HIGH-THROUGHPUT TRANSESTERIFICATION WITH SOYBEAN OIL AND METHANOL BY MICRO-SCALE AND MINI-SCALE DROP-LET-BASED MICROSYSTEMS

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ABSTRACT

In this work study the droplet-based transesterification using NaOH catalyst at room temperature by a flow focusing device in which the soybean oil drop forms directly in methanol flow. The oil conversion was significantly affected by resident time but not temperature and methanol-to-oil volume ratio. The 90-99% of oil conversion was achieved under room temperature over 40 s of resident time in our systems. It has excellent efficiency whereas compared with other systems presented in literatures. Our results demonstrate the droplet-based transesterification consumes much less time of reaction, greater efficiency, and better potential for mass production of biodiesel.

KEYWORDS: Transesterification, Biodiesel production, Droplet-based fluidic device, Bioenergy.

INTRODUCTION

Biodiesel is environmentally beneficial energy because it has low emission, biodegradable, and nontoxic profiles. Transesterification with triglycerides and alcohol in the presence of a chemical catalyst by a batch stirred plant is well known as a common industrial method to produce biodiesel fuel [1]. Supercritical alcohol without any catalyst was investigated [2] to enhance the reaction rate but requires high temperature and pressure. The microfluidics devices for transesterification were also presented previously and demonstrated that they have the advantage of high energy efficiency [3]. We developed the flow focusing device (micro-scale and mini-scale) in which the triglycerides droplet forms directly in methanol flow for transesterification reaction. Figure 1 is the schematic diagram of our system. The triglyceride drop reacts with the surrounding methanol to serially produce diglycerides, monoglycerides, and release methyl ester molecular to the continuous phase. The by-product is glycerides isolated in the drop phase. The experimental tests show that it consumes less time of reaction, has greater efficiency, and has big potential for mass production of biodiesel.

Figure 1: The diagram of high-throughput transesterification reaction for oil droplet
EXPERIMENTAL
The experiments of transesterification were conducted by systematically varying droplet size, temperature, and residence time. The results were served as the designed benchmarking for further development of optimal and mass production of biodiesel via droplet-based microsystems. Figure 2 is the schematic of the experimental setup. The soybean oil and methanol were used as the raw materials of transesterification in our flow focusing microsystem (PDMS based). Sodium hydroxide (0.3 wt% with methanol) was chosen as a catalyst to enhance the reaction. The mixture was collected in the outlet and the conversion ratio is tested by Nuclear Magnetic Resonance (NMR).

RESULTS AND DISCUSSION
Table 1 shows the comparison of the maximum conversion, residence time, and temperature among our results and other literatures. The residence times in our micro-scale size reactor (droplet diameter 340 μm, 0.02 μL) are much shorter than other systems at 96-99% conversion. In addition, our transesterification processes are conducted at room temperature whereas most of others must be operated in a heated temperature. Figure 3 shows the conversion decreases linearly with increasing droplet size at residence time 25 s in our micro-scale size reactor. The conversion is invariably greater than 99% at 25-60 °C if the droplet diameter is smaller than 300 μm. Figure 4 shows that the conversion in the mini-sized reactor (droplet diameter 720 μm) increases from 48% to 90% when the temperatures increase from 30°C to 40°C. Conversion of 99% was achieved at 40 s residence time if the temperature is over 50 °C. The residence time is also an important factor for conversion. In the tests with droplet diameter 720 μm, 99% of conversion was achieved at 30°C if the residence time was increased to 1 min (Table 1). The size of the reactor could be further enlarged for more mass production.

Table 1: A Comparison of transesterification performance with literature and this study

<table>
<thead>
<tr>
<th>Temp., °C</th>
<th>Residence time</th>
<th>Yield, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>This study, droplet-based microsystem, soybean oil droplet size &lt; 0.02 μL (diameter 340 μm)</td>
<td></td>
<td></td>
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<tr>
<td>23</td>
<td>25 s</td>
<td>&gt;99%</td>
</tr>
<tr>
<td>30</td>
<td>25 s</td>
<td>&gt;99%</td>
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<tr>
<td>40</td>
<td>25 s</td>
<td>&gt;99%</td>
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<tr>
<td>50</td>
<td>25 s</td>
<td>&gt;99%</td>
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<tr>
<td>60</td>
<td>25 s</td>
<td>&gt;99%</td>
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<tr>
<td>This study, droplet-based microsystem soybean oil droplet size as &gt; 0.2 μL (diameter 720 μm)</td>
<td></td>
<td></td>
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<tr>
<td>60</td>
<td>1 min</td>
<td>&gt;99%</td>
</tr>
<tr>
<td>Batch stirred reactor [1]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>60 min</td>
<td>99%</td>
</tr>
<tr>
<td>Supercritical system [2]</td>
<td></td>
<td></td>
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<tr>
<td>280</td>
<td>10 min</td>
<td>99%</td>
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<tr>
<td>Narrow channel reactor [3]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>3 min</td>
<td>98%</td>
</tr>
<tr>
<td>Zigzag microreactor [4]</td>
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<td></td>
</tr>
<tr>
<td>25</td>
<td>10 min</td>
<td>96%</td>
</tr>
<tr>
<td>Slit-Channel system [5]</td>
<td></td>
<td></td>
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<tr>
<td>60</td>
<td>3 min</td>
<td>100%</td>
</tr>
</tbody>
</table>
CONCLUSION
The mass transfer across the boundary of immiscible liquids in a channel can be significantly enhanced by internal circulation in segmented liquidises. Over 99% of oil conversion was performed on our system while 1 min resident time and at the room temperature. The 25 s of resident time is the starting retraction of transesterification in our droplet-based system. Extending the resident time over 40 s, the oil conversion was achieved to 90%. It has better efficiency than other systems presented in literatures and is also much better on energy and time saving compared to the other methods that need heating support and need more than 3 min to over half hours of resident time.

Our system creates very high ratio of surface-area to volume to enhance the mass transfer and significantly increases the reaction rate; the oil droplet size is easily controlled to resolve the optimal operation conditions; the products of methanol-methyl mixture and glycerides are relatively easier to separate in the outlet.

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REFERENCES

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