

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