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The influence of bubbles for biodiesel production

Sunisa Homhaul [1], Thanarak Srisurat [1] and Prayut Jiamrittiwong [1,2*]

[1] Faculty of Science, Energy and Environment, King Mongkut's University of Technology North Bangkok, Rayong Campus, Rayong 21120, Thailand

[2] Research and Development Center for Chemical Engineering Unit Operation and Catalyst Design (RCC), 1st and 7th floor (Room 702), STRI Building, King Mongkut's University of Technology North Bangkok, Thailand

*Corresponding author's e-mail address: prayut.j@sciee.kmutnb.ac.th

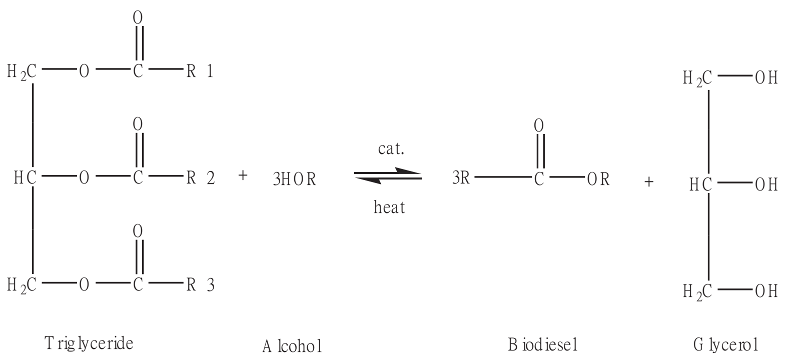
Abstract

Stirrer mixing is the crucial step for biodiesel production via transesterification resulting in high energy consumption. In this research, stirrer mixing step was replaced by waste nitrogen gas obtained from air separation process. Nitrogen gas at room temperature was fed through a diffuser to generate microbubbles in a bubble column filled with the mixture of vegetable oil and methanol. The operating condition used at the bubble column was set at 60 ºC and atmospheric pressure. After 60 min of reaction, samples were collected and analyzed using GC-MS. The results show that homogeneous phase and product yield of 87.76% were observed when nitrogen was fed to the bubble column due to the effect of liquid circulation. This leads to the conclusion that the use of microbubbles from nitrogen gas is an alternative technique for mixing step of biodiesel production process.

Keywords: Biodiesel, Bubble mixing, Nitrogen

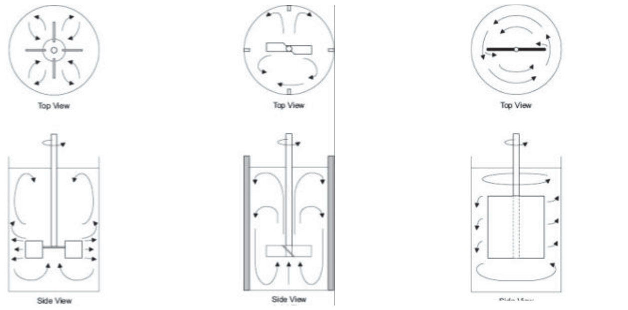
Introduction

It is no doubt that fossil fuels are crucial for our life. They can be used for transportation and production of electricity [1]. Although fossil fuels are running out, the demand of using them are increasing [2]. Researcher is improving the technology for producing renewable energy i.e., bio-fuels, solar energy and wind energy. Bio-fuel especially biodiesel are currently used in the transportation sector [3]. Biodiesel can be produced via transesterification, which vegetable oils or animal fats reacts with alcohols under alkaline catalyst as shown in Eq. 1[4], Mixing is the very important process for biodiesel production via transesterification. This is because alcohols cannot dissolve in vegetable oils or animal fats without mixing. The agitators are normally used for mixing between oils and alcohols resulting in high energy consumption [5]. The fluid flow in reactors using the agitators i.e., axial, radial, and tangential are shown in Figure 1[6]. To decrease the energy consumption, bubbling technique with microbubble size was used.



(1)

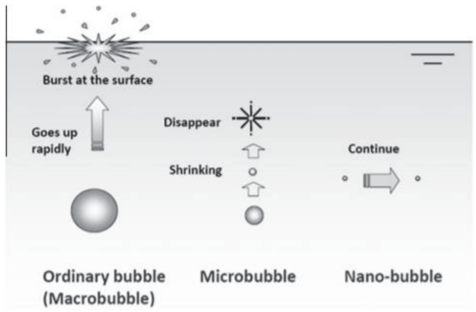
A plenty of nitrogen is currently produced via air and natural gas separation processes [7-8]. The demand of using nitrogen, which is a non-reactive gas, in the industry is quite low resulting in large amount of such gas purged to the environment. To reduce the amount of nitrogen purged, microbubbles generated form this gas was used for mixing between oils and alcohols in the bubble column instead of using agitators.



(a) Radial mixer (b) Axial mixer (c) Tangential mixer

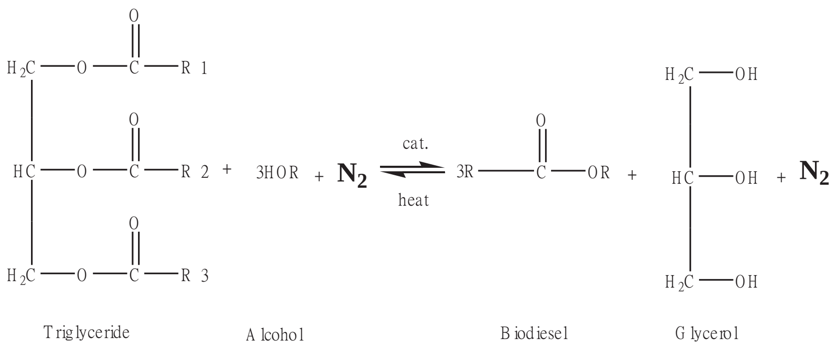
Figure 1 Type of stirrer mixer

Microbubbles are commonly used in water treatment industry [9]. The movement of bubbles increases the mixing efficiency. In addition, the advantage of microbubbles is the surface area to volume ratio. This means that smaller bubbles have higher surface area than larger bubble at the same volume in Figure 2[10]. So, microbubbles can be utilized in the process that large surface area between gas phase and liquid phase are needed [11]. In this work, to decrease the energy consumption using agitator, bubbling technique with microbubble was used. The microbubbles of nitrogen gas was used to mixing in the bubble column for biodiesel production via transesterification process as shown in Eq. 2. The percentage yield of biodiesel was then investigated and compared with the conventional process that the impeller was used as a mixing apparatus.



Reference: Takahashi et al.,25 January 2007 [10]

Figure 2 Schematic show macro micro and nanobubbles



(2)

Materials and methods

Sunflower oil was purchased from local market. It composition was listed in Table 1. Methanol (99.5%) and Sodium hydroxide (99.5%) were obtained from Sigma Aldrich. Nitrogen (99.99%) gas was purchased Bangkok Industrial Gas Company Lmited (BIG).

Sodium hydroxide of 1% by weight was mixed with methanol. Sunflower oil and mixed methanol with the molar ratio of 1:6 was then filled in the reactors. Two glass reactors were used in this study i.e., beaker (500 mL) and bubble column (diameter of 7.5 cm). For beaker reactor, solution contained both reactants of 300 mL and catalyst was heated up to 60 ^{o}C and stirred for 60 minutes with the rotational speed of 500 rpm [13]. For bubble column reactor, such solution was heated up to 60 ^{o}C and nitrogen of 0.5 L/min was then fed to the reactor for 60 minutes as shown in Figure 3. C-101 PR-101, F-101, BR-101, and F-102 represent nitrogen tank, pressure regulator, inlet flow meter, bubble column reactor, and outlet flow meter , respectively.

After 60 minutes of reaction, liquid mixtures i.e., FAME and glycerol obtained from both reactors were separated using a funnel. FAMEs were then washed using distilled water and dired. Samples were analyzed using the GC-MS (Agilent model 7890A and MS Agilent model 5975C). The sample prepareation was based on the EN 14103:2011 [14]. The percentage yield was calculated using Eq. 3[15]

Table 1 Fatty acid composition of sunflower oil

Fatty acid type	Percentage
Palmitic acid (16:0)	10.58
Stearic acid (18:0	4.76
Oleic acid (18:1)	22.52
Linoleic acid (18:2)	52.34
Linolenic acid (18:3)	8.19
Other acid	1.61

Reference: Reyero I. et al., 21 September 2014 [12]

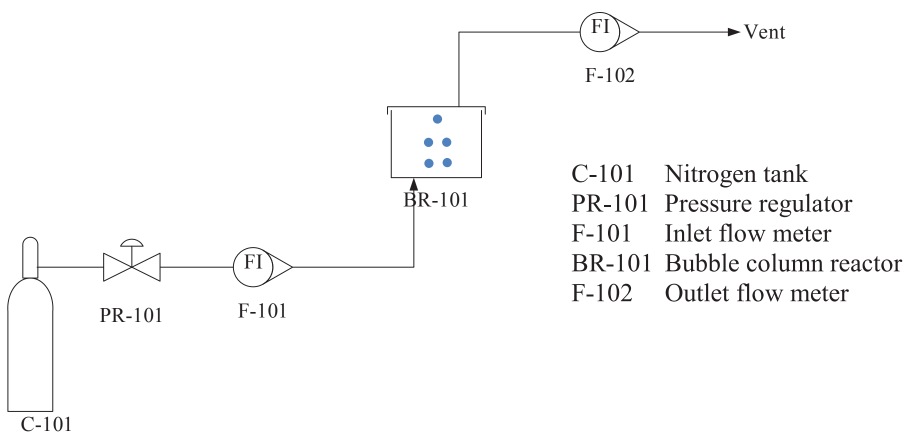


Figure 3 Biodiesel production by microbubble mixing system

$$\textbf{FAME Yeild}\ (\%) = \frac{\textbf{Weight of FAME}}{\textbf{Weight of oil used}} \times \mathbf{100} \quad (3)$$

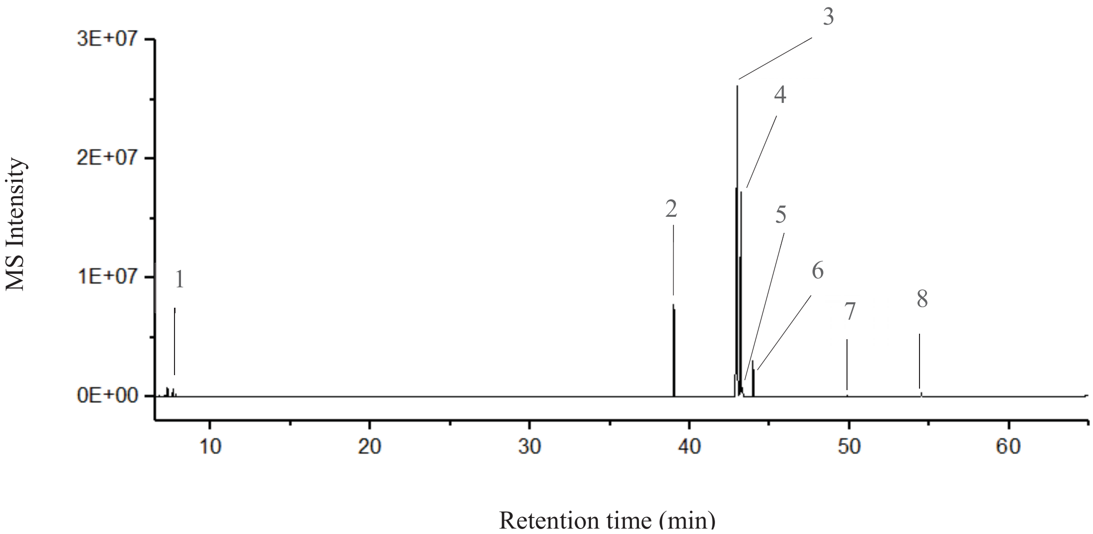
Results and discussion

The liquid mixtures after the reaction obtained from both reactors were shown in Figure 4. Their colors are similar. The mixing technique using the propeller gives the axial mixer of the fluid as shown Figure 1. The turbulent mixing is necessary to complete the reaction resulting in high power consumption when the impeller was employed. Although the stirring technique are currently used for biodiesel production, the energy consumption should be considered. By observation, to obtain the turbulent flow in the reactor, the bubbling technique using nitrogen gas obtained from air separation process shows the good performance of turbulent mixing with low power consumption.

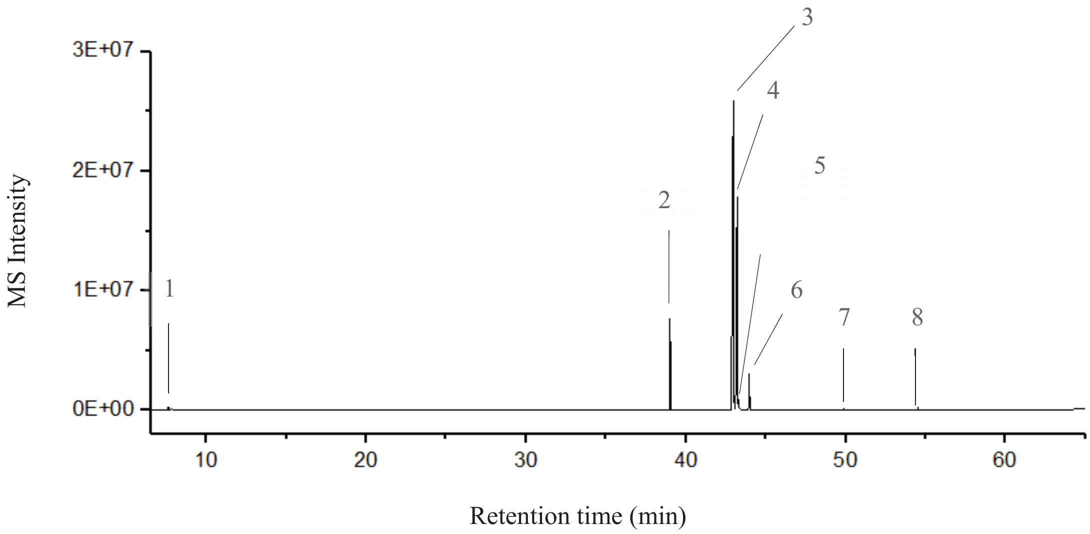
(a) Stirrer mixing (b) Nitrogen microbubble mixing

Figure 4 Fluid behavior of stirrer mixing and nitrogen microbubble mixing

The results obtained from the GC-MS show in Figure 5a and Figure 5b which similar peaks are observed. The identified FAMEs, peak numbers and percentage of FAMEs are listed in Table 2. The percentage of FAMEs gained from both reactors are slightly different as shown in Figure 6 which relates to the experimental results done by Rizwana et.al. [15]. Three types of saturated fatty acid methyl esters i.e., methyl palmitate, methyl stearate, and eicosanoic acid, methyl ester were obsereved, while four types of un-saturated fatty acid methyl esters i.e., methyl linoleate, methyl oleate, e-methyl oleate, and docosanoic acid, methyl ester were also observed as shown Table 2. The percentage yield obtained from stirring and bubbling techniques are 87.81% and 87.76%, respectively. The products via the bubbling technique do not contain the molecule of nitrogen. This means that nitrogen does not affect the transesterification process. This can be concluded that bubbling techinque provides turbulent mixing (circulation flow) with the same as stirring techinque.



(a) Stirrer mixing (SFO_Stirrer)



(b) Bubble mixing (SFO_Bubble)

Figure 5 Total ion chromatogram of biodiesel from sun flower oil (a) SFO_Stirrer (b) (SFO_Bubble)

Table 2 Type of sunflower fatty acid methyl ester

Peak No.	Name	Formula	Percentage of components	
			Stirrer mixing	Nitrogen bubbles mixing
1	Ethylbenzene	C_8H_{10}	0.52	0.26
2	Hexadecanoic acid, methyl ester (Methyl palmitate)	$C_{17}H_{34}O_2$	7.98	7.73
3	9,12-Octadecdienoic acid(Z,Z)-, methyl ester (Methyl linoleate)	$C_{19}H_{34}O_2$	57.05	59.18
4	11-Octadecenoic acid, methyl ester (Methyl oleate)	$C_{19}H_{36}O_2$	26.89	28.65
5	Octadecanoic acid, methyl ester (Methyl stearate)	$C_{19}H_{38}O_2$	1.33	1.80
6	9-Octadecenoic acid, methyl ester,(E)- (E-Methyl oleate)	$C_{19}H_{36}O_2$	3.81	3.82
7	Eicosanoic acid, methyl ester	$C_{21}H_{42}O_2$	0.15	0.14
8	Docosanoic acid, methyl ester	$C_{23}H_{46}O_2$	0.38	0.30

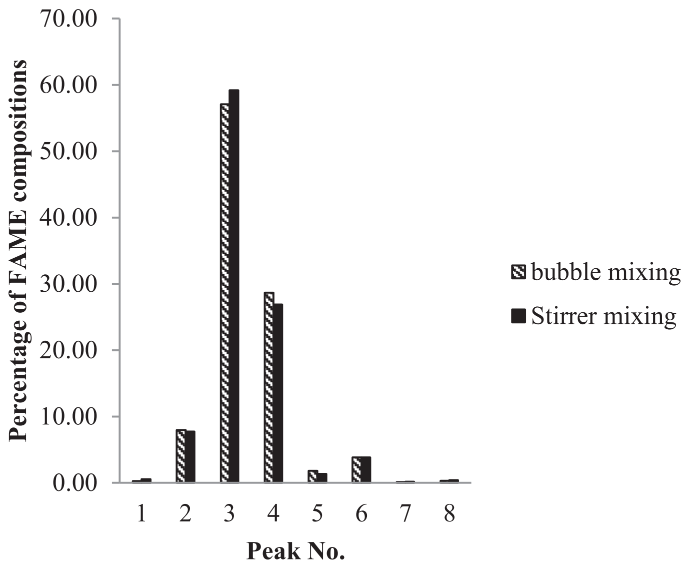


Figure 6 Comparison percentage of FAME between agitator and bubbling techniques

Conclusion

Two techniques including stirred reactor and bubble column reactors were tested for biodiesel production. The percentage yield of FAME obtained from both techniques are similar. Therefore, the bubble column with nitrogen feed can be selected as an alternative reactor for biodiesel production resulting in the reduction of biodiesel production cost.

Acknowledgements

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