# Low-Cost Alternative Biodiesel Production Apparatus Based on Household Food Blender for Continuous Biodiesel Production for Small Communities

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This additional information includes:

Supplementary Text

Table S1-S3 with caption

Figure S1-S4 with caption

References

**Table S1** Properties of fresh refined vegetable oils and WCO

| Type of oil | Density (g/cm$^3$)* | Molecular weight (g/mol)* | FFA content (%) |
|---|---|---|---|
| Palm oil | 0.89 | 847 | ≤ 0.1 [1] |
| Soybean oil | 0.91 | 920 | < 0.05 [2] |
| Corn oil | 0.91 | 865.4 | ≤ 0.1 [3] |
| Sunflower oil | 0.92 | 876.2 | ≤ 0.25 [4] |
| Canola oil | 0.92 | 876.6 | ≤ 0.05 [5] |
| WCO | 0.90 | 845 | 1.21* |

* Data based on experiments

**Table S2** First-order rate constants for transesterification of refined palm oil at different temperatures (refined palm oil, 2,000 mL, residence time 0 - 40 min, 1 wt% NaOH)

| **T (ºC)** | ***k* (min$^{-1}$)** | **$R^2$** |
|---|---|---|
| 50 | 0.0588 | 0.9732 |
| 55 | 0.0838 | 0.9855 |
| 62 | 0.1204 | 0.9906 |
| 65 | 0.1065 | 0.9971 |

**Table S3** Yield efficiency of FAME from intensification technologies

| **Ref.** | **Yield efficiency ($\times 10^{-4}$ g/J)** | **Type of reactor** | **Mode of operation** |
|---|---|---|---|
| Present work (refined palm oil) | 21.14 | High-power fruit blender | Continuous |
| Present work (WCO) | 19.39 | High-power fruit blender | Continuous |
| Wongsawaeng et al. [6] | 45.2 | High-power fruit blender | Batch |
| Appamana et al. [7] | 13.7 | Spinning disc | Continuous |
| Maddikeri et al. [8] | 12.2 | Hydrodynamic cavitation | Recirculation (close loop) |
| Maddikeri et al. [9] | 0.47 | Ultrasound | Batch |
| Bokhari et al. [10] | 12.5 | Hydrodynamic cavitation | Recirculation (close loop) |

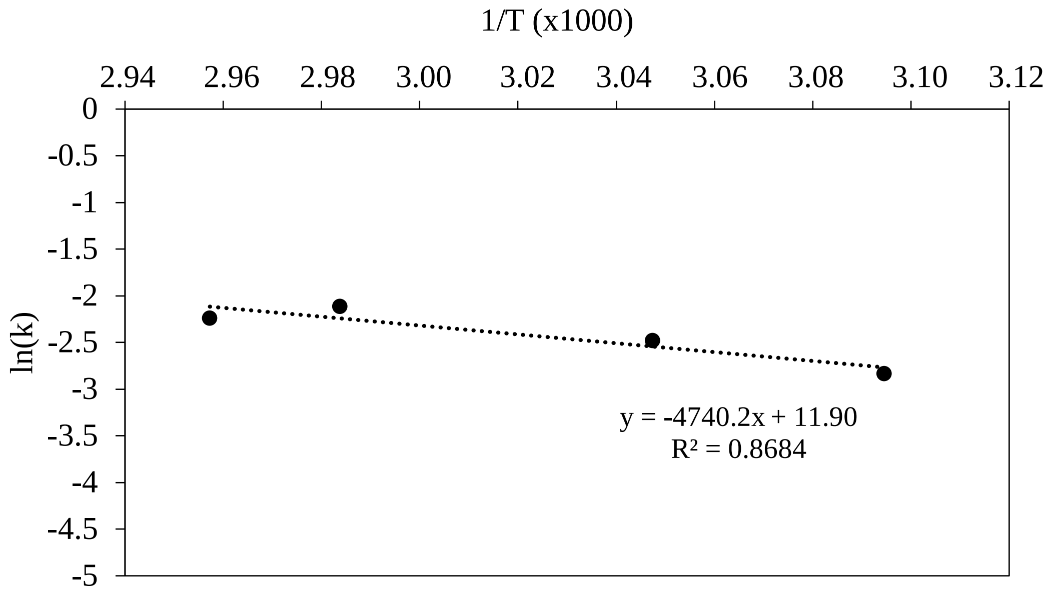


**Fig. S1.** Arrhenius plot of studied transesterification (refined palm oil, 2,000 mL, 1 wt% NaOH)

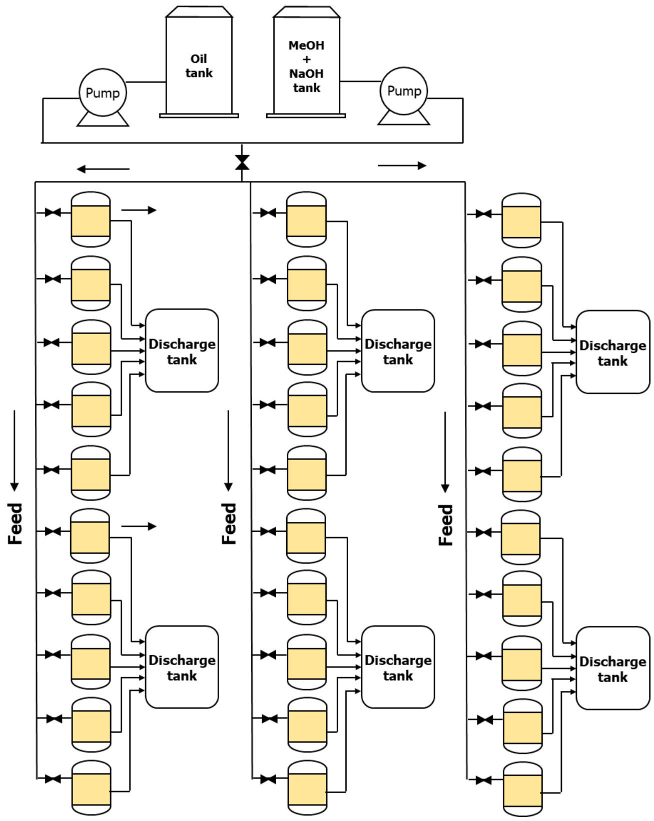


**Fig. S2.** Preliminary model of biodiesel production system for small communities

## Characteristic of impeller

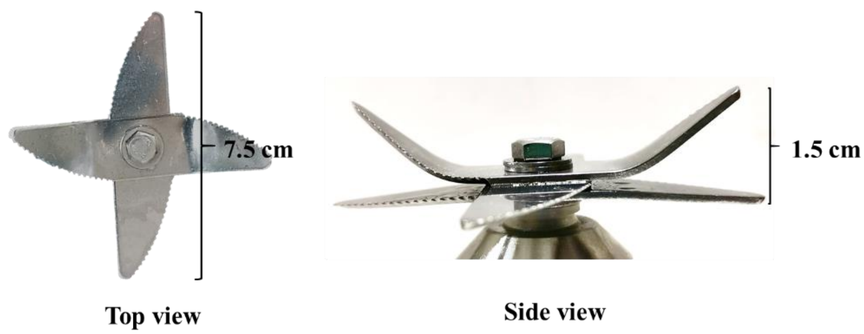


**Fig. S3.** Characteristic of impeller

The configuration of the impeller is shown in Fig. S3. The impeller is a wide-blade impeller type (propeller) consisting of 3 sets of 2 blades each (total 6 blades). One side of each blade on the direction of the rotation exhibits a sharp, serrated teeth-like feature while the opposite side is smooth. The impeller is obviously designed to cut materials; however, as it was proven by Wongsawaeng et al. [6], the impeller is very effective in mixing vegetable oils and methanol as well. The ratio of the impeller diameter (D) to the tank diameter (T) should be in the range 0.4 - 0.6. As the impeller diameter is 7.5 cm and as the reactor diameter is 15 cm, the D/T ratio of the present reactor is 0.5, which is proper.

## Experimental set up

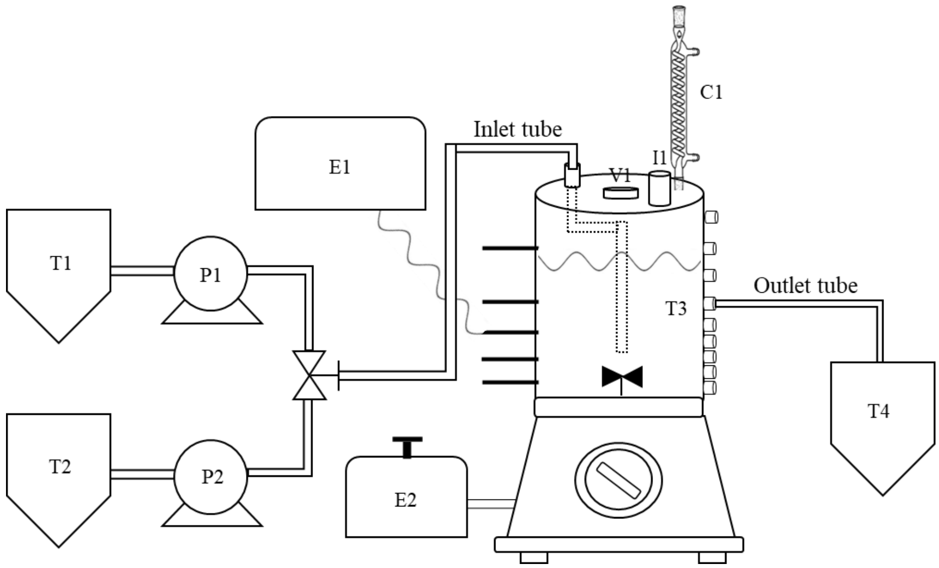


**Fig. S4.** Schematic diagram of continuous FAME production (T1: oil tank, T2: methanol + NaOH tank, T3: chemical reactor, T4: discharge tank, P1: peristaltic pump for oil tank, P2: peristaltic pump for methanol tank, E1: thermocouple reader connected to a thermocouple, E2: variac, V1: viewport, I1: inlet port, C1: condenser)

Fig. S4 shows a schematic diagram of the setup for continuous transesterification aiming for household utilization, so it was kept as simple and as convenient as possible. The oil and the mixture of methanol with dissolved catalyst were co-fed into an inlet port on the lid of the reactor by peristaltic pumps. The fluid temperature in the reactor was measured by thermocouples installed on the side of the reactor. The voltage supplied to the fruit blender was regulated by a variac to control the impeller speed and the reaction temperature. A plug-in power meter was used to measure the instantaneous and accumulation of energy consumption to allow yield efficiency calculation. The liquid mixture naturally discharges from the reactor by overflowing through an open outlet port at the elevation from the bottom of the reactor corresponding to studied volume.

**Determination of fuel properties**

*Density [11]*

The density of the produced FAME was measured in the laboratory corresponding to the ISO 4787 standard at 30°C using a pycnometer. The tests were repeated two times and the average value was reported.

*Kinematic viscosity [11]*

The kinematic viscosity was determined at 40°C through the ASTM D445 standard by means of a viscometer. FAME was heated using a heating tape instead of a water bath, and a falling time of the moving liquid between the two horizontal lines marked on the viscometer tube was measured. The experiments were performed three times for each sample.

*Cloud point*

The cloud point was measured following the ASTM D 2500 [12] standards using Walter Herzog GmbH, Germany equipment.

*Acid value*

The acid value indicates the presence of acidity in FAME determined by the AOCS method by titration. A quantity of 2 g of biodiesel sample was dissolved in 30 mL isopropyl alcohol. The mixture was boiled for 2 min and titrated with a 0.1 N KOH solution with phenolphthalein as a color indicator [13]. Acid value can be evaluated from Eq. (1).

$$\text{Acid value} = \frac{(\mathrm{S}-\mathrm{B}) \times \mathrm{N} \times 56.1}{\text{Weight of sample (g)}} \tag{1}$$

where S is the titrant (KOH) volume used for the sample (mL), B is the titrant volume used for the blank (mL), and N stands for normality of the KOH standard.

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