INTRODUCTION

Continued social development increased the consumption of fossil fuels in the past several decades. However, fossil fuel reserves are gradually decreasing. Moreover, the large-scale consumption of fossil fuels imposed a huge environmental burden owing to excessive emissions of greenhouse gases (e.g., CO₂), which contribute to the greenhouse effect (Yilmaz & Atmanli, 2017). As an alternative of fossil fuel, biofuel has received considerable attention in various countries. There are two pathways for converting biomass or vegetable oils into hydrocarbons. The first involves the conversion of biomass into bio-oil by pyrolysis, followed by a variety of ways to produce hydrocarbon fuels (Huber et al., 2006). The second uses vegetable or animal oils to produce hydrocarbons via hydrodeoxygenation (Chuck & Donnelly, 2014). The vegetable and animal oil pathway exhibits higher conversion rates and thus offers a better research perspective.

Unsaturated fatty acids in vegetable oils can be hydrotreated and deoxidized using a two-step method. In the first step, unsaturated fatty acids are converted to saturated alkanes over a sulfide Ni–Mo/Al₂O₃, Ni–W/Al₂O₃, or Co–Mo/Al₂O₃ catalyst.
In this study, *Jatropha* oil was used as a model raw biomass to prepare fuel components, including $\text{C}_8-\text{C}_{22}$ alkanes, by one-step hydrotreatment over Pt/Al-MCM-41 catalysts etched with sulfuric acid, citric acid, or hydrochloric acid, respectively. The textural and morphological properties of the modified catalysts were characterized and the catalytic performance for the hydrodeoxygenation and hydroisomerization of *Jatropha* oil was also evaluated.

2 | MATERIALS AND METHODS

2.1 | Materials and reagents

*Jatropha* oil was collected in Chuxiong city, Yunnan province, China. The fatty acid composition of *Jatropha* oil, as determined by gas chromatography–mass spectrometry (GC-MS), is shown in Table 1.

All chemical reagents, including hydrochloric acid, sulfuric acid, citric acid, dichloromethane, quartz sand, methanol, Pt(NO$_2$)$_3$(NH$_3$)$_2$ liquor (97.4%), and Al-MCM-41 molecular sieves ($n$(SiO$_2$)/$n$(Al$_2$O$_3$) = 25), were of analytical grade.

2.2 | Instrumentation

An MRT-H00521JB high-pressure fixed-bed reactor (designed and manufactured by Yubao Chen Biomass R&D Group, Yunnan Normal University, China) was used for catalyst evaluation. GC-MS measurements were performed using a Clarus 680-SQ8T instrument. X-ray fluorescence (XRF) spectra were collected using an S4 Explorer spectrometer. Transmission electron microscopy (TEM) images were obtained using a Tecnai F30 instrument. N$_2$ adsorption–desorption isotherms were folliculated using a Nova 2000e physical adsorption apparatus. The temperature-programmed desorption of NH$_3$ (NH$_3$-TPD) was performed using a Chemi80rb adsorption instrument. Pyridine adsorption infrared (Py-IR) spectroscopy was carried out using a Nicolet 380 FT-IR spectrometer.

2.3 | Analytical methods

2.3.1 | Preparation of catalysts and aviation kerosene

In the first step, Al-MCM-41 molecular sieves (10 g) were impregnated with a solution of sulfuric acid (0.25 mol/m$^3$), citric acid (0.25 mol/m$^3$), or hydrochloric acid (0.25 mol/m$^3$) for 30 min in a water bath at 40°C. The product was collected by vacuum filtration, washed with deionized water to

| Component                  | Chemical formula | Relative content (%) |
|----------------------------|------------------|----------------------|
| Palmitic acid              | C$_{16}$H$_{32}$O$_2$ | 8.39                 |
| Oleic acid                 | C$_{18}$H$_{34}$O$_2$ | 86.72                |
| 1,2,3-Trilinoleoylglycerol | C$_{57}$H$_{98}$O$_6$ | 3.72                 |
| Other                      | —                | 1.17                 |
a surface pH of 7, dried for 12 h in an oven at 110°C, and finally roasted at 500°C in a muff furnace for 4 h to obtain the modified molecular sieves.

In the second step, using a Pt(NO$_3$)$_2$ solution as the metal precursor and the modified molecular sieves as the carrier, supported catalysts with a Pt loading of 2 wt.% were prepared by impregnation. After dropping the solution onto the molecular sieve carrier, the mixture was stirred for 6 h and then dried in an 80°C water bath, rotated at 110°C for 12 h, and calcined at 500°C for 4 h in a muff furnace. The Pt-loaded molecular sieves treated with sulfuric acid, citric acid, and hydrochloric acid were labeled as Pt/A-M-41(S), Pt/A-M-41(C), and Pt/A-M-41(Cl), respectively.

The catalysts were evaluated in a fixed-bed reactor (diameter $\phi$ of 10 mm) designed by our research group using 6 ml of prepared catalyst. The process flow diagram of the high-pressure fixed-bed reactor is shown in Figure 1. The product composition was determined by GC-MS analysis using the operation conditions described by Li et al. (2019).

2.3.2 Characterization methods

Powder XRD patterns of the catalysts were obtained using CuK$_\alpha$ radiation ($\lambda = 0.154$ nm). Narrow-angle diffraction scans were collected in the range of 0.5°–6° at a rate of 0.5°/min and wide-angle diffraction scans were collected in the range of 8°–80° at a rate of 10°/min. XRF spectroscopy, performed at 60 kV and 40 mA using Rh radiation, was used to analyze the chemical composition of the catalysts. TEM was used to investigate the morphologies of the modified catalysts. The TEM samples were prepared by dispersing the catalyst in ethanol by ultrasonication and then dropping the suspension onto an ultrathin carbon film. The specific surface areas and pore sizes were determined by N$_2$ physisorption using the Brunauer–Emmett–Teller (BET) and Barrett–Joyner–Halenda (BJH) methods.

The acid strengths of the catalysts were evaluated using NH$_3$-TPD as follows. The sample was pretreated at 350°C for 2 h under a 10% H$_2$/Ar atmosphere. Then, the temperature decreased to 100°C and 10% NH$_3$/He was introduced at a flow rate of 20 ml/min for 1 h. Finally, any physically adsorbed NH$_3$ was removed in a He atmosphere by increasing the temperature from 100°C to 800°C at a rate of 10°C/min. CO chemisorption measured the number of Pt atoms exposed on the catalyst surface. The catalyst (≈50 mg, 40–60 mesh) was filled into a quartz U-tube and reduced at 350°C for 2 h under 10% H$_2$/Ar. After purging with He for 0.5 h and the temperature was lowered to 50°C, the pulse adsorption was performed with 10% CO/He. The test ended after the pulse signal is stable.

2.3.3 Calculation methods

Using GC-MS, a qualitative analysis of the product composition after one-step hydrotreatment was conducted using relative retention, whereas a quantitative analysis was performed using the corrected normalization method.

The conversion of products was calculated as follows:

$$X(\%) = \frac{M_{(T0)} - M_{(TD)}}{M_{(T0)}} \times 100\% ,$$
where $M_{(T0)}$ is the mass percent of *Jatropha* oil before the reaction and $M_{(TG)}$ is the mass percent of *Jatropha* oil after the reaction is completed (%).

The selectivity for C8–C16 alkanes was calculated as follows:

$$Y(\%) = \frac{\sum M_{(i)}}{M_{(T0)} - M_{(TG)}} \times 100\%,$$

where $M_{(i)}$ is the total mass percent of C8–C18 alkanes in the liquid products (%).

The selectivity for C8–C16 arenes was calculated as follows:

$$W(\%) = \frac{\sum M_{(Y)}}{M_{(T0)} - M_{(TG)}} \times 100\%,$$

where $M_{(Y)}$ is the total mass percent of C8–C18 arenes in the liquid products (%).

The selectivity for C8–C16 iso-alkanes was calculated as follows:

$$Z(\%) = \frac{\sum M_{(x)}}{M_{(T1)} - M_{(T2)}} \times 100\%,$$

where $M_{(T2)}$ is the mass percent of alkanes before the reaction and $M_{(T1)}$ is the mass percent of alkanes after the reaction is completed (%). $M_{(x)}$ is the mass percent of iso-alkanes.

### 3 | RESULTS

Al-MCM-41 was etched with various acids and loaded with Pt to catalyze the one-step hydrotreatment of *Jatropha* oil. According to the results, treatment with sulfuric acid, citric acid, and hydrochloric acid all could slightly decrease the surface area of Al-MCM-41 while enhance the pore volume. Among these three acids, citric acid demonstrates the extraordinary performance in pore volume increasing, because etching with citric acid is more persistent. The catalyst modified by citric acid showed the highest selectivity on alkanes and conversion. As the citric acid-modified catalyst demonstrates more Pt active sites and higher acidity, the alkane selectivity and conversion rate of this obtained catalyst are far more acceptable. The Pt/MCM-41 catalysts modified by acids exhibited higher selectivity of long-chain alkanes (C17–C18), but the selectivity of isomeric alkanes and short-chain (C8–C16) alkanes was lower. Further modification by other methods to improve cracking and isomerization capabilities can be explored.

### 4 | DISCUSSION

#### 4.1 | Textural and morphological properties of catalysts

**4.1.1 | XRD characterization**

The diffraction patterns of the modified catalysts are shown in Figure 2. The characteristic diffraction peaks of the (100), (110), and (200) crystal faces are found in the region of 2.2°–6° for the pure MCM-41 molecular sieve (Kresge et al., 1999). However, no peaks are observed in this region for Al-MCM-41 and the modified catalysts (Figure 2a), as these peaks are known to disappear when the Si/Al ratio is less than 26 (Yan et al., 2019). A disperse peak is observed at 15°–40° (Figure 2b), which is indexed to the pore wall structure of amorphous silica. According to the position of the peaks, acid modification and Pt loading did not change the crystal phase structure of Al-MCM-41. The Pt-loaded modified molecular sieves also showed small Pt (111), Pt (002), and Pt (022) diffraction peaks at 39.9°, 46.2°, and 67.5°, respectively.

**FIGURE 2** (a, b) X-ray diffraction patterns of Al-MCM-41 and the Pt-loaded acid-modified catalysts
In general, the full width at half maximum is proportional to the size of the metal particles. However, further characterization is required to elucidate the properties of Pt.

### 4.1.2 TEM characterization

The dispersion and particle size of loaded metals affect the mass transfer of heterogeneous intermediates. The TEM images of the Pt-loaded modified catalysts are shown in Figure 3. Some Pt is observed to be agglomerated while the rest is evenly dispersed over the molecular sieves. The molecular sieve modified with hydrochloric acid shows no obvious characteristic diffraction peak at 39.9° (Figure 2b), whereas a Pt lattice fringe of 0.226 nm is observed by TEM (Figure 3c). These results suggest that Pt/A-M-41(Cl) has high Pt dispersion and a small Pt particle size. In contrast, the observation of characteristic diffraction peaks for the catalysts modified with sulfuric acid and citric acid (Figure 2b) indicates a larger Pt particle size, suggesting more severe aggregation of the active Pt component. According to the particle size statistics (Table 2), Pt are uniformly distributed on the modified Al-MCM-41 catalysts and the molecular sieve modified with hydrochloric acid has the smallest particle size. Highly disperse active components with smaller particle sizes are known to improve catalytic activity and the hydrocracking of Jatropha oil (Liu et al., 2013; Song et al., 2006). However, catalytic performance for oil hydrogenation is also related to other factors.

### 4.1.3 N₂ physisorption characterization

The pore structure in supported solid catalysts influences product selectivity. The specific surface area determines the...
amount and dispersity of the active sites on the catalyst. The morphologies and structures of the catalysts were evaluated based on the N₂ adsorption–desorption isotherms (Table 3). The specific surface area was determined using the BET method. The pore size distribution was obtained using the DFT method because this method is suitable for analyzing multistage pore distributions. The mesoporous pore volume was obtained by the BJH method because most of the pores were mesopores.

As shown in Table 3, acid modification with sulfuric acid, citric acid, or hydrochloric acid decreases the specific surface area of Al-MCM-41. All of the samples showed type IV isotherms (Figure 4), indicating that the acid-modified molecular sieves maintained the original Al-MCM-41 pore structure. TEM and XRD analyses confirmed that Pt was successfully loaded on the modified molecular sieves. Owing to the etching effect of acids on the molecular sieve, some aluminum is removed, which leads to a decrease in specific surface area. As a dihydric acid, sulfuric acid has a better dealumination effect than hydrochloric acid at the same concentration; thus, the surface area of the catalyst modified by hydrochloric acid is slightly higher. Citric acid, as an organic acid, will continuously ionize H⁺, resulting in a further decrease in specific surface area. The continuous impact of citric acid on the molecular sieves results in concentrated defects, leading to a slight increase in pore volume (Fan et al., 2020). The acid etching effect also result in the appearance of micropore in the molecular sieves with an accompanying increase in pore volume. According to the pore size distribution (Figure 5), the majority of pores are mesopores with sizes of 2–4 nm, while some micropores with sizes of 1–2 nm are also present. Although unmodified Al-MCM-41 has a mesoporous structure, micropores appear after acid etching to form molecular sieves with a multistage pore structure.

4.2 | Compositional analysis

4.2.1 | XRF analysis

The chemical composition of molecular sieves and the loading of active components are important factors in catalytic reactions (Table 4). After acid etching, Al-MCM-41 showed dealumination and desilication. The Pt loading amounts were consistent with the designed value of 2%, except for that of the catalyst modified with hydrochloric acid, which

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**TABLE 2** Pt particle sizes on the Pt-loaded acid-modified catalysts

| Sample       | Pt particle size (nm) | Transmission electron microscopy | X-ray diffraction |
|--------------|-----------------------|----------------------------------|-------------------|
| Pt/A-M-41(S) | 1–25                  | 17–22                            |                   |
| Pt/A-M-41(C) | 1–26                  | 16–19                            |                   |
| Pt/A-M-41(Cl) | 1–24                  | 14–17                            |                   |

**TABLE 3** Pore structure properties of Al-MCM-41 and the Pt-loaded acid-modified catalysts

| Sample     | Surface area (m²/g) | BJH adsorption volume (cm³/g) | BJH pore size (nm) |
|------------|---------------------|-------------------------------|-------------------|
| Al-MCM-41  | 766                 | 0.26                          | 3.60              |
| Pt/A-M-41(S)| 722.97              | 0.26                          | 3.41              |
| Pt/A-M-41(C)| 722.151             | 0.28                          | 3.41              |
| Pt/A-M-41(Cl)| 756.198             | 0.26                          | 3.41              |

**FIGURE 4** N₂ adsorption–desorption isotherms of the Pt-loaded acid-modified catalysts

**FIGURE 5** Pore distributions of the Pt-loaded acid-modified catalysts, as calculated using DFT method
also indicated that the surface area was not significantly decreased. The SiO$_2$/Al$_2$O$_3$ ratios of the three acid-etched catalysts were reduced, indicating that the acid site density was increased. As the selectivity of the catalytic reaction is determined by the acid content and distribution, further characterization is needed to explore the acidity of the catalysts.

4.2.2 | CO chemisorption analysis

The dispersion of Pt and the density of Pt surface sites were determined by CO chemisorption (Table 5). The dispersion of Pt is reduced after acid treatment, decreasing in the order Pt/A-M-41(S) > Pt/A-M-41(C) > Pt/A-M-41(Cl). However, Pt/A-M-41(C) has the highest surface density of Pt sites.

4.2.3 | Py-IR and NH$_3$-TPD analyses

The factors affecting hydrocracking reactions are the amount and the distribution of acid sites. Therefore, the distribution of reaction products is affected by changes in acidity. Py-IR is the traditional method for determining the type and amount of acid sites. In the Py-IR spectrum, the bands at 1540 and 1450 cm$^{-1}$ are attributed to Brønsted acid sites and Lewis acid sites at 150°C and 350°C, respectively, and the band at 1490 cm$^{-1}$ corresponds to the total acidity at 150°C and 350°C (Guo et al., 2012; Pieterse et al., 1999).

The Py-IR spectra of the three acid-modified catalysts are shown in Figure 6 and the determined acid site contents are shown in Table 6. Acid modification significantly increased the amount of acid sites, except in the case of the catalysts modified with sulfuric acid. As a dihydric acid, sulfuric acid ionizes more H$^+$ than hydrochloric acid at the same concentration, resulting in a decrease in skeletal aluminum, which leads to a decrease in acidity. This behavior is consistent with the previous characterization results. Etching with hydrochloric acid resulted in moderate dealumination accompanied by recrystallization and bond reformation to form bridges. As a result, the large pores are transformed into multiple pores, thus increasing the pore volume and acidity, which is consistent with the observation of micropores in the pore size distribution (Zhang et al., 2007). The NH$_3$-TPD results (Figure 7) confirmed that the acid strength of the catalysts decreased in the following order: Pt/A-M-41(Cl) > Pt/A-M-41(C) > Pt/A-M-41(S).

4.3 | Effects of acid etching on the performance of modified Pt/Al-MCM-41 catalysts

The acid and metal activities of bifunctional catalysts are the key factors in the hydrogenation of inedible vegetable oils to prepare biofuels. The modification of molecular

| TABLE 4 Compositions of the Pt-loaded catalysts |
|-----------------------------------------------|
| Sample         | Al$_2$O$_3$ (%) | SiO$_2$ (%) | Pt (wt.%) | SiO$_2$/Al$_2$O$_3$ |
|----------------|-----------------|-------------|-----------|---------------------|
| Pt/Al-MCM-41   | 4.04            | 93.83       | 1.91      | 23.22               |
| Pt/A-M-41(S)   | 3.80            | 87.36       | 1.93      | 22.99               |
| Pt/A-M-41(C)   | 3.85            | 84.39       | 2.03      | 21.92               |
| Pt/A-M-41(Cl)  | 4.04            | 90.06       | 1.71      | 22.30               |

*Calculated from CO chemisorption.

| TABLE 5 CO chemisorption properties of the Pt-loaded catalysts |
|---------------------------------------------------------------|
| Sample           | CO adsorption (μmol/g) | Dispersion (%) | No. of Pt$^b$ sites g(cat)$^{-1}$ (×10$^{19}$) | Surface density of Pt$^b$ sites/m$^2$ (×10$^{16}$) |
|------------------|------------------------|----------------|-----------------------------------------------|---------------------------------------------------|
| Pt/Al-MCM-41     | 22.4                   | 22.9           | 1.34848                                       | 1.76042                                           |
| Pt/A-M-41(S)     | 19.8                   | 22.6           | 1.19196                                       | 1.57625                                           |
| Pt/A-M-41(C)     | 19                     | 18.3           | 1.14380                                       | 1.58388                                           |
| Pt/A-M-41(Cl)    | 16.2                   | 16.4           | 0.97524                                       | 1.34894                                           |

$^a$Calculated from CO chemisorption.

$^b$Calculated as the number of Pt sites per g(cat) divided by the BET surface area of Pt/Al-MCM-41.
sieves using different acids can be used to regulate the distribution of acid sites and the amount and dispersion of supported metals. In particular, the distribution of Lewis and Brønsted acid sites determines the distribution of the catalytic products (Ahmadi et al., 2014; Liu et al., 2013). In this study, Jatropha oil was selected as a model raw material, and the performance of the catalysts modified with different acids was evaluated under the following reaction conditions: temperature = 360°C, LHSV = 1 h⁻¹, hydrogen–Jatropha oil ratio (H/O) = 1000, and hydrogen pressure = 4 MPa. The obtained results are summarized in Table 7.

As shown in Figure 8, the conversion and selectivity for alkanes changed significantly after modification. The activity of the catalyst modified with citric acid was higher than those modified with the two inorganic acids, as was the selectivity for C₉–C₁₆ alkanes. Weak Brønsted acid sites affect the cracking of alkanes in the catalytic reaction. As citric acid continuously ionizes H⁺ to etch the molecular sieve, the resulting defect sites penetrate into the crystal interior to form more mesopores and micropores, which provides more weak Brønsted acid sites. All the acid-modified catalysts produced a high content of C₁₇–C₁₈ alkanes because they contain more Lewis acid sites. Following triglyceride decomposition to form oleic acid, an electron pair can be obtained from the Lewis acid site to form octadecane. Alternatively, oleic acid molecules can be directly decarboxylated on Pt to form heptadecane. According to our previous work, an increase in the amount of Brønsted acid sites increases the amount of cracking products, whereas the increase in the amount strong Lewis acid sites increases the number of isomerization products (Chen et al., 2020; Li et al., 2019).

Triglycerides are the major components in Jatropha oil, and the hydrotreatment process mainly results in the hydrodeoxygenation and cracking of oleic acid, which originates from triglycerides, and the isomerization of alkanes, which originate from long-chain alkanes. As shown in Figure 9, the catalyst modified with citric acid achieves the highest conversion. The conversion is higher after citric acid modification because this catalyst has the most Lewis acid sites and the highest surface density of Pt sites. The deoxidization of oleic acid from triglycerides mainly proceeds via the synergistic action of Pt and Lewis acid sites to remove H₂O or via direct decarboxylation by Pt (Deldari, 2005). In this case, long-chain alkanes (C₁₇–C₁₈) account for most of the products. C₈–C₁₆ iso-alkanes are an important index of liquid fuel, as selectivity for these products affects the freezing point. Because of the relatively small number of strong Lewis acid sites, the selectivity for iso-alkanes is low. However, the pore structure of the catalysts also affects the selectivity for iso-alkanes. Compared with our previously synthesized SAPO-11 series of catalysts, the Al-MCM-41 molecular sieves have relatively poor selectivity for C₈–C₁₆ iso-alkanes (Chen et al., 2020; Li et al., 2019).

The time-on-stream (TOS) of the catalyst is very important. The relationship between the selectivity for each product and TOS is shown in Figure 10. The distribution of each product gradually increases to plateau, with the largest amplitudes observed for the C₁₅–C₁₆ and C₁₇–C₁₈ alkanes. Furthermore, the amount of short C₉–C₁₄ alkanes is stable. The amount of weak Brønsted acid sites was relatively small, resulting in fewer cracking products. However, the increased amount of weak Lewis sites synergistically acted with Pt to produce more long-chain alkanes. The low selectivity for iso-alkanes was attributed to the presence of fewer strong Lewis acid sites, which led to isomerization.
Based on the observed product distributions and the catalyst characteristics, the effect of acid etching on Al-MCM-41 can be explained as follows. The $^{29}$Si NMR spectra of Al-MCM-41 and the acid-modified catalysts are shown in Figure 11. The signals located at $-88, -97, -103, -108$, and $-112$ ppm are attributed to the Si(4Al), Si(3Al, 1Si), Si(2Al, 2Si), Si(3Al,
Si), and Si(4Si) species, respectively (Fan et al., 2020; Fellenz et al., 2012; Verboekend et al., 2014). The peaks at −108 and −112 ppm decreased after acid treatment, which clearly indicates that Si(4Si) and Si(1Al) were extracted. Although acid modification resulted in a decrease in Si species, the peak shape did not change significantly, which suggests that the acid etching of Al-MCM-41 only proceeded to a certain extent. The signal strength at −103, −108, and −112 ppm for the catalyst modified with citric acid indicate the extent of defect-induced dissolution is greater in organic acids, but the decrease in Si content was not comparable to that observed with mineral acid etching (Fan et al., 2020; Qiao et al., 2016). Thus, the contents of Al₂O₃ and SiO₂ in the molecular sieves decrease after treatment with the three kinds of acids. However, the lower SiO₂ content after treatment with citric acid led to a decrease in the Si/Al ratio and an increase in acidity. Meanwhile, a mechanism for oriented nanoparticle attachment has proposed by Lupulescu and Rimer (2014), which may account for the defect distribution in the crystal cores.

4.4 Reaction pathway for one-step hydrotreatment

The main components of *Jatropha* oil were triglycerides. Based on the observed product distributions, a reaction pathway for the one-step hydrotreatment of *Jatropha* oil over the modified Pt/Al-MCM-41 catalysts was inferred. The conversion of *Jatropha* oil into hydrocarbons can be roughly divided into the following steps (Figure 12):

- Step 1. Triglycerides are converted into oleic acid molecules at high temperatures and pressures.
- Step 2. Oleic acid molecules are adsorbed on Pt metal, where they receive electron pairs from Lewis acid sites to produce octadecane by hydrolysis or they are decarboxylated directly by Pt to produce heptadecane (reaction processes (1) and (3)). Octadecane can also be converted to heptadecane by β-cracking (reaction process (2)).
- Step 3. Octadecanoic acid is formed by direct hydrogenation of oleic acid and then further cracking to form n-hexadecanoic acid. Subsequent decarboxylation of n-hexadecanoic acid gives n-hexadecane, which is cracked into short-chain alkanes by β-cracking (reaction processes (5)–(7)).
- Step 4. Octane is rearranged to form (1-methylethyl)cyclohexane (reaction process (8)).

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**DATA AVAILABILITY STATEMENT**

The data that support the findings of this study are available in the Supporting Information of this article and from the corresponding author upon reasonable request.

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**FIGURE 12** Reaction mechanism for the one-step hydrotreatment of *Jatropha* oil over acid-modified Pt/MCM-41 catalysts
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**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section.

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