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Acceleration of transesterification using ultrasonic spray of triolein containing CaO into methanol vapor

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Highlights

- A new transesterification reactor with ultrasonic spray device was investigated for higher temperature condition.
- The optimum operation condition of spray flow rate was found.
- The proposed reactor showed higher reaction rate compared to conventional batch type reactor.

1. Introduction

Biodiesel has shown itself as an attractive substitute for conventional fossil fuels due to its renewability and combustion performance properties nearly same as actual diesel fuel. Generally, biodiesel is produced by the transesterification of vegetable oil, algal oil or animal fat as a feedstock[1] by the help of homogenous catalyst. The disadvantage of the homogenous process is that after the reaction, the catalyst remains in the product. The washing stage is required to purify the product before the usage and thus wasted water could not be directly released to the environment. The use of CaO[2] catalyst as solid catalysts leads to economical production costs due to catalyst recycling, reusability, simultaneous transesterification and environmental friendliness. However, the reaction rate shows slow especially at the initial stage of the reaction. To compensate the disadvantage, we proposed a new reactor with ultrasonic spray of triolein containing CaO into methanol vapor that can be operated under higher temperature condition.

2. Methods

Figure 1 shows the experimental apparatus used here. Triolein containing suspended CaO particles was placed in the glass vessel. The suspension was circulated using a peristaltic pump through an ultrasonic spraying device that sprayed the droplets of the suspension into methanol vapor flowing counter current. After reacting with methanol, the droplets fell to the suspension at the bottom of the reactor. The circulation time was set as 60 minutes. The experimental parameters investigated here were triolein flow rates of 2.5, 6 and 9 ml/min, methanol feed rates of 1.5, 3 and 4.5 ml/min and catalyst amount of 1, 3, 5 wt %. The reaction was performed at 90^{o}C under atmospheric pressure. The suspension was sampled periodically and analyzed it's composition with gas chromatography.

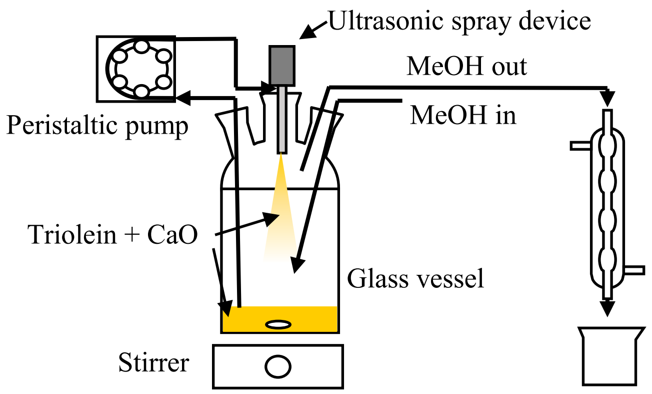

Figure 1. Experimental set up.

3. Results and discussion

Figure 2 shows the effect of Triolein feed rate on Methyl ester (ME) yield. The circulation time was not equal to the reaction time because the reaction only took place when the droplets contacted in methanol vapor, that was, between the tip of the ultrasonic spray device and the upper surface of the suspension. The reaction time could be calculated by the terminal velocity of the droplet in the methanol vapor flowing counter currently with frequency of circulation directly affected by triolein feed rate. From Figure 2, it was found that the feed rate of 6 ml/min was optimum, because the total volume of the droplet and the droplet size were changed by the triolein feed rate, resulting in the highest total surface area of the droplets at the condition.

The experiments also indicated that higher yield was obtained with higher amount of CaO in the system. Higher loading of catalysts increased the total reaction area, resulting in higher yield. The effect of methanol feed rate was also investigated. At higher methanol feed rate, the yield was also increased. It might be an effect of the methanol countercurrent flow because the residence time of the droplet became longer at higher methanol feed rate. Figure 3 indicates the comparison of the results here with the conventional liquid-solid reaction process in the batch reactor with ultrasound irradiation. The proposed reactor was effective for accelerating the reaction at the initial stage of the reaction. After the initial stage, another process should be integrated to achieve higher yield.

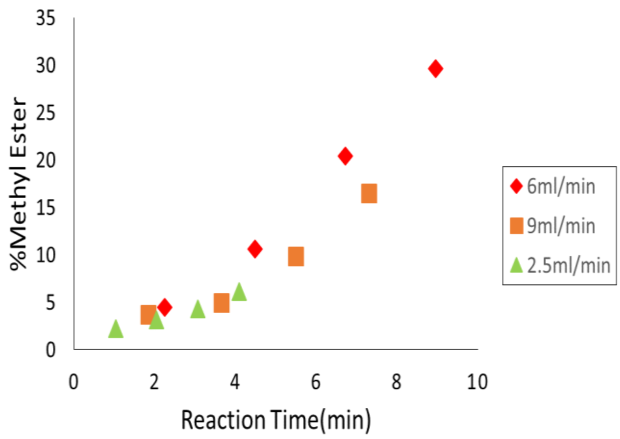

Figure 2. Effect of Triolein feed rate on ME yield at 90ºC, methanol feed rate at 4.5 ml/min, and 5 wt% CaO.

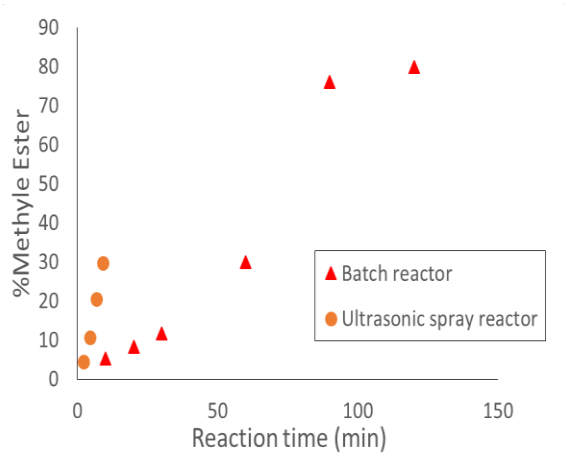

Figure 3. The comparison between Ultrasonic spray reactor and batch reactor
Batch reactor; CaO 1%wt, MeOH : Oil ratio 6:1 with 150 W ultrasonic assist, 60^{o}C
Ultrasonic spray reactor; CaO 5%wt, MeOH feed rate of 4.5 ml/min, triolein feed rate of 6 ml/min, 90 ^{o}C

4. Conclusions

The ultrasonic spray reactor for transesterification reaction could enhance the reaction rate at the initial stage of the reaction. An optimum condition of spray flow rate was observed. The reaction rate was higher than the conventional batch reactor.

References

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Keywords
ultrasonic spray; methanol vapor; transesterification; biodiesel