RESEARCH ARTICLE

Comparative study of trans esterification of *pongamia pinnata* in an oscillatory baffled reactor (obr) & conventional batch reactor

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Manuscript details:

Available online on
http://www.ijlsci.in

ISSN: 2320-964X (Online)
ISSN: 2320-7817 (Print)

Editor: Dr. Chavhan Arvind

Cite this article as:
Ganvir VN, Shende AC and Dube Vinit (2016) Comparative study of trans esterification of *pongamia pinnata* in an oscillatory baffled reactor (obr) & conventional batch reactor, *Int. J. of Life Sciences*, A6:29-32.

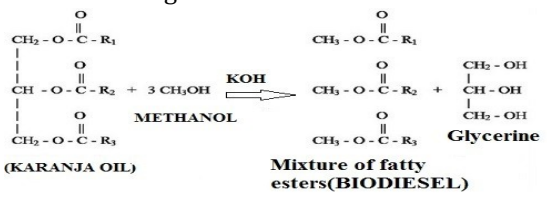
ABSTRACT

The world energy requirement is mainly provided by petroleum products. Its, extensively utilization has led to climate change, environmental pollution, and health problems. To reduce these adverse affects, it is necessary to enhance the use of renewable energy sources. Among many renewable energy sources biodiesel is one such alternate. Biodiesel is produced by trans-esterification where vegetable oils react with alcohol in present of catalyst such as (NaOH, KOH). In India, there are many trees bearing oil like mahua (*madhuca indica*), jatropha, and karanja (*pongamia pinnata*) etc. Among these species, which can yield oil as a source of energy in the biodiesel, *Pongamia pinnata* has been found to be one of the most suitable species. Conventionally, Biodiesel was produced in batch reactor by trans-esterification process and optimum condition were found to be 1:9 oil to methanol ratio, 0.75% w/w KOH base catalyst, and minimum 55-60^{0}c temperature and minimum 1hr reaction time. A Novel reactor oscillatory baffled reactor has been designed and fabricated. The optimum conditions for trans- esterification reaction in OBR were as 1:9 oil to methanol ratio, 0.75% w/w KOH base catalyst, and maximum 10 min reaction time. The different properties of biodiesel were analysed as per ASTM standards.

Keywords: Biodiesel, trans-esterification, *pongamia pinnata*, batch reactor, oscillatory baffled reactor.

INTRODUCTION

The world energy requirement is mainly provided by non renewable resources such as petroleum products, and coal. Since the demand of petroleum based fuel is increasing rapidly, there is need to replace these conventional (non renewable) source of energy with the renewable energy sources. Among many renewable energy sources, biodiesel is one such alternate. Biodiesel is produced by trans-esterification reaction where vegetable oils react with alcohol in present of catalyst such as (NaOH, KOH).
Biodiesel is produced through a trans-esterification reaction as shown below,



Where R_1, R_2, and R_3 are long hydrocarbon chains; sometimes called fatty acid chains.

In this paper, Biodiesel production is carried out in conventional reactor as well as in oscillatory baffled reactor (OBR). Oscillatory baffled reactors are used in biodiesel production, it consisting of tube containing equally spaced orifice plate baffles. An oscillatory motion is superimposed upon the net flow of the process fluid, creating flow patterns conducive to efficient heat and mass transfer, whilst maintaining plug flow. That's why in oscillatory flow reactor the reaction time is less that is 10 minutes at temperature in range of room temperature (20°C-25°C) compared to batch reactor. Batch reactor takes minimum 1 hr and at temperature of about 55°C-60°C for reaction under similar conditions.

Base material for biodiesel: Biodiesel can be produced from vegetable oils or animal fats. Basically, vegetable oil is used for biodiesel production. The reason is that in compared with animal fats, they are easy to use and do not have bad odour. Various raw materials used for biodiesel production are edible oils (such as Soybeans, Cotton seed, Sunflower, etc), non-edible oils (Mahua, Jatropha, Karanja, Neem oil) and Animal fats (Fish oil, Poultry fats, Tallow, Lard).

Karanja oil: Among all these species, which can yield oil as a source of energy in the biodiesel, *Pongamia pinnata* has been found to be one of the most suitable species due to its various favorable attributes like hardly nature, high oil recovery, and quality of oil, etc. The main production area for the Karanja oil is in the village level and villagers use this oil in some of their daily activities. The seed potential of this tree in India is 2, 00,000 tons and oil potential is 55,000 tons. Moreover, *Pongamia pinnata* based methyl esters (biodiesel) can be directly used in diesel engines without any engine modifications.

Table 2: Fatty acid profile of *Pongamia pinnata*

Properties of *Pongamia pinnata*:		
Sr. No.	**Properties**	**Units**
1	Acid value	3.44mg of KOH/gm of oil
2	Viscosity @40°C	11.01 cst
3	Specific gravity @20°C	0.8972
4	Saponification value	143
5	Flash point and Fire point	112 °C and 119 °C

Experimental Procedure:

The trans-esterification reaction of *pongamia pinnata* is carried out in two reactors conventional batch reactor and oscillatory baffled reactor (OBR).

A) Conventional batch reactor:

Process description:

1. Karanja oil is poured into the Reactor (1:9 oil to methanol ratio).
2. The mixture of potassium hydroxide (0.75% w/w) with Methanol is then added into the reactor and the reaction is carried out with continuous stirring.
3. Reaction is continued for 1 hr at 55-60°C.
4. Then Mixture is allowed to settle for 6-8 hours. Two layers are formed. Upper layer is methyl ester with lower acid value and bottom layer is glycerol. The upper layer is washed with water till neutral water is obtained after washing. And then different properties of biodiesel were analysed as per ASTM.

B) Oscillatory baffled reactor (OBR): Apparatus and experimental setup:

Oscillatory baffled reactors are a novel type of reactor, consisting of tubes containing equally spaced orifice plate baffles. These reactors exploit the uniform and efficient vortex mixing that can be achieved when an oscillatory fluid motion interacts with orifice plate baffles in a tube. Effective and energy efficient heat transfer can be obtained by oscillatory flow mixing for both the batch fluid oscillation situation and for the batch baffle oscillation, due to the mechanisms of vortex interaction. The Oscillatory baffled reactor is schematically shown below.

The mechanism of mixing in the OBR is illustrated which shows two half cycles over an oscillation period. Vortices are formed behind baffles on an upstroke, drawing fluid from near the walls into the eddies. On the reverse stroke, the vortices formed are pushed into the central region of the device while new vortices are generated at the same time behind the opposite baffles, and the cycle repeats. The mechanism of mixing in OBR generated at the same time behind the opposite baffles, and the cycle repeats. The mechanism of mixing in OBR is shown below:

Characteristics of biodiesel:

Fatty Acid	**Formula**	**Structure**	**Wt %**
Palmitic	$C_{16}H_{32}O_2$	16:0	3.7-7.9
Stearic	$C_{18}H_{36}O_2$	18:0	2.4-8.9
Arachidic	$C_{20}H_{40}O_2$	20:0	1.1-3.5
Oleic	$C_{18}H_{34}O_2$	18:1	44.5-71.3
Linoleic	$C_{18}H_{32}O_2$	18:2	10.8-18.3

Process description:

1. Karanja oil is poured into the Reactor (1:9 oil to methanol ratio).2.
2. The mixture of potassium hydroxide (0.75% w/w) with Methanol is then added into the reactor and the reaction is carried out with continuous stirring.
3. Reaction is continued for 10min at room temperature (25^{0}C).
4. Then Mixture is allowed to settle for 6-8 hours. Two layers are formed. Upper layer is methyl ester with lower acid value and bottom layer is glycerol. The upper layer is washed with water till neutral water is obtained after washing. And different properties of biodiesel were analysed as per ASTM.

The fuel properties namely, density, kinematic viscosity at 400 C, flash point, pour point, cloud point, acid value and of *Pongamia pinnata* (Karanja oil) and karanja oil methyl ester were determined in the laboratory, which is summarized in Table 3. It can be seen that Karanja oil methyl ester (biodiesel) had comparable fuel properties with those of diesel and was within the Limits prescribed in the latest standards for biodiesel.

RESULT AND DISCUSSION

The effect of various parameters like oil to methanol ratio, concentration of catalyst, reaction time, and temperature on quantity of biodiesel produced in both conventional batch reactor and Oscillatory baffled reactor is as follows.

1) Effect of catalyst concentration on yield of biodiesel

From the figure given below, it is clear that yield of biodiesel in Oscillatory baffled reactor is more as compared to yield of biodiesel in conventional batch reactor.

2) Effect of Reaction temperature on yield of biodiesel:

It is seen that the yield of biodiesel in Oscillatory baffled reactor is independent of temperature where as conventional batch reactor the yield of biodiesel varies widely with temperature as shown:

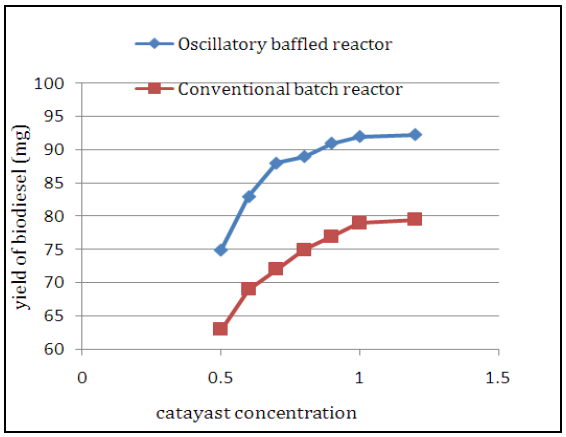


Fig 1: Effect of catalyst concentration on yield of biodiesel in OBR and conventional batch reactor

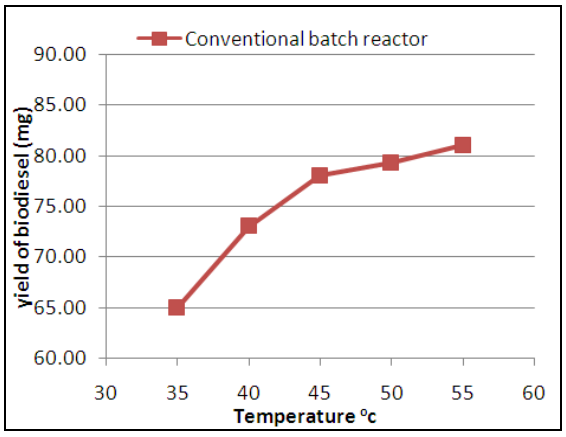
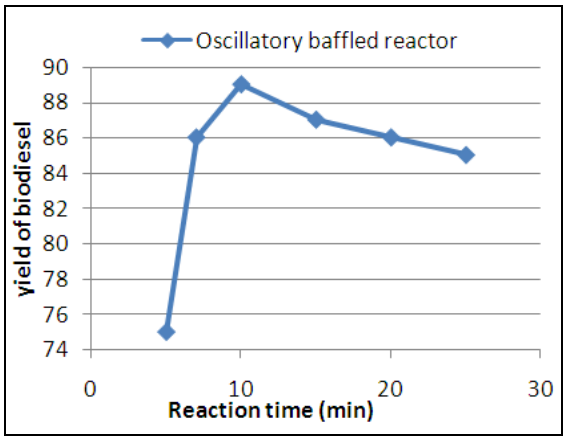


Fig 2: Effect of temperature on yield of biodiesel in conventional batch reactor



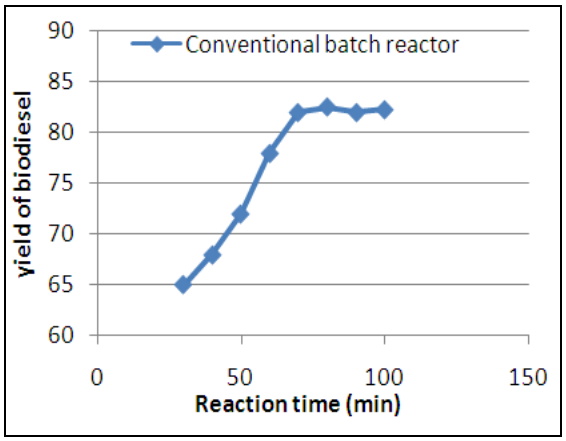


Fig 3: Effect of reaction time on yield of biodiesel in OBR and conventional batch reactor

3) Effect of Reaction time and molar ratio on yield of biodiesel:

These two parameters have the same effect on yield of biodiesel in Oscillatory baffled reactor and conventional batch reactor. But the reaction time for OBR is 10 min & for conventional batch reactor is 1hr minimum. And the nature of curve for OBR & conventional batch reactor is same.

CONCLUSIONS

From the above discussion, the optimum condition for oscillatory baffled reactor and conventional batch reactor were obtained. The optimum condition for conventional batch reactor is 1:9 oil to methanol ratio, 0.75% w/w KOH base catalyst, and minimum 55-60^{0}c temperature and minimum 1hr reaction time. The optimum conditions for Oscillatory baffled reactor (OBR) is 1:9 oil to methanol ratio, 0.75% w/w KOH base catalyst, and maximum 10 min reaction time. Thus, Oscillatory baffled reactor requires less energy and less time as compared to conventional batch reactor. So, Oscillatory baffled reactor can be used as an efficient way for energy and time saving if used in industrial practice.

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