



# Extraction and Use of Potassium Hydroxide from Ripe Plantain Peels Ash for Biodiesel Production

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The extraction of the ash of ripe plantain peels to obtain potassium hydroxide (KOH) and its application in the trans-esterification of refined rapeseed and crude jatropha oils have been investigated. At 30 °C, extraction time 1 hr and volume of 5, 7.5 and 10 ml/g ash, the percentage recovery of KOH progressively increased in the first stage, from 26.05 to 26.20 and then to 30.75% respectively, but decreased in the second stage (extraction of the spent ash from stage 1), from 2.20 to 2.10 and to 1.90% respectively. Same trend was also observed at 40 and 50 °C but cumulatively, KOH values recovered increased relatively with increasing extraction time and temperature. The percentage cumulative recovery of KOH was 40.10% at extracting temperature of 50 °C, extracting volumes 10 ml/g ash and extraction time of 3 hrs while it was 40.00% at 50 °C, 10 ml/g ash and 2 hrs extraction time. The least percentage cumulative recovery of KOH was 28.25% at 30 °C with 5 ml extracting volume/g ash and 1 hr extraction time. The percentage purity of the extracted KOH gave 80.0%. The trans-esterification of the two vegetable oils showed the percentage conversion obtained with rapeseed oil was 71.01% using 1 g of KOH extract from ripe plantain peels ash at reaction temperature and time of 75 °C and 4 hours respectively. Under the same reaction conditions, 1 g of commercial caustic potash recorded 70.06% conversion of the rapeseed oil. From the optimized batch process, 97.15% conversion was achieved with crude jatropha oil using 1 g caustic potash extract from ripe plantain peels ash; at reaction temperature and time of 83 °C and 4 hours respectively.

**Keywords:** Biodiesel, Extraction, Potassium Hydroxide, Plantain Ash.

## 1. INTRODUCTION

About 70% of sub-Saharan African population are rural dwellers and biomass derived energy is the major source of energy used by these rural dwellers. The lack of chemical plants for the manufacture of simple chemicals such as NaOH or KOH in most sub-Saharan African countries leads to high cost of imported chemicals making them less readily available to the rural poor. A need exists for efficient use of renewable biomass resources including biomass wastes as a feedstock to produce heat and chemicals especially for the rural dwellers in sub-Saharan Africa.

Bananas and plantains are considered to be amongst the most abundant fruit crop in the world. The world production is estimated to be 28 million tons, in which Africa alone produces about 9 million tons of bananas annually.<sup>1</sup> This huge production figures give one an indication of the

large kitchen wastes that would be generated the world over in plantain and banana peels Potassium is the most abundant mineral in plantain peels with an estimated value of 37 g kg<sup>-1</sup> in the green peel.<sup>2-4</sup> This value is increased by a small amount during the ripening process.<sup>5</sup> Potash alkali and metal contents of ashes obtained from plantain peels have been investigated by a number of researchers<sup>6</sup> and showed that the alkali content of the ash ranged from 69 to 81.9% and the analyzed potassium concentration in the peels gave as high as 750 mg/kg.<sup>6</sup>

Combustion is the main process for using biomass energy directly<sup>7,8</sup> with resultant production of ash by-products. The combustion of biomass produces ash from where potassium oxide may be extracted.<sup>9,10</sup> The plantain peel or biomass is burned in a very hot fire to make very white ash. In this way, all of the potassium salts is converted to potassium oxide<sup>10</sup> which is a lot cheaper than the commercial KOH. It has been observed that the ash-derived potash gives a promising future as a sustainable source of raw material for potash-based industries.<sup>6</sup>

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Potash has found world-wide domestic and commercial applications in the pulp and paper, flat glass and chemicals industries.<sup>11</sup> The potash from plantain peels is used for local (black) soap production<sup>12</sup> and traditionally used as a cleansing agent. From the available literature, information is lacking on the application of potash extracts from biomass sources for biodiesel production. This is in spite of the fact that base catalyzed biodiesel processes are more predominantly used in commercial productions.<sup>13</sup> It is also true that edible vegetable oils from oil palm, soybean, and canola have been used for biodiesel production in different countries which have proven to be good substitutes for petro-diesel.<sup>14,15</sup> However, a major setback in the commercialization of biodiesel production in developing countries from edible vegetable oils is their high production cost, which is due to the high demand for human consumption of such oils. Reducing the cost of the feedstock is therefore, necessary for biodiesel's long-term commercial viability. One other way to reduce the cost of biodiesel production in rural Africa, in addition to using cheaper KOH from biomass sources, is to use less expensive feed stocks—such as the use of non-edible plant oils.<sup>14–16</sup> *Jatropha* oil is one example of non-edible oilseed crops<sup>17,18</sup> that can be used in the production of biodiesel.

Hence, the present work is aimed at using renewable biomass wastes (plantain peels) as a feedstock to produce heat and chemicals (potassium oxide) for biodiesel production. In the production of biodiesel, *jatropha* oil was trans-esterified using ethyl alcohol in the presence of the extracted KOH from plantain peels as catalyst. This work is an attempt to set a bench mark by using KOH from renewable locally sourced biomass materials (plantain peels) and non-edible oil (*jatropha*) for future biodiesel production in our rural areas. Potassium hydroxide thus obtained would help to reduce over-dependence on the commercial potassium hydroxide which most times is very difficult to come by especially in rural areas where it is needed to produce soap, biodiesel and other household uses. Results are reported on the feasibility of using an all local renewable resources for biodiesel production.

## 2. EXPERIMENTAL PROCEDURES

### 2.1. Apparatus/Equipment

Analysis of the biodiesel was done using the Proton Nuclear Magnetic Resonance (<sup>1</sup>HNMR) at the FAMU-FSU Tallahassee, Florida. All the glassware used were Pyrex product. They include a 3-neck flat bottom flask mounted on a hot plate magnetic stirrer (Thermo Scientific, SP 131015 IOWA, USA). To it were attached a reflux condenser and a quick fit 0–250 °C thermometer. The third opening on the flask served as raw materials charging port. The set up was used for all the trans-esterification reactions. For the KOH extraction from the ash of ripe plantain peels, 500 ml beakers, 250 ml Erlenmeyer flasks, 50 ml burette, 25 ml pipettes, 500 ml volumetric flasks, 500 ml

separating funnels 1 liter stainless steel cups, hot plate magnetic stirrer (Thermo Scientific, SP 131015 IOWA, USA), glass thermometer (0–100 °C) and retort stands were used.

### 2.2. Materials

The biomass wastes-plantain peels used were obtained from the Covenant University Cafeteria in Ota, crude *jatropha* oil purchased from Obeka Engineering Company in Kaduna State, Nigeria. Potassium hydroxide (>85% purity, Sigma Aldrich analyzed) and ethanol (absolute, Sigma Aldrich analyzed) were used. Refined rapeseed oil purchased from a vegetable oil importer—Justrite, Ota, Ogun State, Nigeria, de-mineralized water obtained from Elga B114 (UK) de-ionizer, filter papers (125 mm diameter, Whatman) and pH papers (1–14).

### 2.3. Preparation of Ripe Plantain Peels Ash

The samples (ripe plantain peels) were first sun dried until they became easily combustible. The samples were then burnt in an air-rich and specially constructed local stove. The stove helps to trap and prevents the ash from being blown off by air current. The ash obtained were respectively collected and stored in two clearly labeled polythene bags for the various extraction processes carried out.

### 2.4. Extraction of Potassium Hydroxide (KOH) from Ripe Plantain Peels Ash

Recovery of potassium oxide (K<sub>2</sub>O) in its hydrated form (KOH) from the ash sample was done in two stages. In experiment 1 (first stage), 20 g each of the plantain ash sample was weighed and thoroughly mixed with the required volume (10, 7.5 and 5 ml/g ash respectively) of mineral free-water in 500 ml beakers. The container with its mixture was then placed on a hot plate magnetic stirrer, kept under stirring and heating to the required temperature (30, 40 and 50 °C respectively) for the required time (1, 2 and 3 hrs respectively). The resultant solution was then filtered using filter paper and stored. Then in experiment 2 (or the second stage), the residue from experiment 1 was further extracted under the same conditions as in stage 1. The resultant solution was again filtered. After the 2nd stage, the solution from the residue tested neutral or almost neutral to pH paper. The filtrates from the two stages were collected respectively in two separate stainless steel containers and evaporated to dryness. The dried sample was collected, weighed and bottled in a plastic container. The percentage of KOH recovered was calculated using the formula

$$\% \text{ KOH recovered} = \frac{\text{weight of KOH recovered}}{\text{weight of ash extracted}} \times 100 \quad (1)$$

KOH samples obtained were stored in a single plastic container from where the quantity required was weighed for analysis and used for biodiesel production.

## 2.5. Analysis of Carbonate and Hydroxide Content in the Crude Potash

The double indicator method<sup>19</sup> was used for the analysis. The percentage content of the potassium hydroxide and carbonate were determined using Eqs. (2) and (3) described below.

$$\% \text{ KOH} = \frac{0.56x}{0.56x + 0.69y} \times 100 \quad (2)$$

$$\% \text{ K}_2\text{CO}_3 = \frac{0.56y}{0.56x + 0.69y} \times 100 \quad (3)$$

Where  $x$  is the average titre value for the neutralization of KOH and  $y$  is the average titre value for the neutralization of potassium carbonate.<sup>19</sup>

## 2.6. Biodiesel Production

Biodiesel, using refined rapeseed oil, ethanol (absolute) and pure potassium hydroxide (catalyst) dissolved in the ethanol, was first produced. This served as the control. Here, 50 g of ethanol (absolute) and 50.75 g of the oil were first measured in two separate beakers that have been previously washed and dried. 1 g of the catalyst (potassium hydroxide, analar) was dissolved in 50 g of ethanol (absolute) and the resultant solution (potassium ethoxide) was then charged into the reactor and pre-warmed until temperature rose to 50 °C. The oil which, was also pre-warmed to the same temperature in a separate beaker was carefully added to the potassium ethoxide in the reactor and was then reacted at 75 °C at varied times of trans-esterification reactions. The same procedures were repeated using ethanol (absolute) and the extracted potassium hydroxide from the ripe plantain peels. The rapeseed oil was finally replaced using crude *Jatropha* oil, ethanol (absolute), with first, pure potassium hydroxide, second with extracted potassium hydroxide.

## 3. RESULTS AND DISCUSSION

The extraction of potash from ripe plantain peels was carried out going by their relative abundance as waste agricultural biomass in most rural settings in Nigeria.

These were burnt and the ashes collected and extracted to obtain potash (hydrated  $\text{K}_2\text{O}$ ) or KOH, an invaluable raw material for the production of biodiesel. Conditions were carefully selected in order to optimize KOH obtained from the extraction process at minimal energy cost. The waste biomass material could itself serve as real source of heat for evaporating the potash solutions to obtain its solid.

### 3.1. Effect of Extraction Volume on KOH Recovery

Two stages of extraction were conducted in which, equal amount of water was used in both stages. Each of Figures 1–3 shows the aggregate plot of the two extraction

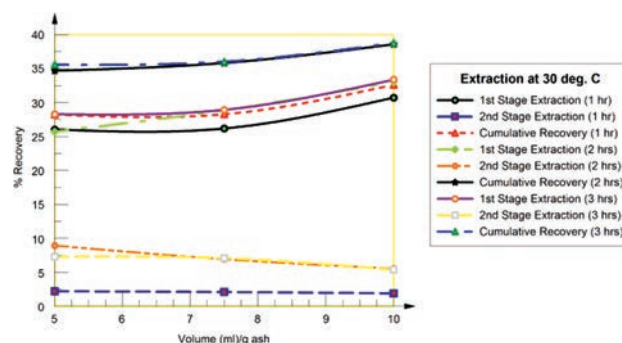


Fig. 1. Variation of extracted potash with volume of water (ml) from the ash of ripe plantain peels at 30 °C and varied extraction times.

stages and its cumulative values at a constant temperature. The cumulative percentage recovery of KOH (% KOH) obtained from the ripe plantain ash at varied times and constant temperatures, increased progressively with volume of water used per g of ash during the extraction: At 30 °C, % KOH recovered increased from 28.25 to 32.65% for 1 hour extraction time, 34.7 to 38.6% for 2 hours extraction time and 35.6 to 38.8% for 3 hours extraction time as the volume of water used was increased from 5 to 10 ml per g of ash used. At 40 °C, % KOH recovered increased from 30.5 to 33.25% for 1 hour extraction time, from 35.3 to 39.5% for 2 hours and 36.0 to 39.45% for 3 hours extraction time, also as the volume of water used was increased from 5 to 10 ml per g of ash used. While at 50 °C, the % KOH recovered increased from 32.0 to 34.48% for 1 hour extraction time, from 36.0 to 40.0% for 2 hours extraction time and from 39.0 to 40.1% for 3 hours extraction time as the volume of water used was increased from 5 to 10 ml per g of ash used. The increase in the percentage potash recovered was expected because increasing volume and temperature of the extracting solvent generally favors extraction since more solvent at higher temperature would be available to extract more solute. From the foregoing, the maximum recoverable potash per g of ripe plantain peels ash is approximately 40.1% (see Fig. 3). This was corroborated as the confirmatory test carried out on the filtrate tested neutral to litmus paper indicating absence

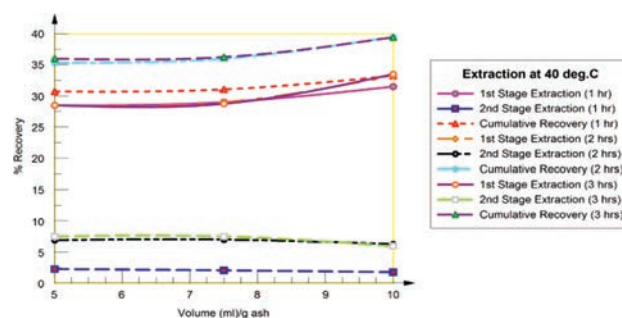


Fig. 2. Variation of extracted potash with volume of water (ml) from the ash of ripe plantain peels at 40 °C and varied extraction times.



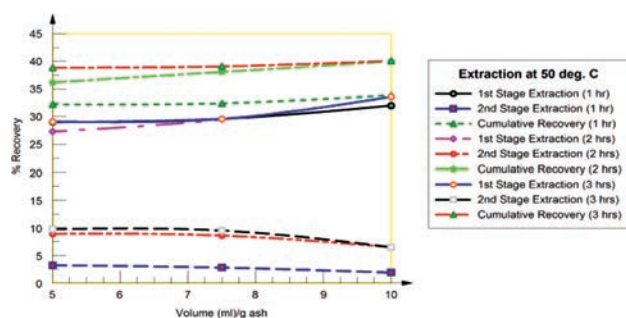


Fig. 3. Variation of extracted potash with volume of water (ml) from the ash of ripe plantain peels at 50 °C and varied extraction times.

of alkalinity. Thus the optimum conditions for maximizing potash extract per g of ripe plantain ash could be (i) a two-stage extraction of the ash with 10 ml of water at each stage, temperature of 40 °C, and 2 hours extraction time,

(ii) a two-stage extraction of the ash with 10 ml of water at each stage, temperature of 50 °C, and 2 hours extraction time or

(iii) a two-stage extraction of the ash with 10 ml of water at each stage, temperature of 50 °C, and 3 hours extraction time.

If however, cost of energy and time factor are considered, condition

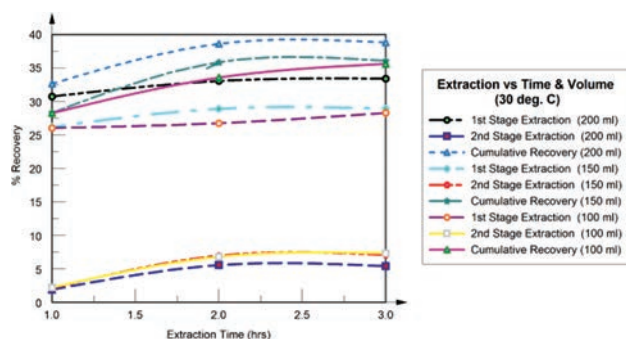


Fig. 4. Variation of extracted potash from ripe plantain ash with time (hr) and volume (ml) at 30 °C.

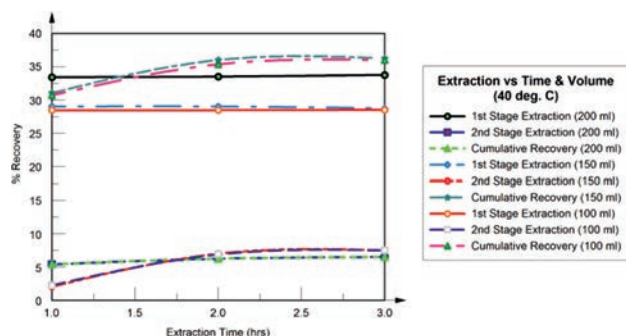


Fig. 5. Variation of extracted potash from ripe plantain ash with time (hr) and volume (ml) at 40 °C.

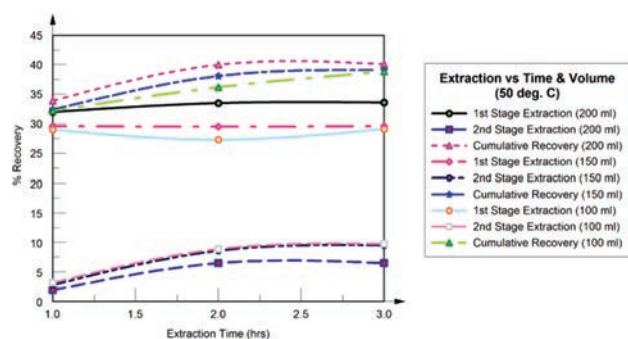


Fig. 6. Variation of extracted potash from ripe plantain ash with time (hr) and volume (ml) at 50 °C.

- (i) must be adopted otherwise condition (ii) which gave the first overall maximum may be chosen.

### 3.2. Effect of Extraction Time on KOH Recovery

Just as the cumulative quantity of potash obtained from the ash samples increased with volume of extracting solvent, so did the cumulative potash recovered increased with time of extraction. But in comparison, the 2nd stage trend as observed here, behaved totally different from the 2nd stage process of preceding Section 3.1. Whereas the % recovery increased with increasing extraction time, it decreased with increasing extraction volume. This was expected. As more time is allowed for intimate contact, more solute is

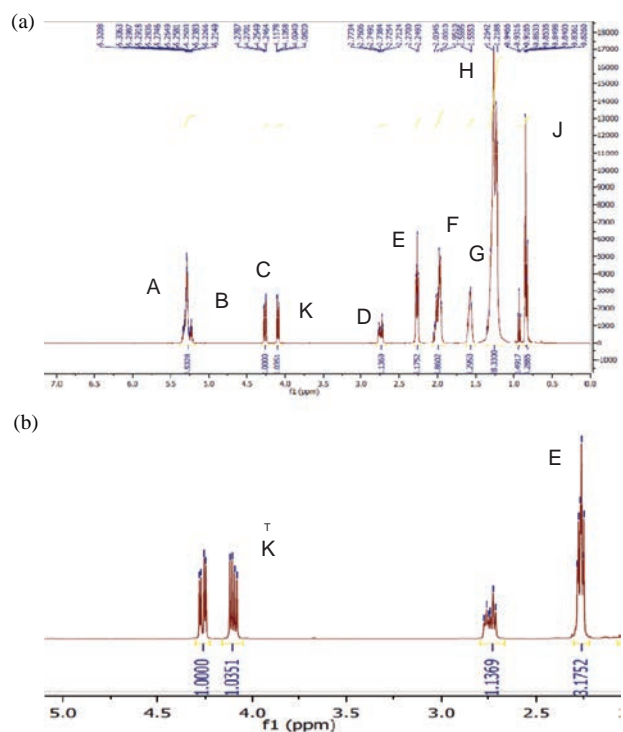


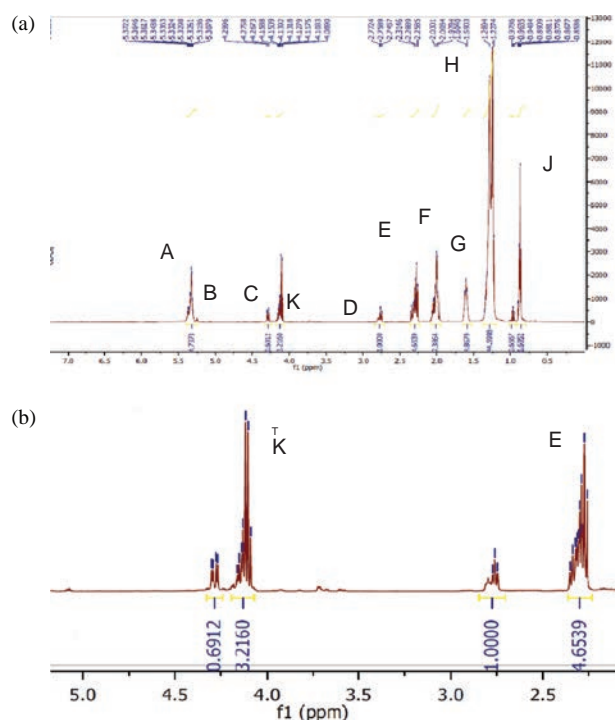
Fig. 7. (a) <sup>1</sup>H NMR spectrum of refined rapeseed oil (Unreacted) (Sample 1). (b) Magnified chemical shift regions of refined rapeseed oil (Unreacted).

expected to go into solution. This explains the reason for the increasing potash extracts for both stages of extractions with time at constant temperature. The representative aggregate plots are shown in Figures 4–6.

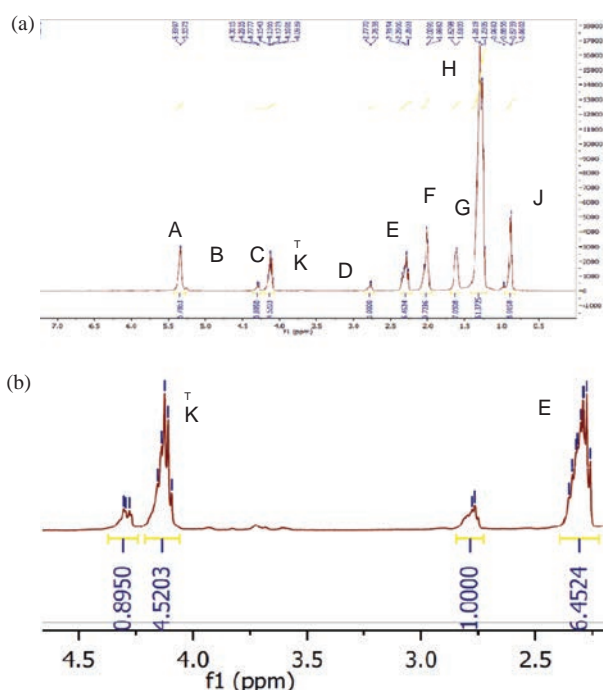
### 3.3. Characterization of Biodiesel

The characterization of the biodiesel produced from this research work followed the work of Guzato et al.<sup>20</sup> where they investigated the trans-esterification double step process modification for ethyl ester biodiesel production from vegetable and waste oils (See Eq. (4)).

In this research work, trans-esterification reactions using a simple batch process (described in Section 2.6) were carried out firstly, with refined rapeseed oil and secondly with crude jatropha oil. One of the main objectives was to show the possibility of using potash extracted from ripe plantain peels (kitchen wastes) to produce bio-diesel and hence obtain the percentage conversion of the oils to ethyl esters from the process. The oil conversion to ethyl ester biodiesel was evaluated using <sup>1</sup>H NMR spectroscopy. Figure 7(a) shows the spectrum of the untreated refined rapeseed oil while Figures 8–11 give the spectra of the partially converted rapeseed oil at the different reaction conditions specified under each figure. Furthermore, Figure 12 gives the spectra of the untreated crude jatropha oil while Figures 13–16 give the spectra of the partially converted crude jatropha oil at the different reaction



**Fig. 8.** (a) <sup>1</sup>H NMR of rapeseed biodiesel (sample 2). Pure KOH 1.0 g, rapeseed oil 50.7 g, Ethanol (absolute) 50 g, reaction time 3 hrs and tempt. 75 °C. (b) Magnified chemical shift regions for rapeseed biodiesel (Sample 2).



**Fig. 9.** (a) <sup>1</sup>H NMR of rapeseed biodiesel (sample 3). Pure KOH 1.0 g, rapeseed oil 50.7 g, Ethanol (absolute) 50 g, reaction time 4 hrs and tempt. 75 °C. (b) Magnified chemical shift regions for rapeseed biodiesel (sample 3).

conditions. Generally, part (b) of the figures high lightens the chemical shift regions of interest. These regions or peaks of interest have been labeled *K* and *E* for rapeseed biodiesel while *J* and *E* are for jatropha biodiesel. It was observed that rapeseed oil has one more peak than jatropha oil in the same region considered. The high lightened peaks were selected and their integration data were used to evaluate the percentage conversion of the oils to biodiesel using the equation developed by Guzato et al.<sup>20</sup>

$$C_{EE} = \frac{I_{EE-CH_2}/2}{I_{\alpha-CH_2}/2} \quad (4)$$

Where  $C_{EE}$  = the ethyl ester percentage conversion.

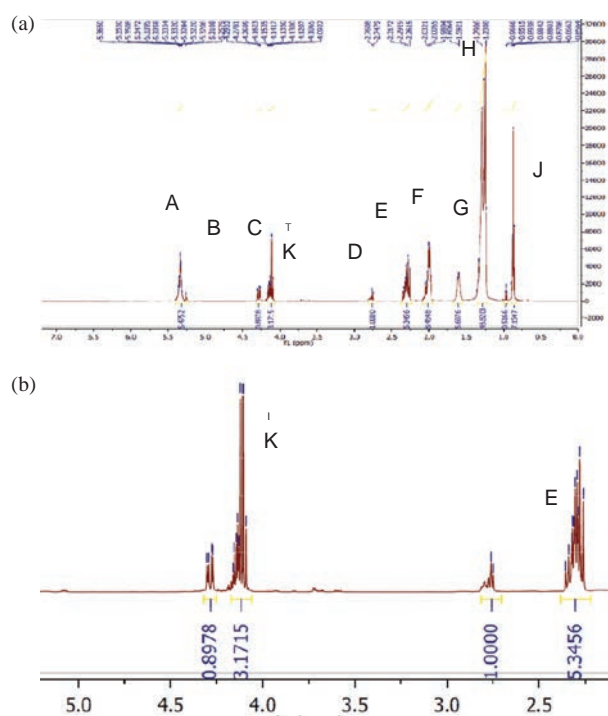
$I_{EE-CH_2}$  = the <sup>1</sup>H NMR integration values of the ethyl ester  $CH_2$  hydrogen atoms.

The chemical shift for the ethyl ester peaks occurred between  $\delta$  of 4.0 and 4.3 ppm for all the converted biodiesels except for sample 8 (Fig. 14) where its  $\delta$  values started at 3.9 ppm.

$I_{\alpha-CH_2}$  = integration value of the methylene group hydrogen atoms that are adjacent to the carbonyl group. This occurred at  $\delta$  values of between 2.1 and 2.4.

The factor '2', which divides the integration values, is the normalization factor.

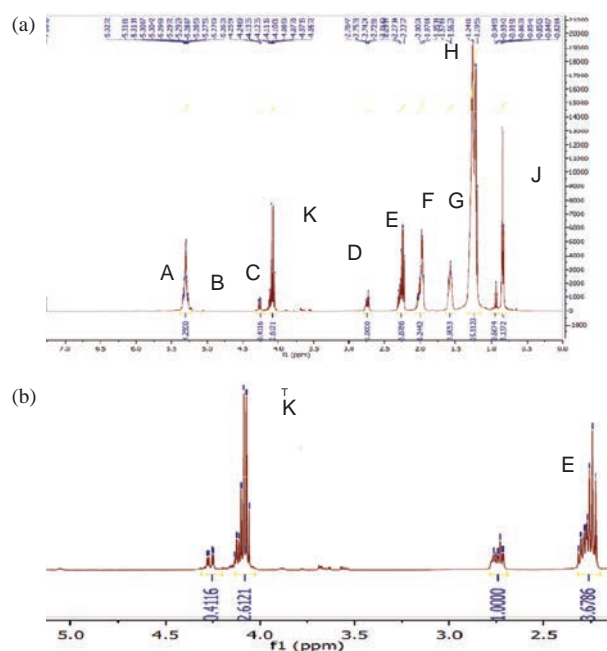
The terminal methyl group hydrogen atoms of the fatty acid chains for the rapeseed oil and its biodiesel are labeled as peak *J* occurring between 0.79 and 0.97 ppm, while it is between 0.71 and 0.88 ppm for jatropha oil



**Fig. 10.** (a)  $^1\text{H}$ NMR of rapeseed biodiesel (sample 4). Plantain peels KOH 1.0 g, rapeseed oil 50.7 g, ethanol (absolute) 50 g, reaction time 3 hrs., and temp.  $75^\circ\text{C}$ . (b) Magnified chemical shift regions for rapeseed biodiesel (sample 4).

and its biodiesel labeled as peak I, depending on the sample being considered. The peaks *D–H* are attributed to the methylene internal hydrogen atoms of the triglyceride fatty acid chains. These signals occur between 1.23 and 2.70 ppm for rapeseed oil/rapeseed biodiesel while for jatropha oil/jatropha biodiesel the signals occur between 1.05 and 2.77 ppm, depending on the sample being considered. The external glycerol fragment hydrogen atoms (peak *C*) are located for rapeseed oil/rapeseed biodiesel between 4.20 and 4.30 ppm while they are located for jatropha oil/jatropha biodiesel between 4.19 and 4.23 ppm. The carbon–carbon double bond olefinic hydrogen (peak *A*) are located between 5.32 and 5.35 ppm for rapeseed oil/rapeseed biodiesel while they are located for jatropha oil/jatropha biodiesel between 5.19 and 5.26 ppm and the internal glycerol fragment (glyceridic) hydrogen (peak *B*) at 5.25–5.35 ppm for rapeseed oil/rapeseed biodiesel while they are located for jatropha oil/jatropha biodiesel between 5.15 and 5.19. These are all shown in Figures 7–11 for rapeseed oil/rapeseed biodiesel, Figures 12–16 for jatropha oil/jatropha biodiesel.

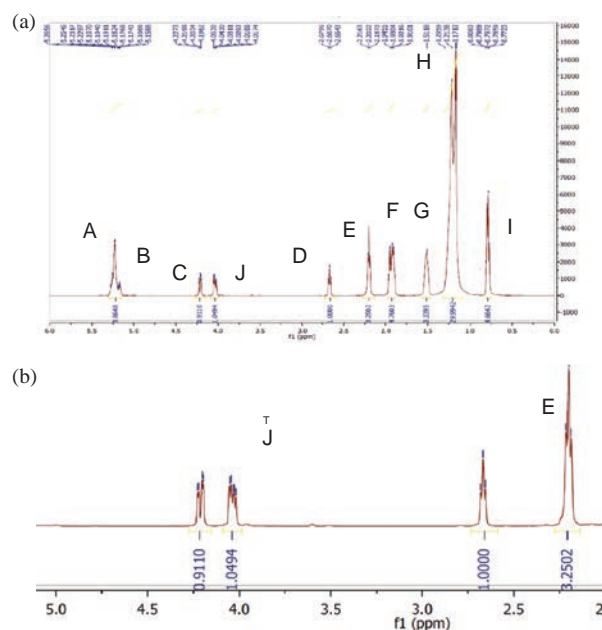
According to the reaction mechanism, the mono- and di-acylglycerides are the transesterification reaction intermediates. The methylene group hydrogen signals of the mono-, di- and tri-acylglycerides are located in the same region between 4.09 and 4.2 ppm. Peaks *K* in rapeseed oil/rapeseed biodiesel are due to the ethyl ester  $\text{CH}_2$  groups



**Fig. 11.** (a)  $^1\text{H}$ NMR of rapeseed biodiesel (sample 5). Ripe plantain peels KOH 1.0 g, rapeseed oil 50.7 g, ethanol (absolute) 50 g, reaction time 4 hrs. temp.  $75^\circ\text{C}$ . (b) Magnified chemical shift regions for rapeseed biodiesel (sample 5).

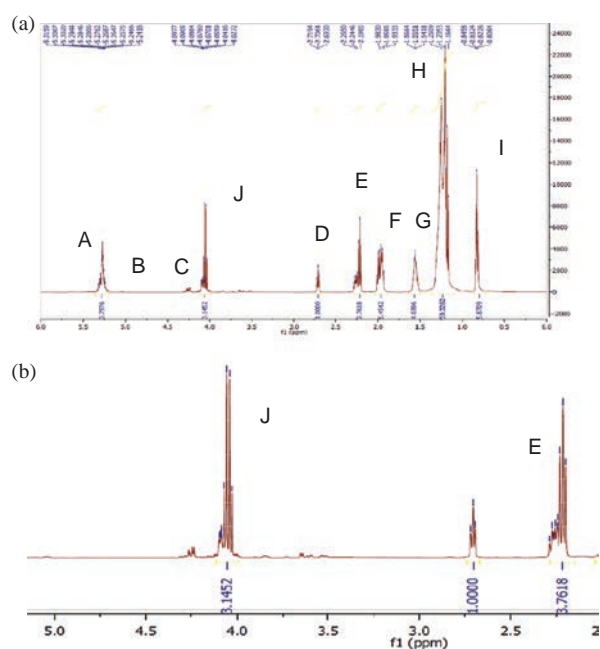
confirming the trans-esterification reaction occurrence, but are depicted as Peaks *J* in jatropha oil/jatropha biodiesel.

The highest percentage conversion obtained was 71.01% using 1 g of KOH extract from ripe plantain ash at transesterification time of 4 hours and temperature of  $75^\circ\text{C}$  (Fig. 11). This was closely followed by 70.06% conversion



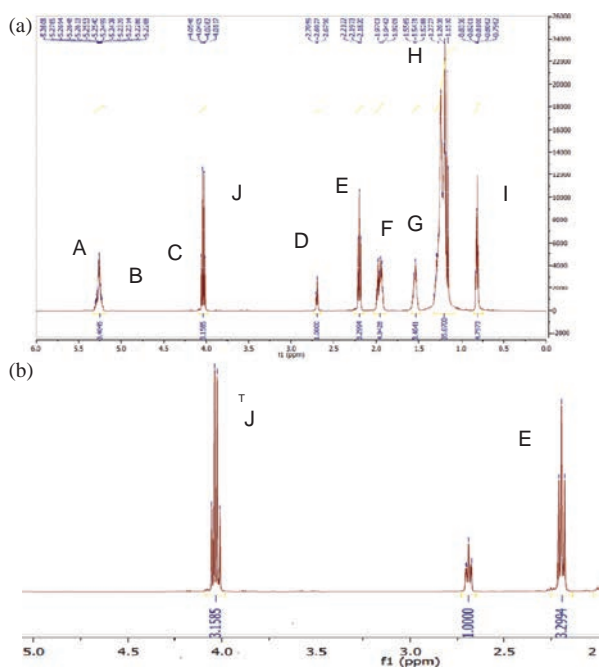
**Fig. 12.** (a)  $^1\text{H}$ NMR of 102312-1 crude jatropha oil (sample 6). (b) Magnified chemical shift regions for crude jatropha oil (sample 6).



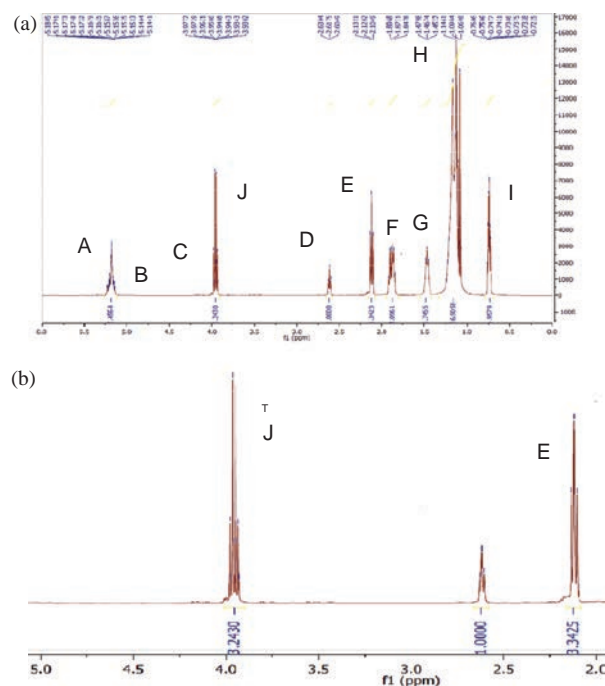


**Fig. 13.** (a)  $^1\text{H}$  NMR of jatropa biodiesel (112112-1) sample 7. Ripe plantain peels KOH 1.0 g, jatropa oil 51.0 g, ethanol (absolute) 50.7 g, reaction time 3 hrs, tempt. 75 °C. (b) Magnified chemical shift regions for crude jatropa biodiesel sample 7.

using 1 g of commercial caustic potash (Fig. 9), 69.10% conversion was obtained using 1 g of commercial caustic potash, (Fig. 8), 59.33% using 1 g of potash from ripe plantain ash (Fig. 10). From the foregoing, it was observed

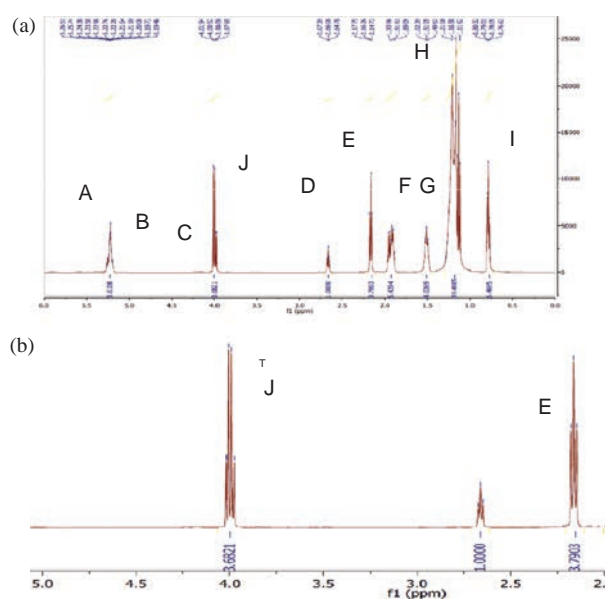


**Fig. 14.** (a)  $^1\text{H}$  NMR of jatropa biodiesel (112012-6): sample 8. Ripe plantain peels KOH 1.0 g, jatropa oil 51.0 g, ethanol (absolute) 50.7 g, reaction time 4 hrs, tempt. 75 °C. (b) Magnified chemical shift regions for jatropa biodiesel sample 8.



**Fig. 15.** (a)  $^1\text{H}$  NMR of jatropa biodiesel (102312-2) sample 9. Ripe plantain peels KOH 1.0 g, jatropa oil 51.0 g, ethanol (absolute) 50.7 g, reaction time 3 hrs, tempt. 83 °C. (b) Magnified chemical shift regions for jatropa biodiesel sample 9.

that conversion values increased with trans-esterification time using caustic potash from both the analar grade and biomass source. For the fact that rapeseed biodiesel obtained using pure caustic potash did not yield greater than 90% informs that the batch process employed in this



**Fig. 16.** (a)  $^1\text{H}$  NMR of jatropa biodiesel (112012-7): sample 10. Ripe plantain peels KOH 1.0 g, jatropa oil 51.0 g, ethanol (absolute) 50.7 g, reaction time 4 hrs, tempt. 83 °C. (b) Magnified chemical shift regions for crude jatropa biodiesel sample 10.

**Table I.** Chemical shift, areas and percentage conversion from biodiesel spectra.

Lab. sample I.D no.	Chemical shift regions, $\delta$ (ppm) (Ethyl ester peak)	Peak area (ethyl ester)	Chemical shift regions, $\delta$ (ppm), $\alpha$ -CH <sub>2</sub> peak	Peak area (methylene group) $\alpha$ -CH <sub>2</sub> peak	Percentage conversion
Rapeseed biodiesel			Unreacted refined rapeseed oil		
1					
2	4.0890–4.1588	3.2160	2.2585–2.3146	4.6539	69.10
3	4.0939–4.1543	4.5203	2.2603–3.154	6.4524	70.06
4	4.0922–4.1623	3.1715	2.2615–3.172	5.3456	59.33
5	4.0572–4.2554	2.6121	2.2277–2.914	3.6786	71.01
Jatropha biodiesel			Unreacted crude jatropha oil		
6					
7	4.0272–4.0977	3.1452	2.1985–2.2650	3.7618	83.61
8	4.0117–4.0546	3.1585	2.1820–2.2122	3.2994	95.73
9	3.9302–3.9772	3.2430	2.1049–2.1351	3.3425	97.02
10	3.9765–4.0194	3.6821	2.1473–2.1775	3.7903	97.15

experimental set up must be optimized. It implied that with an optimized process put in place, potash from ripe plantain peels ash would be equally as good as commercial caustic potash. Thus in our rural settings in Nigeria and indeed Africa, ripe plantain peels would provide a rich and available source of potassium hydroxide for base catalyst in biodiesel production. Imported potash is very difficult to source by rural dwellers and where it may be obtained the cost is usually prohibitive.

The spectra of crude jatropha have been displayed in Figure 12 while its corresponding biodiesels have their spectra displayed in Figures 13–16. It was discovered that higher percentage conversions were generally achieved with jatropha bio-diesel at higher temperature. 1 g KOH extract from ripe plantain peels, reaction temperature of 83 °C gave 97.15% conversion in 4 hours trans-esterification time. This was closely followed by 97.02% conversion obtained in 3 hours trans-esterification time at 83 °C (See Figs. 15 and 16 respectively). Two temperatures, 75 °C and 83 °C, at varied times of between 3 and 4 hours were investigated in the trans-esterification of crude jatropha oil to its biodiesel using potassium hydroxide extracted from ripe plantain peels. Figures 13 and 14 give the partially converted crude jatropha oil at 75 °C in 3 and 4 hrs trans-esterification times respectively. The performance of the caustic potash extract from ripe plantain peels was generally very outstanding. (See samples 4–10 in Table I, where their percentage conversion values have been indicated). This further buttresses the fact that caustic potash from ripe plantain peels could conveniently be used in place of the scarce and costly imported caustic potash especially in the rural settings. It is quite interesting to note that all the biodiesel samples produced at 83 °C recorded more than 75% conversion. Percentage conversion was observed to increase with time and temperature of the reaction. On the other hand, ripe plantain peels is a very rich source of potassium hydroxide. Aside from deep blue color change to litmus paper, it was a very effective catalyst in the conversion of vegetable oil to its biodiesel, producing

more than 97% conversion. This provides reasonable evidence of the possibility of using potassium hydroxide from biomass or agricultural waste sources for the production of biodiesel from vegetable oils or fats.

#### 4. CONCLUSION

The application of potassium hydroxide extracts from agricultural wastes (or biomass) materials-ripe plantain peels for biodiesel production has been investigated. A number of useful findings and deductions were made during the extraction and biodiesel production stages of the research:

- The cumulative percentage of potassium hydroxide recovered increased with volume of water/g ash used.
- The cumulative percentage of potassium hydroxide recovered increased with temperature of extraction.
- The cumulative percentage of potassium hydroxide recovered increased with time of extraction.
- The second stage extraction process is necessary in order to reduce the potash content of the spent ash to a negligible level.
- At constant volume and temperature the 2nd stage potassium hydroxide extract increased with increasing time of extraction.
- At constant temperature and time, the 2nd stage potassium hydroxide extract decreased with increasing extracting volume.
- At constant time and volume, the 2nd stage potassium hydroxide extract increased with increasing extraction temperature.
- Extraction at low temperatures (30–50 °C) is feasible as against the boiling method employed in the traditional methods, where the ash is constantly added to boiling water and left for 24 hours before filtration.
- The higher the caustic content of the biomass extract, the higher the percentage conversion of the vegetable oil to bio-diesel.
- Sun drying of the waste biomass materials is naturally feasible without having to expend energy for the drying process.



- The higher the temperature of transesterification, the higher the vegetable oil conversion to its biodiesel.
- Percentage conversion was observed to increase with temperature for ripe plantain ash.
- Potassium hydroxide from ripe plantain ash could conveniently substitute imported caustic potash in biodiesel production. This innovation must be encouraged and popularized amongst our rural African population for in-house bio-diesel production. The process is very practicable and would help to reduce over-dependence on petro-diesel and hence ameliorate the lingering energy crises.

**Acknowledgment:** We acknowledge with thanks the financial grant received from the Management of Covenant University that helped us a great deal to purchase the needed materials for the research work and the samples analyses in the United States of America.

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Received: 6 September 2015. Accepted: 30 September 2015.