Hetero-Sonic Methanolysis of Palm Kernel Oil To Produce Biodiesel Fuel

H. O Boyo[1], O. T. Ogundipe[2], A. O. Boyo[3], L. A. Adams[4], N. N. Okwara[5]
[1,5]Hardware Development Laboratory, Department of Physics, University of Lagos
[2]Molecular Systematic Laboratory, Department of Botany, University of Lagos
[3]Department of Physics, Lagos State University, Ojo, Lagos
[4]Department of Chemistry, Faculty of Science, University of Lagos

ABSTRACT

The valuable oil obtained from the kernel of the African oil palm, Elaeis guineensis was used for the production of biodiesel fuel (BDF). A prototype production plant based on hetero-sonic agitation was designed, fabricated and tested in the Hardware Development Laboratory. The produced plant was used to investigate the effect of hetero-sonic mixing on the methanolysis of palm kernel oil (PKO) in comparison to its absence in the conventional catalysis method. The susceptibility of commercial stocks of PKO to mesophilic and thermophilic fungi was investigated at the Molecular Systematic Laboratory. Its effect on the breakdown of PKO into free fatty acid (FFA) resulting into unpredictable quality of produced BDF was also investigated. Results showed that; Acoustic cavitations condition created by hetero-sonic agitation produced high speed mixing and mass transfer between methanol and oil. The net effect was a higher yield of biodiesel fuel within a shorter time frame. It proved to reduce the transesterification time. Rancidity of Palm kernel oil was facilitated by moisture, light exposure and atmospheric oxygen resulting to changes in odour and pH. Due to the biodegradation conditions, a pH change of $5 \pm 10\%$ was observed on a 3 month average storage at the University of Lagos. This project provides the clue for sustainable and economic growth of the Nigerian energy sector which requires; a stock pile preservation of raw materials (PKO) and fast production plant (hetero-sonic mixer) to meet potential market quality and demands.

KEYWORDS: *Hetero-sonic Agitator (HA), Acoustic Spectral Control (ASC), virtual instrument (VI), Biodegradation, Biodiesel fuel (BDF).*

1. INTRODUCTION

1.1 IMPORTANCE

Biodiesel fuel (BDF) is a biodegradable and non-polluting fuel which has proved to be eco-friendly far more than fossil fuels. Biodiesel fuel made from natural ingredients is much better for the environment "reduces green house effect" since it produces fewer carbon emissions than conventional diesel fuel (FDF), the major contributor to global warming by about 75%. It also produces very little sulfur when burned, thereby reducing the risk of acid rain [1]. In Nigeria the use of fossil diesel fuel engines for domestic and industrial generation of electricity or automobiles could result to environmental issues, concerned with the exhaust gases emission. One big advantage is that BDF can favorably replace FDF since it can be used in any diesel engine [4] without modification.

1.2 PRODUCTION TIME

Making biodiesel is a complicated and time consuming process [3] which makes it necessary for the study of the production process based on the raw materials, palm kernel oil (PKO), lye (NaOH) and methanol (CH_3OH) to optimize production time and reduce cost. The convectional (batch) production process of making BDF is quite slow and phase separation of the glycerin is time-consuming, often takes eighteen (18) hours or more. It involves mixing oil with an alcohol, usually methanol (CH_3OH) or ethanol (C_2H_5OH) and an alkali catalyst. A reduction in production time would translate to a relative reduction in the end cost of BDF. It was shown that ultrasonic agitation reduces production time by ninety seven point five percent (97.5%) thus favoring continuous production process. In the ultrasonic production process; ultrasonic waves cause the reaction mixture to produce and collapse bubbles constantly. This phenomenon is termed acoustic cavitations which mimics simultaneously the mixing and heating required to carry out transesterification process [5].

1.3 STORAGE

There has also been a report of involvement of microbial activity in the break down of PKO into free fatty acids [2]. In Nigeria today we continue to enjoy subside in fossil fuel prices with rocket shoot-up prices during scarcity. To ensure reasonable price stability for BDF, so as not to be subjected to unexpected shortage, we need long term storage of raw material. Specific to this project, Palm kernel oil (PKO) is the raw material which displays 3rd order biotic activity. It belongs to the class of goods in which respiration processes are suspended, but in which biochemical, microbial and other decomposition processes still proceed. Oils and fats spoil by readily becoming rancid. Rancidity is promoted by light, atmospheric oxygen and moisture and leads to changes in odor, pH, and taste. The acid value of oil may be used as a measure of quality. The high acid value of the oil denotes an excessively high content of free fatty acids, which causes the oil to turn sour. Discoloration may also occur.

1.4 CHALLANGES

More challenging is to determine suitable acoustic frequencies and amplitudes necessary to facilitate fast production of BDF. It would require designing a reactor tank capable of producing such waves and a spectral display of the same signals. This project aims to fabricate the mentioned equipment using locally sourced materials. We hope that a reduction in production time would translate to a relative reduction in the end cost of BDF; even if complete reduction cannot be attained a possible mixture of both BDF and FFD could reduce the environmental consequences of using only fossil fuel. In the near future, we also intend to evaluate the production potential for other non edible oils.

II. MATERIALS AND METHOD

Materials used include;

- palm kernel oil (PKO), Lye (NaOH) and Methanol (CH_3OH)
- Hetero-sonic mixer (designed and constructed)
- Laptop Computer configured as a Virtual Instrument

The hetero-sonic mixer and agitator were constructed with tunable acoustic frequencies between 5 KHz and 45 KHz (Figure 1A and 1B). A Virtual Instrument was built into a laptop using its sound card and associated transducers as a spectrum analyzer. The sound spectrum code was developed on a National Instruments LabView G-programming platform. For a start palm kernel oil (PKO) mixed in the alcohol (with base catalyst NaOH) was separated into two equal halves, one is left to separate naturally (conventional method) and the other half was sonicated with the built hetero-sonic mixer. The virtual instrument spectrum analyzer was used to tune the sonicator to the same frequency peaks and spectral power (Figure 2). Colour changes during the chemical reactions (transesterification) and total BDF produced were used to identify how the reaction progressed. Colonizing microbes were isolated from the PKO using relevant media. This was done using fresh and three month stored PKO. The effect of the Palm kernel oil on the growth of some thermophilic and mesophilic microbes was also investigated *in vivo* as described by Adekunle and Ozonweke (2001).

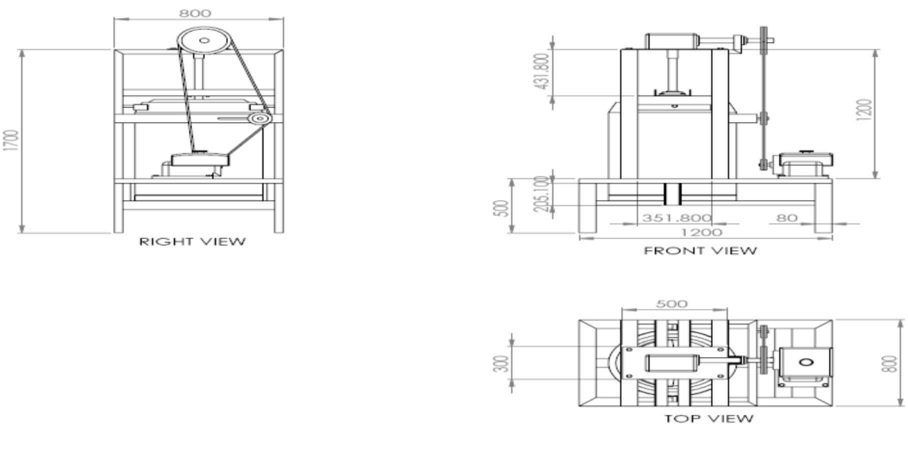


Figure 1A: Projections of the heterosonic mixer.

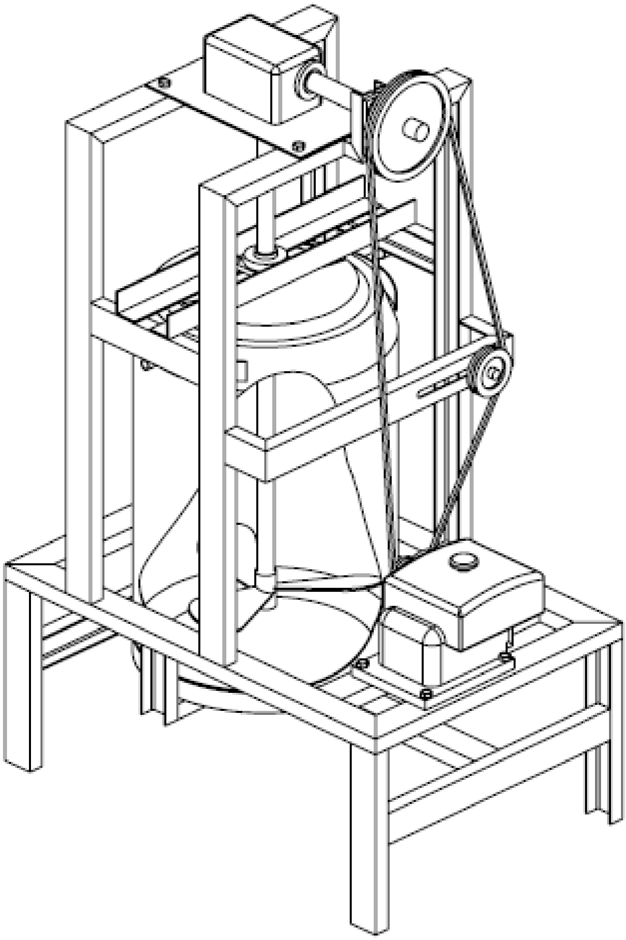


Figure 1B: Isometric view of the heterosonic mixer.

III. THEORY

Multiple frequency waves are generated using the built Hetero-sonic mixer. The spectral waves with characteristic frequencies cause the reaction mixture, to produce and collapse bubbles constantly. These cavitations provided simultaneously the mixing and heating required accelerating the transesterification process [5]. Production can be maximized by determining the appropriate frequencies where the peak power resides. Its location is aided with the built Power Spectrum Analyzer and tunable hetero-sonic mixer. The Virtual Instrument codes are based on the Fast Fourier transform and Lomb's periodogram. Since the sampler is software based, it is subjected to uneven sampling space due to priority interrupts from the Laptop microprocessor. The Lomb's periodogram defined as below yields an approximate Power spectrum.

$$P_N(\omega) = \frac{1}{2S^2}\left\{\frac{\left[\sum(h_j-\bar{h})\cos\omega(t_j-t)\right]^2}{\sum cos^2\omega(t_j-t)} + \frac{\left[\sum(h_j-\bar{h})\sin\omega(t_j-t)\right]^2}{\sum sin^2\omega(t_j-t)}\right\}$$

$$\tan 2\omega t = \frac{\sum \sin 2\omega t_j}{\sum \cos 2\omega t_j}$$

Where

$$\bar{h} = \frac{1}{N}\sum h_j,\quad s^2 = \frac{1}{N-1}\sum\left(h_j-\bar{h}\right)^2, \omega = 2\pi f$$

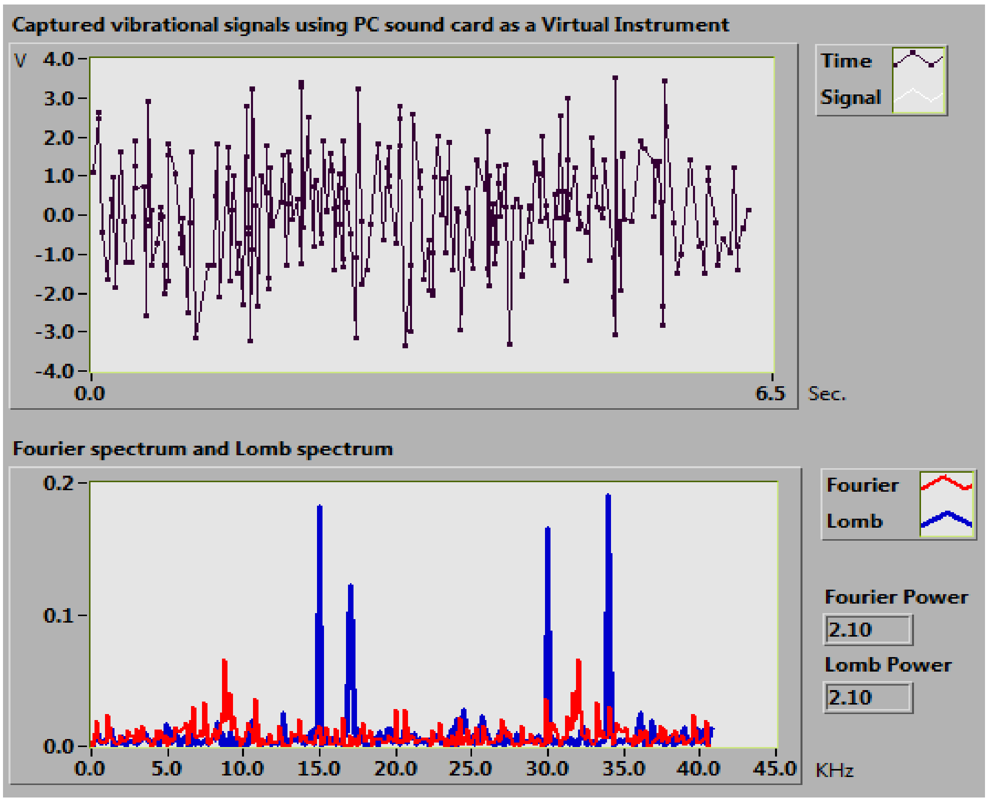
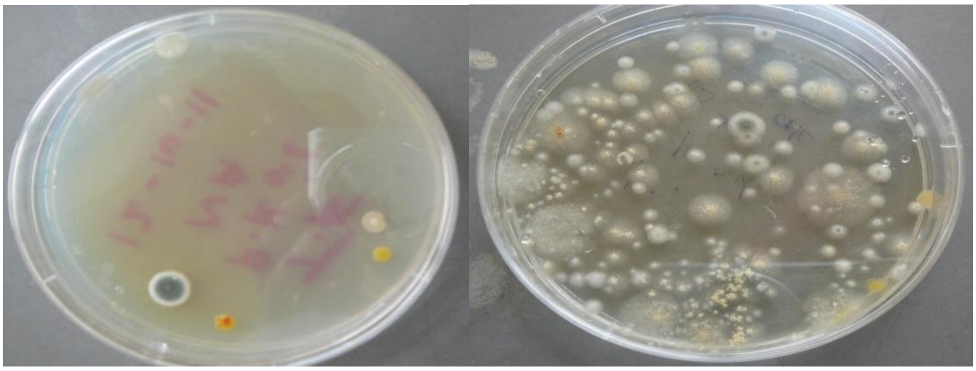


Figure 2: The spectrogram to peak the power for cavitation frequencies with a virtual instrument.

IV. RESULTS

Results by relative colour changes in the reaction of sonicating the transesterifcation process appears completed compared to the conventional (without sonication). The hetero-sonic waves agitated the alcoxy solution mixed with oil which resulted in cavitations, thereby increasing the mixing ratio of the two liquids; consequently the time for transesterification was drastically reduced to 30 minutes as we found the BDF golden-yellowish floating on top the creamy yellow glycerol after 30 minutes.It was also observed that when the hetero-sonic irradiation power or spectral power was reduced by half, the transesterification time extended from thirty minutes (30 min.) to one hour (1 hr.). It is therefore evident that the processing and separation time is related to the effect of sonification. Hetero-sonic agitations reduce the processing time and the separation time significantly to achieve a biodiesel yield in excess of 98.1%.More microbial growth were observed (figure 3) in the cultured three month stored PKO as compared to the fresh PKO (30-300 and 7 respectively). PKO was found to preferentially promote the cultured mesophilic fungi (*Aspergillus flavus*, *Aspergillus niger*) as compared to the thermophilic fungi (*Penicillium spp*, *Aspergillus terreus*) as seen in table 1.



A B

Figure 3: A- isolated microbes from fresh PKO, B- isolated microbes from 3 months stored PKO.

Table 1: shows effect of PKO on the growth of some fungi.

	THERMOPHILE						**MESOPHILE**					
	Penicillium spp			***Aspergillus terreus***			***Aspergillus flavus***			***Aspergillus niger***		
	24hrs	48hrs	72hrs	24hrs	48hrs	72hrs	24hrs	48hrs	72hrs	24hrs	48hrs	72hrs
PDA with oil 1	00 00	10 05	12 07	00 00	08 05	10 08	10 10	12 12	14 14	14 13	18 16	22 20
PDA with oil 2	00 00	10 05	12 07	00 00	08 05	10 08	10 10	12 12	14 14	14 12	18 15	22 28
PDA with oil 3	00 00	10 05	12 07	00 00	08 05	10 08	10 10	12 12	14 14	14 12	18 16	22 19
PDA without oil 1	11 08	13 10	15 12	08 06	11 08	14 11	12 10	16 14	20 18	10 08	12 10	14 12
PDA without oil 2	10 08	12 10	14 12	08 06	11 08	14 11	12 10	16 14	20 18	10 08	12 10	14 12
PDA without oil 3	11 09	13 11	15 12	08 06	11 08	14 11	12 10	16 14	20 18	10 08	12 10	14 12

IV. DISCUSSION

Thus the effect of using an ultrasonic agitator for biodiesel production drastically reduces the reaction time, reaction temperatures, and energy input. Hence the process of transesterification can run continuously inline rather than using the time consuming batch process convectional method. An estimated production cost is ₦250 Naira per liter of BDF using the hetero-sonic agitator relative to ₦145 Naira per liter of FDF. While the conventional BDF production still stands at ₦400 Naira per liter.

V. CONCLUSION

In this project we have constructed (Figure 4) a Hetero-sonic Agitator (HA) with Acoustic Spectral Control (ASC) virtual instrument (VI) and used it to catalyze the production of Biodiesel fuel (BDF). We also showed that Ultrasonic agitation reduced the production time by 98.1 % which favors continuous production line. It therefore proved to be a promising and an effective method for industrial production of fatty acid methyl esters (FAME). The 98.1% reduction in production time compared to 18hours with the conventional production process translates to reduced cost and economic advantages.

Figure 4: The Hetero-sonic Agitator (HA) with Acoustic Spectral Control (ASC).

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