FAME synthesis by transesterification reaction using a vibromixer

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Highlights

- The use of vibromixer improves significantly the transesterification reaction
- High FAME percentage can be obtained after 30 min reaction time

1. Introduction

Biodiesel is an alternative biofuel and it has appeared as a complementary source of energy to diversify the conventional fossil fuels for many years. Moreover, biodiesel has the advantage of being biodegradable, non-toxic and sustainable since it is produced from vegetable oils, animal fats, waste cooking oils, greases and other fats and oils. The most common method to produce biodiesel is a homogeneous transesterification process using a basic catalyst such as NaOH. However, this reaction is limited by the slow mass transfer between two-phase oil-alcohol mixture. Stirred-tank reactors are commonly employed in industrial biodiesel production however process performance is limited due to non-uniform droplet dispersion and the size of the droplets thereby impacting mass transfer rates.

This study explores the potential of the vibromixer for improving the transesterification reaction for biodiesel production. Indeed, this process technology is effective for liquid-liquid dispersions but is not well known and has been the focus of very few scientific studies [1]. In this work, experimental investigations of the transesterification reaction are by complemented by flow simulations, which help understand the hydrodynamics and the behaviour of the pattern flow in the vibromixer system.

2. Material and Methods

The principle of the FUNDAMIX vibromixer [2] is based on a vibrating plate immersed in a fluid. The vibration is created and transmitted through a shaft to the horizontal plate that has conical holes (Fig. 1). As the plate oscillates in the vessel, it pumps the fluid and creates flow. The plate located at half-height from the bottom vessel can be installed in the reactor in two configurations, resulting in an upwards or downwards flow. The ranges of operating conditions studied were: oscillation amplitude (1.5, 2, 2.5, 3, 3.5, and 4 mm), the plate diameter (D=45, 54, and 64 mm) and the operating time (max 30 minutes); the frequency is fixed at 100 Hz. The reaction was conducted at 60°C in a vessel (diameter 0.10 m, liquid height 0.10 m) with a methanol to sunflower oil molar ratio of 6:1 and 1 wt% concentration of KOH. After centrifugation, the composition of the synthesized FAME was obtained by gas chromatography and the content of FAME in the products was determined. CFD simulations of the flow were carried out using ANSYS Fluent. The liquid-liquid dispersion was simplified as pseudo-homogenous mixture and modelled as a single phase with an apparent viscosity equal to 0.004 Pa.s, which was measured using a sample of the mixture. A deforming mesh was employed to model the vibration of the plate and the SST k-omega turbulence model was used to model the flow.

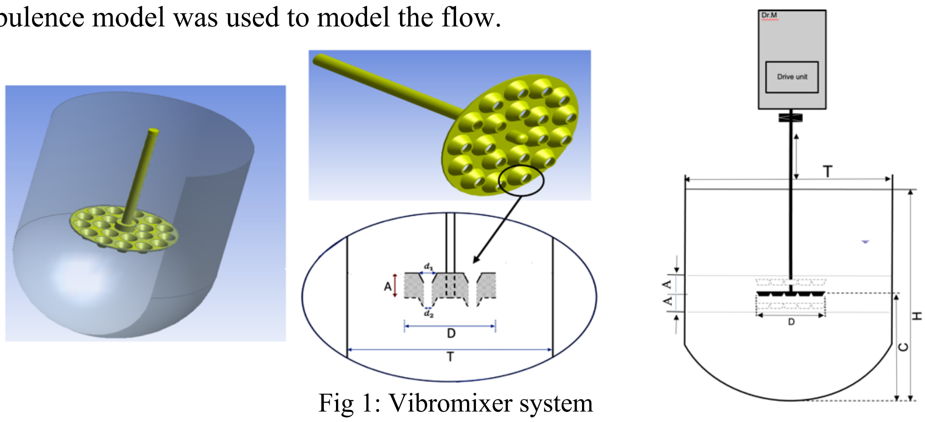

Fig 1: Vibromixer system

3. Results and discussion

• *Effect of pumping direction*
The results indicate that the orientation of the plate has not significant effect on the percentage of FAME content.

• *Effect of the amplitude and plate diameter*
Fig 2 clearly shows that FAME content increases significantly with increasing vibration amplitude, regardless of the plate diameter. For example, the percentage of FAME after 30 minutes increases 5% (from 92% to 97%) increasing the amplitude of the 54 mm diameter plate from 1 mm to 4 mm. Increasing vibration amplitude generates higher mechanical energy and shear forces in the fluid, which enhances flow circulation and makes it possible to obtain smaller drop diameters by promoting breakage of the droplets. This leads to increased surface area between the immiscible reactants and enhances the chemical reaction. Increasing the plate diameter also causes an increase in the FAME content regardless the amplitude of the vibrations. This is potentially due to enhanced turbulence resulting from two mechanisms. Firstly, as the diameter of the plate increases, the plate surface changes leading in greater energy dissipation in the liquid. Secondly, because of the shape of the holes and the number of holes (which is different for each plate), an acceleration of the velocity fluid and a change of the direction occurs at each oscillation due to Bernoulli effect and this is expected to favour drop breakup and increase interfacial area between reactants.

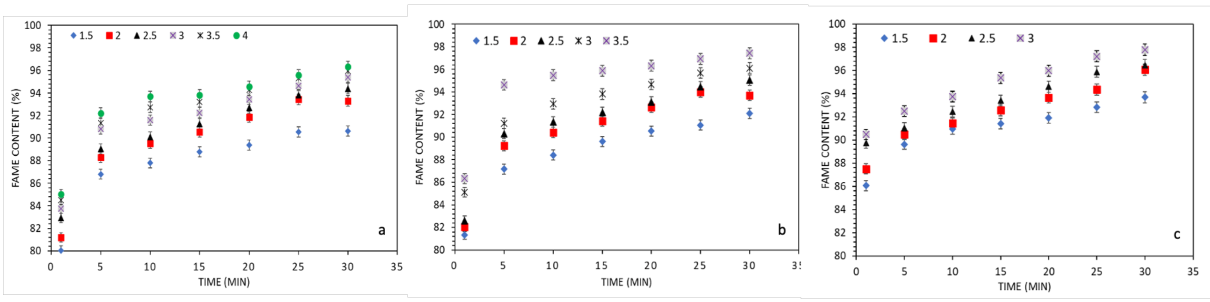

Figure 2. Effect of amplitude vibration on the FAME content for different plate diameters (a) D=45mm, (b) D=54mm, (c) D=65mm.

• *Flow patterns*
The initial CFD simulations show that strong flow circulation is generated by the vibrating plate; the principal circulation loops occur below and above the plate. In addition, high velocity gradients occur in the holes of the plate which are expected to play a major role in drop breakup. Further analysis of the results will focus on turbulence levels.

4. Conclusions

This study has shown that the vibromixer is a suitable technology to improve contact between immiscible fluids, leading to sufficiently small droplets that enhance chemical reaction. Its use for FAME production, which requires high mass transfer between the phases, is promising. Products containing 98% FAME are obtained within 30 min; this is equivalent or shorter than in classical stirred tanks [3]. However, the behaviour of the vibromixer system is very complex as it depends on geometrical and operating parameters; further investigations are required. CFD could provide additional knowledge, even if its implementation is not so easy and requires considerable calculation time.

References

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Keywords
Biodiesel; Multiphase fluid flow; Mixing