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**Research article**

# PRODUCTION OF BIODIESEL FROM JATROPHA OIL USING CONTINUOUS OSCILLATORY BAFFED REACTOR ARRANGEMENT AND HOMOGENEOUS CATALYST.

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## ABSTRACT

The purpose of this work is to investigate the effects of process variables such as Methanol-oil ratio, Residence time, Temperature of reaction and catalyst concentration on the transesterification of Jatropha oil to biodiesel using a homogenous catalyst (Sodium Hydroxide) in a continuous oscillatory baffled reactor system. The maximum conversion of Jatropha oil was 94% at a temperature of 50$^{o}$C, Methanol-oil ratio of 6:1, and reaction time of 5minutes and catalyst concentration (catalyst/oil) of 1% wt%.

**Keywords**: COBRA, Biodiesel Yield, Jatropha oil, homogenous catalyst

## INTRODUCTION

Biodiesel is composed of esters produced from long-chain fatty acids and alcohol ( Bugaje and Mohammed, 2007). It is produced through the transesterification reaction of vegetable oil with methyl alcohol or ethyl alcohol in the presence of a base or acid catalyst. Chemically, biodiesel is called methyl ester if the alcohol used is methanol. Biodiesel has a great potential as an alternative diesel fuel. Its fuel properties are quite similar to those of conventional diesel fuels (Bugaje 2006; Noureddini and Zhu, 1997; Kavitha, 2003).

Jathropha oil is produced from Jatropha curcas seed through extraction process. The seeds of the nut are a good source of oil, which can be used as a diesel substitute ( Chhetri et al., 2008).

Mixing is at the heart of chemical and pharmaceutical industry as it dominates the consideration of heat/mass transfer, reaction performance and product uniformity (Anh et al., 2011). Engineers often require reactors with well defined residence times and good fluid mixing, and seek devices which exhibit close to plug flow behaviour (Reis et al., 2006). To achieve plug flow, continuous system must be used, e.g. continuous stirred tank reactors (CSTR) (Levenspiel, 1999). In theory when the number of CSTR goes to infinite, plug flow is attained. Such operations mean high capital and running costs. Tubular reactor is one of the alternatives to the CSTR. However near to plug flow can only be obtained in tubular reactors at turbulent flows, i.e. very high flow rates, this means that very long tube length is necessary even to accommodate a short reaction time of 15 minutes, severely compromising the viability of such an operation (Darnoko and Chergen, 2000). In contrast, the continuous oscillatory baffled reactor arrangement (COBRA) is a tubular reactor that decouples mixing from net flow, thus provides plug flow under laminar flow conditions (Mackley, 1991). The COBRA consists of periodically spaced orifice baffles along the length of the tubular reactor that is superimposed with a reversing oscillatory component, giving both high fluid mixing and narrow residence time distributions. The formation and dissipation of eddies in the oscillatory baffled flow result in significant enhancement in processes, such as heat transfer, mass transfer, particle suspension, polymerisation, flocculation and crystallisation (Anh and Harvey, 2010; Stephen and Mackley ,2002).

Oscillatory flow baffled tubes has been studied for many years and much work have been done in areas related to fluid dynamics heat and mass transfer and residence time distribution ( Takriff and Masyithah, 2002; Stonestreet and Mackley, 2002). Many advantages have been characterized for oscillatory flow mixing such as efficient dispersion for immiscible fluids, uniform particle suspension, gas-in-liquid dispersions and multiphase mixing ( Roberts and Mackley, 1995 and Palma and Giudici, 2003). Recent researchers have indicated that oscillatory flow in a baffled tube has significant potential for process and product enhancement in a wide range of application (Adam et al., 2003;). Hence, the aim of this work is to determine the biodiesel yield from continuous oscillatory baffled reactor arrangement using homogenous catalyst (Sodium Hydroxide solution).

## EXPERIMENTAL METHODS

The biodiesel yield was determined from the transesterification reaction of Jatropha oil in the COBRA at different factors that affect the reaction such as catalyst concentration, temperature, oil-methanol ratio, mean residence time and frequency of oscillation.

## Experimental Materials

Refined Jatropha oil (NARICT) with a density and viscosity of 914 kg/m$^3$ and 31.2mm$^2$/s at 60$^o$C respectively was used as a source of triglyceride. The Methanol and Sodium Hydroxide (NaOH) used are of analytical grades (Sigma –Aldrich).

## Experimental Equipment

The continuous oscillatory baffled reactor arrangement that was utilized in this work as shown in Figure1 was designed and constructed in the department of Chemical Engineering University of Maiduguri, Nigeria. The device consisted of two vertically positioned jacketed stainless steel tubes of 1.4 m length and 0.1 m internal diameter, connected at the top by an inverted U-tube, fitted with manually operated purge valve of 0.21 m length. The overall internal volume of the reactor was 2.41x10$^{-2}$ m$^3$. A series of orifice type stainless steel baffles with a diameter 0.05 m and baffle spacing of 0.15 m were welded to the tube wall. The baffle spacing was 1.5 times the tube diameter as suggested in literature to achieve effective mixing over broad range of oscillation amplitudes and frequencies [4]. Both ends of the tubes were attached to an oscillation unit that consists of a pair of pistons. Pneumatically driven pistons that work in a push and pull sequence were used to oscillate the fluid within the COBRA at a frequency range of 1.0 to 10 Hz. Reactor temperature was maintained by a Haake F6/B5 heater /circulator unit. The net flow was provided by a liquid pumps from the feed vessels (Tank$_1$ with stirrer for Methanol/Catalyst and Tank$_2$ for oil) using a twin-headed positive displacement metering pumps of 0.5 hp and the flow rates were monitored by flow meters. Temperatures were maintained in the feed vessels and supply lines by Eurotherm temperature controllers, regulating the output to the hotplates beneath the feed vessels and the tapes around the supply lines respectively.


**Figure 1:** Continuous Oscillatory Baffled Reactor Arrangement (COBRA)

## RESULTS AND DISCUSSIONS

Stoichiometrically, the methanolysis of Jatropha oil requires three moles of methanol for each mole of oil.
Since, transesterification of triglycerides is reversible reaction; excess methanol is required to shift the equilibrium towards the direction of ester formation. As can be seen from Figure 2**,** the maximum conversion was achieved at methanol to oil molar ratio 6:1. It is comparable to the work carried out by Hanny and Shizuko. (2008) obtained 90% conversion using methanol as an alcohol with triolein oil to alcohol molar ratio of 1:6 and KOH as a catalyst. Hanny and Shizuko (2008) have obtained above 98% yield using 1:9 Jatropha oil to methanol molar ratio and heterogeneous solid catalyst used was Na/SiO2. Present study shows that with molar ratio of methanol to oil ratio of 6:1, maximum conversion was achieved in 5 minutes only and after that it almost a constant over an extended reaction time. Molar ration of 3:1 and 9:1 are not showing good results. One of the reasons for the same may be the predominance of esterification reaction at the initial phase, to transesterify the FFA present in the Jatropha oil, of transesterification which can consume methanol present in the reaction mixture and hence, the amount of methanol available for transesterification may not be sufficient to drive the reaction forward for longer time.
Figure 3 shows the conversion versus reaction time at different temperatures. It could be seen from the plot that the conversion increased in the reaction time range of 1 to 5 minutes with the increase in temperature, and there after remained nearly constant as a representative of a nearby equilibrium conversion. The nearly equilibrium conversion was found to be about 94% at 5 minutes of reaction time.
Effect of variation of amount of catalyst on conversion was also studied. Catalyst amount was varied in the range of 1% to 5% (wt/wt of the oil taken). As shown in Figure 3, the conversion increased firstly with the increase of catalyst amount from 1% to 2.5%. But, with further increase in the catalyst amount from 2.5% to 5%, the conversion decreased due to soap formation.

 

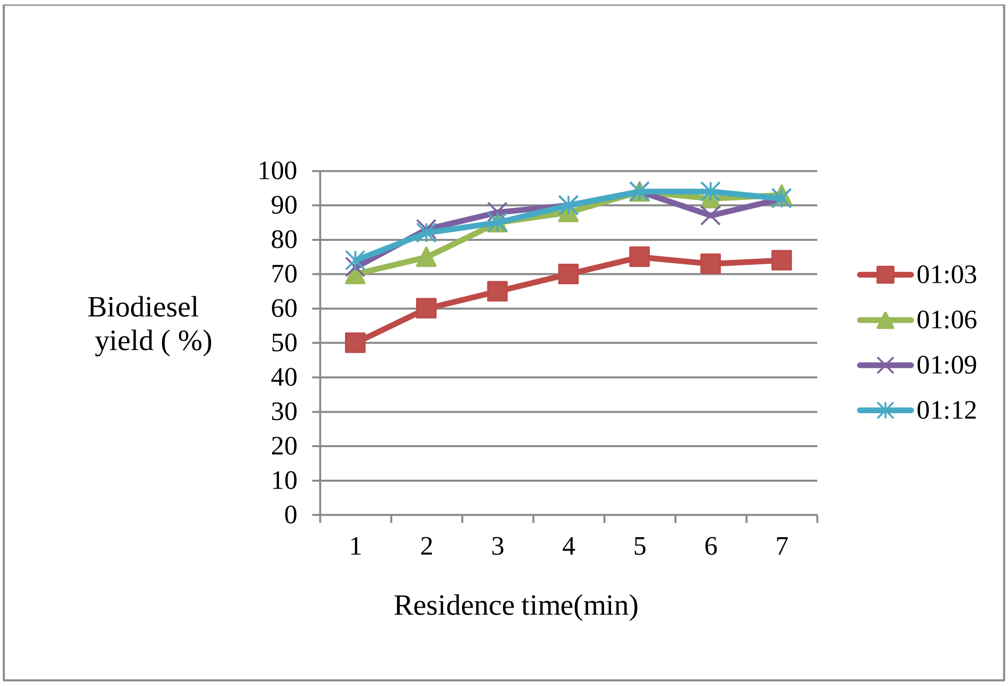


**Figure 2:** Effect residence time on biodiesel Yield at different oil to methanol molar ratio at 323K

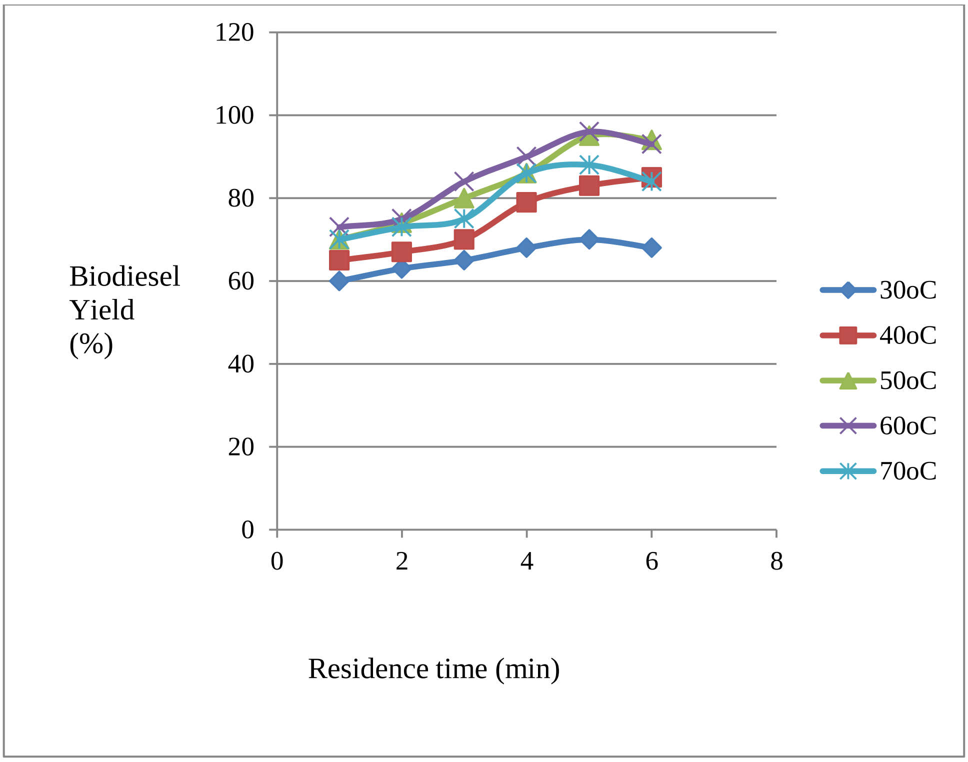


**Figure 3:** Effect of Residence time and Temperature on Biodiesel Yield from Jatropha oil Continuous oscillatory baffled reactor

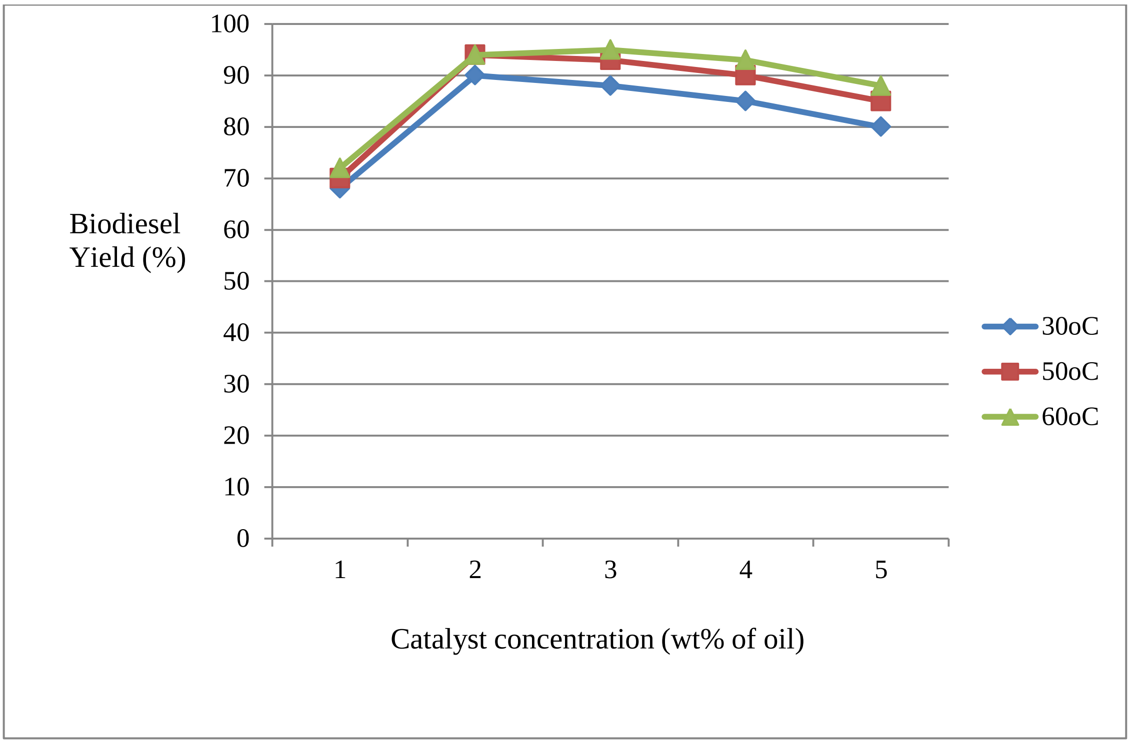


**Figure 4:** Effect of catalyst concentration on Biodiesel Yield from Jatropha oil At different temperatures in continuous oscillatory baffled reactor

## CONCLUSIONS

The transesterification of Jatropha oil in a continuous reactor system was found to be promising by reducing the time of reaction to 5 minutes when compared with the time of reaction of 30 minutes while using batch reactor system (Amish et al, 2011). At methanol to oil ratio of 6:1, temperature of 50oC, reaction time of 5 minutes and catalyst concentration of 2%wt% of oil, the maximum conversion of Jatropha oil was found to be 94%.

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