

## EVALUATION OF OPTIONS IN WOOD WASTE MANAGEMENT: BURNING AND CONSEQUENT ALKALI PRODUCTION

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### Abstract

The study assessed burning and consequent alkali production as options for management of wood waste. Management of municipal solid waste in Nigeria has become a hydra-headed problem; the menace of solid waste in the environment has never justified both the efforts of government and individuals; and hence the need for continual research on various options for sustainable management of solid wastes. Nine different common African wood species - *Irvingia gabonensis* (Orokoro), *Celtis Zenkeri* (Ita), *Albizia zygia* (Ayunre), *Terminalia superba* (Afara), *Cola gigantia* (Obi), *Cordia millennia* (Omo), *Funtumia elastica* (Ire), *Ceiba petandra* (Araba) and *Ficus exasperata* (Obobo), were assessed for combustion and alkali production as options for management of wood waste. The wood waste (sawdust) from these species was obtained from a wood factory located behind Bodija market in Ibadan. Ashing was conducted on saw dusts in porcelain crucibles at 500°C for 4 hours in a muffle furnace for the determination of ash contents. Extraction of potash from the ashes was done using distilled water with a set of filtration system made up of 4-litre transparent plastic bottle with ash sediment itself serving as a sieve while the extract solution leaked out through pin-holes made at the bottom of the bottle. The purity of the crude potash and proportions of hydroxides and carbonates were determined by titrimetry; while recrystallization of the crude potash was carried out on three of the wood species which showed low purity to evaluate possible enhancement of their purity. The average reduction in volume of sawdust was 95% after combustion. The ash content obtained ranged from 1.25 to 8.80%; potash content, 2.77 to 26.88%; crude potash purity, 4.50 to 96.50%. Volumetric estimation may portray a better picture of ash and potash yield potentials of the plant materials, and hence expressed as 1.42 to 15.18 kg/m<sup>3</sup>, for ash content; potash yield ranged between 4.74 to 53.76 kg/m<sup>3</sup> of ashes and 0.21 to 1.53 kg/m<sup>3</sup> of saw dust. The hydroxide content obtained ranged from 0.00 to 1.22%; carbonate content, 4.09 to 96.09%; non-alkali content, 3.50 to 95.50%. The purity was enhanced from 61.50% to 83.10% for *Albizia zygia*, 65.00% to 80.90% for *Funtumia elastica*, and 46.50% to 68.00% for *Ceiba pentandra*.

Keywords: wood waste, ash, potash, alkali.

### Introduction

Approximately three million tons of wood ash is produced annually in the United States, out of which 70% is being landfilled, around 20% is being used as soil supplement, and the remaining 10% is being used in miscellaneous applications (Tarun et al., 2003). The use of wood ash in the past had primarily

been restricted to its utilization as liming agent and a source of nutrients for plant (Campbell, 1990).

The chemical composition of an ash depends on that of the substance burned: palm bunch wastes, cocoa pod, plantain leaves, maize cob, wood and sugar beet waste (Irvine, 1965); wood

ash contains metal carbonates and oxides formed from metals originally compounded in the wood; seaweed ash contains sodium carbonate, potassium carbonate, and iodine that can be extracted (CEE, 2003).

Exploration of ash-derived alkalis for domestic use is an age-old craft (Onyegbado et al., 2002; Nwoko, 1982). Studies of chemical composition of wood

Analysis of extracts from ashes by Nwoko (1980) and others (Onyegbado et al., 2002; Onyekwere, 1996; Kuye and Okorie, 1990) showed that the extract was chiefly potassium hydroxide with some quantities of sodium hydroxide, while other metallic ions constituting about 2% were  $\text{Ca}^{2+}$ ,  $\text{Cr}^{2+}$ ,  $\text{B}^{3+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Pb}^{2+}$  and  $\text{Ni}^{2+}$ . Tarun et al. (2003) tested different sources of wood ash from USA and Canada; they had a specific gravity between 1.6 and 2.8, unit weight between 365 and 980Kg/m<sup>3</sup>; the major elements in the wood ashes tested were carbon (5 to 30%), Calcium (7 to 33%), potassium (3 to 4%), and sodium (0.2 to 0.5%). Ashes have a composition which varies according to the kind of wood and the soil in which it grew (Kevin, 2003). The physical and chemical properties of wood ash vary significantly, depending upon various factors, which in addition to the kind of wood and soil include method and manner of combustion, efficiency of the boiler, and other supplementary fuel used with wood (Tarun et al., 2003).

Several authors have studied the potash yield of plant materials : carbonate content of 40-60% (Afrane, 1992) and 56.73±0.16% (Taiwo and Osinowo, 2001) were obtained for cocoa husks; 78% for ripe plantain peel and 94% for fresh plantain trunk (Ankrah, 1974); 82% in unripe plantain peel (Onyegbado et al., 2002); 43.15±13% in palm bunch, 16.65±0.05% in groundnut shell, 12.40±0.08% in sorghum chaff (Taiwo and Osinowo, 2001) and alkali content of 6.3-86.7% in the peels of some varieties of Nigeria grown *Musa* species (Babayemi et al., 2010b). Potassium

ash in the past have primarily been restricted to the elemental composition (Baker et al., 1964) as the focus was largely on the agricultural use of wood ash. A common assumption in most of these analyses has been that the minerals present are oxides of different elements (Mahendra, et al., 1993). The assumption may be sufficient to identify the extent of alkalinity of wood ash (Shelton and Shapiro, 1976).

content of some wood species were analyzed by Misra et al (1993): pine (16.24%), aspen (11.25%), yellow polar (7.93%), red oak (6.08%), and white oak (10.25%).

Potash has been described as a white crystalline residue that remains after aqueous extract from ashes is evaporated (Kevin, 2003). It is an impure form of potassium carbonate mixed with other potassium salts (Wikipedia, 2007). These could be produced locally and industrially. There are various local extraction technologies, depending on the desired quality, quantity and intended use of the resulting potash (Babayemi et al, 2010a). Generally, containers made of aluminum are to be avoided since alkali attacks aluminum. Fig. 1 shows a typical ancient traditional extraction technology. It consists of two clay pots (of about 50 litres each) mounted on each other. The one on top is open at the base, with radius about half the open top. The open base is completely blocked with pieces of sticks, followed by a layer of wood charcoal. The remaining space on top is then packed with ashes which had already been moistened with water for some days to aid quick extraction. Water is then carefully poured on top, as to only saturate the ashes, and not to leach the desired component yet. After few hours, when the ash would have completely absorbed the water and every large pores and air spaces blocked, sufficient water is then carefully poured on top. The water slowly leaches the potash into the lower pot, the ash itself serving as a filter. Perhaps the charcoal removes

some unwanted organics from the leaching potash. The potash produced this way is usually coloured brown, and

may have contributed to the black colour of the local soap produced with it.

Fig. 2 shows a corresponding laboratory experimental set-up used by Kevin (2002). At the top is a transparent plastic bottle of about 2 litres capacity and at the base is a beaker. The bottle is filled with ashes to about one-third. Sufficient water is added, capped and then shaken thoroughly to dissolve the soluble components. The ash is allowed to settle, till a clear liquid is observed at the top. One or two pin-holes are made at the bottom, and then placed on the beaker, while the cap is removed. The solution on top is filtered by the ashes as it leaks into the beaker. The potash solution obtained this way is usually clear, that is, colorless, although it also depends on the source of the ash.

and ashes take a considerable percentage of solid wastes being generated in Nigeria every day. Wood factories, including saw mills, are established in their thousands in various states, with thousands of tons of wood shavings and saw dusts being generated each day (Aina, 2006). At present in Nigeria, apart from the insignificant use as poultry deep litters, the largest percentage of saw dusts and wood shavings end up in dump sites as waste, where they are burnt and the ashes carried away by flood every year. The ashes generated, including those from combustion of firewood in various homes and food canteens, are either land-filled or open-dumped. This report evaluates the efficiency of burning and consequent extraction of alkali from the resulting ash, as options for management of wood waste.

One of the major management problems in the mega-cities of Nigeria is that of solid waste disposal. Wood waste

## Materials and Methods

### Sample collection

Saw dusts of each species of wood were collected from sawmill at Bodija Market, Ibadan, Nigeria. The samples were collected instantly as the woods were being milled.

The samples were air-dried for about four weeks.

$$MC = \frac{(W_1 - W_2) \times 100}{W_1}$$

$$DM = \frac{W_2 \times 100}{W_1}$$

$$DS = \frac{W_2}{V_1} (g/ml)$$

Where  $V_1$  is the volume (determined by slight modification to GEA Niro Method No. A 2a, 2006) of quantity ( $W_2$ ) determined.

### Determination of moisture content (MC), dry matter content (DM) and density of the samples (DM)

A known weight ( $W_1$ ) of air-dried samples was taken and oven-dried at 105°C for 3 hours (Miroslave and Vladimir, 1998). It was transferred into desiccator to cool and then weighed again to give a new weight ( $W_2$ ).

### Ash content (AC) and density of ashes (DA)

A known weight ( $W_3$ ) of samples dried in the oven at 105°C for 3 hours was

combusted to ashes in a muffle furnace set at 500°C for 4 hours using porcelain crucibles. After cooling, the weight ( $W_4$ ) of the ash residue was determined. The ash content was calculated using the following relationships:

$$AC = \frac{W_4}{W_3} \times 100$$

$$DA = \frac{W_5}{V_2} \text{ (g/ml)}$$

Where  $V_2$  (GEA Niro Method No. A 2a, 2006) is the volume of the quantity of ash ( $W_5$ ).

#### Extraction of alkali from ashes

About 30kg of the sample were combusted to ashes in an open combustion pan. Extraction of 150g of the ash residue was carried out with 2 litres of distilled water in a set of filtration system made up of four 4-litre transparent plastic bottle. The bottle with its contents was covered, thoroughly shaken; and it was allowed to stay for about 12 hours, hanging on a retort stand. The lid was removed and few pin-holes were made at the bottom of the bottle using injection needle. The extract solution leaked into a collecting bucket as it filtered through the ash sediment. 1.5 liters of the extract solution were evaporated to dryness, and then dried to

constant weight in an oven set at 105°C for 3 hours. After cooling in a desiccator, the weight ( $W_6$ ) of the potash in the crucible was determined using metler balance. The actual amount of potash from the 150g of ashes was calculated as follows:

1.5 litres of extract solution contained  $W_6$ , then 2 litres of extract solution would contain

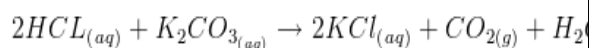
$$\frac{(W_6 \times 2)}{1.5} \text{ (g)}$$

Therefore,

$$\text{Potash} = \left( \frac{W_6 \times 2 \times 100}{1.5} \right) \times \frac{1}{150}$$

#### Determination of purity of the crude potash

With the assumption that the ash-alkali was mainly potassium carbonate, 3.45g of the crude potash were dissolved in distilled water and made up to mark in a 250-ml standard flask. 10 ml were pipetted into a conical flask and then titrated with 0.1M hydrochloric acid, using methyl orange as indicator (Babayemi *et al*, 2010c). 5 replicates were obtained, from which average titre was calculated. The chemical reaction could be shown as :



The concentration of the alkali was calculated from the following expression:

$$\frac{C_A V_A}{C_B V_B} = \frac{2}{1}$$

Where  $C_A$  and  $V_A$  are concentration in  $\text{mol dm}^{-3}$  and volume in ml of alkali, respectively.

Concentration in  $\text{g dm}^{-3}$  was calculated as: concentration in  $\text{mol dm}^{-3}$  X Molar mass;

Assuming this equals x grams, it implied x grams were contained in 1000 ml of solution, then

$$\frac{x}{1000} \times 250$$

would be contained in 250 ml;

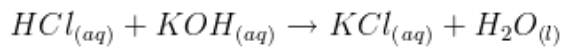
Assuming this equals y grams, therefore,

$$\text{Purity} = \frac{y}{3.45} \times 100$$

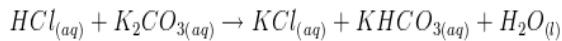
#### Analysis of carbonate and hydroxide contents

Double-indicator method was used in the acid-base titration analysis of the mixture of alkali hydroxide and carbonate (Ojokuku, 2001). 10 ml of the sample solution were pipetted into a conical flask. 2 drops of phenolphthalein indicator were added, and then titrated with 0.1M hydrochloric acid until a colourless solution was obtained. At that point, the whole of the hydroxide and half of the carbonates had been titrated, giving a burette reading  $V_1$ . The equations of reaction are as shown below:

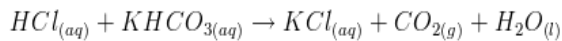
(i)



(ii)



Methyl orange was then added to the resulting colourless solution, and titrated until the colour changed from yellow to orange. At that point, the remaining bicarbonate was neutralized by the acid, the burette reading now being  $V_2$ . The equation of reaction is as follows :



**Calculations:**

Titre for neutralization of  $KHCO_3 = V_2 - V_1$

$$= 0.69y \text{ gdm}^{-3}.$$

Therefore,

$$KOH = \frac{0.56x}{0.56x + 0.69y} \times 100$$

$$K_2CO_3 = \frac{0.69y}{0.56x + 0.69y} \times 100$$

*KOH,  $K_2CO_3$  and non-alkali contents*

Titre for neutralization of KOH =  $V_1 - (V_2 - V_1)$

Titre for neutralization of  $K_2CO_3 = 2(V_2 - V_1)$

Assuming the average titre for neutralization of KOH,  $V_1 - (V_2 - V_1) = x$  ml,

And that of  $K_2CO_3$ ,  $2(V_2 - V_1) = y$  ml;

Then, molar concentration of KOH =  $\frac{0.1 \times x}{10}$

$$= 0.01x \text{ moldm}^{-3};$$

Concentration in  $\text{gdm}^{-3} = 0.01x \times$  molar mass of KOH

$$= 0.01x \times 56$$

$$= 0.56x \text{ gdm}^{-3};$$

The molar concentration of  $K_2CO_3 = \frac{0.1 \times y}{2 \times 10}$

$$= 0.005y \text{ moldm}^{-3};$$

Concentration in  $\text{gdm}^{-3} = 0.005y \times$  molar mass of  $K_2CO_3$

$$= 0.005y \times 138$$

The amount of KOH,  $K_2CO_3$  and non-alkali contents of the crude potash were calculated as follows:

%KOH =  $t \times$  %Purity of crude potash;

% $K_2CO_3$  =  $z \times$  %Purity of crude potash;

%Non-alkali contents =  $100 -$  %Purity of crude potash;

where  $t$  and  $z$  are the percentage of KOH compared to  $K_2CO_3$  and percentage of  $K_2CO_3$  compared to KOH, respectively.

### Purification of crude potash

Three of the wood species which showed low purity were tested for improvement on the purity of their crude potash. The crude potash was re-dissolved in sufficient distilled water and heated gently till there was an appearance of precipitates, and then allowed to cool to room temperature. The less soluble components crystallized out on cooling; the remaining solution was decanted off

and evaporated to dryness and finally dried to constant weight. The dried crystals were subjected to titrimetric analysis to determine the purity.

### Correlation

Using Pearson worksheet function, correlations were made between ash and potash contents, and between ash and alkali contents.

### Results and Discussion

Table 1 shows the results of the moisture content, dry matter content, density of sample, and density of ashes; the values ranged from 12.50 to 18.16%, 81.84 to 87.50%, 0.06 to 0.23g/ml, and 0.05 to 0.40g/ml respectively. The values of ash and potash contents obtained (Figure 3) ranged between 1.25 to 8.80% and 2.77 to 26.88% respectively. Crude potash purity (4.50 to 96.50%), hydroxide content (0.00 to 1.22%), carbonate content (4.09 to 96.09%), and non-alkali content (3.50-95.50%) are presented in Table 2. The results of ash and potash yield based on volumes (Table 3) were 1.42 to 15.18 kg/m<sup>3</sup>, for ash content; potash yield, 4.74 to 53.76 kg/m<sup>3</sup> (of ashes), and 0.21 to 1.53 kg/m<sup>3</sup> (of saw dust). The average reduction in volume of sawdust was 95% after combustion. Table 4 shows the amount of KOH compared to K<sub>2</sub>CO<sub>3</sub>, and the values ranged from 0.00 to 9.21% and 90.79 to 100% respectively. The purity was enhanced from 61.50% to 83.10% for *Albizia zygia*, 65.00% to 80.90% for *Funtumia elastica*, and 46.50% to 68.00% for *Ceiba pentandra* (Figure 4). Figure 5 (correlation coefficient, R<sup>2</sup> = 0.0324) and Figure 6 (correlation coefficient, R<sup>2</sup> = 0.0795) show the correlations between ash and alkali contents (% of sawdust samples) and between ash content and potash content, respectively.

*Funtumia elastica* gave the highest moisture content while *Funtumia elastica* had the lowest dry matter content. *Ceiba pentandra* had the lowest

moisture content, highest dry matter content, lowest density and lowest ash yield. *Terminalia superba* had relatively lower moisture content, relatively higher dry matter content, relatively high density and highest ash yield. *Funtumia elastica* gave the lowest ash yield, while *Terminalia superba* gave the highest. This observation was completely reversed in the case of potash yield: *Terminalia superba* gave the least potash yield. A higher yield was obtained for *Funtumia elastica* and *Ficus exasperata* gave the highest yield. It may then be inferred that where ash yield is of interest, *Ficus exasperata* offers the best option; and where potash yield is of interest, *Ficus exasperata* offers the best option.

As shown in Table 3, the results of the determination of ash content in terms of volume ranged from 1.62 to 15.18kg/m<sup>3</sup> (of sawdust). Taking the upper value (15.18kg/m<sup>3</sup>) as the ash content, it implied 1m<sup>3</sup> sawdust generated 15.18kg ashes; the density of the ash under consideration was 0.32g/ml; then the volume of ashes produced would be 0.05m<sup>3</sup>, implying 95% reduction in volume. And assuming the wood factories generated 82 368m<sup>3</sup> of sawdust per day (Babayemi and Dauda, 2009), it gave 1 250 346.2kg ash generation rate per day, and 456 376 363kg or 1 503 216m<sup>3</sup> per year. Potash content of the ashes ranged between 4.74 and 53.76kg of potash per cubic metre of ashes. Taking 53.76kg/m<sup>3</sup> as the

potash content of the ashes, 1 503 216m<sup>3</sup> of ashes will yield approximately 80 812

892kg of potash annually. What a great resource!

Alkali content observed for *Ficus exasperata* was the highest; and *Irvingia gabonensis*, being the least. The high alkali content suggests potential use as laboratory reagent, since these results are comparable to the recommended purity of 99.999% (for primary standards). In the results of hydroxide compared to carbonate contents, the observation showed that 80% of the wood species gave hydroxide content of less than 1%. It may then be inferred that potash from ashes is predominantly carbonate of potassium or sodium. The formation of oxides K<sub>2</sub>O and Na<sub>2</sub>O suggested by Onyegbado et al (2002) could only be true for the burning of pure metals in air; this may not be applicable to the burning of these metals in organic matrices: the potassium or sodium in plant materials is bound in organic matrix of which carbon is a major constituent. During combustion, there is a high release of carbon (IV) oxide, leading to the formation of carbonate rather than

oxide of the metals as suggested by these authors.

*Irvingia gabonensis* contained the highest non-alkali content and *Ficus exasperata* contained the least. A very high percentage of 95.50 of non-alkali salt in *Irvingia gabonensis* also call for further studies, as this could be a breakthrough in the discovery of another source of raw materials for chemical industries.

The results obtained after the enhancement of purity of the crude potash by recrystallization show the possibility of improving upon purity of potash alkali and making it fit for various uses.

If R<sup>2</sup> approaches 1.0000, it means there is a very high relationship between the compared parameters; otherwise, there is little or no relationship. The two Figures 5 and 6 showed no correlations.

### Conclusion

*Ficus exasperata*, *Ceiba pentandra* and *Funtumia elastica* gave higher potash yield and very high purities were obtained for *Ficus exasperata*. These wood species could be recommended as choice materials for potash production.

Wood waste volume could be reduced by 95% after combustion, and the resulting ashes could serve as a source of the much needed potash in the production of soap and other potash-based materials.

**Table 1.** Moisture content (MC) (%w/w), dry matter content (DM) (%w/w), sawdust (wood) density (SD) (g/ml) and ash density (AD) (g/ml)

	SP <sub>1</sub>	SP <sub>2</sub>	SP <sub>3</sub>	SP <sub>4</sub>	SP <sub>5</sub>	SP <sub>6</sub>	SP <sub>7</sub>	SP <sub>8</sub>	SP <sub>9</sub>	SP <sub>10</sub>
MC	13.54	16.42	12.99	12.99	12.50	13.28	18.16	12.84	12.77	13.08
DM	86.46	83.58	87.01	87.01	87.50	86.72	81.84	87.16	87.23	86.92
DS	0.16	0.12	0.15	0.23	0.06	0.15	0.13	0.23	0.17	0.14
DA	0.05	0.20	0.20	0.12	0.09	0.24	0.12	0.32	0.40	0.13

**Table 2.** Crude potash purity, amount of KOH, K<sub>2</sub>CO<sub>3</sub> and non-alkali (NA) contents (%) (of crude potash).

Wood species	Purity		KOH	K <sub>2</sub> CO <sub>3</sub>	NA
<i>Irvingia gabonensis</i>	4.50	0.41	4.09	95.50	
<i>Celtis zenkerii</i>	45.60	0.00	45.60	54.40	
<i>Albizia zygia</i>	61.50	0.00	61.50	38.50	
<i>Annogissus celocarpus</i>	93.00	1.22	91.78	7.00	
<i>Terminalia superba</i>	44.00	0.42	43.58	56.00	
<i>Cola gigantia</i>	4.50	0.00	4.50	95.50	
<i>Cordia millennii</i>	64.50	0.39	64.11	35.50	
<i>Funtumia elastica</i>	65.00	0.39	64.61	35.00	
<i>Ceiba pentandra</i>	46.50	0.00	46.50	53.50	
<i>Ficus exasperata</i>	96.50	0.41	96.09	3.50	

**Table 3** Ash (AC) and potash (PC) contents of some different wood (sawdust) samples (WS)

Content	SP <sub>1</sub>	SP <sub>2</sub>	SP <sub>3</sub>	SP <sub>4</sub>	SP <sub>5</sub>	SP <sub>6</sub>	SP <sub>7</sub>	SP <sub>8</sub>	SP <sub>9</sub>
AC (kg/m <sup>3</sup> )	3.22	5.52	4.17	4.24	1.42	4.93	1.62	15.18	3.45
<sup>a</sup> PC <sub>1</sub> (kg/m <sup>3</sup> )	4.74	53.76	25.41	9.25	17.85	16.58	15.55	11.09	9.19
<sup>b</sup> PC <sub>2</sub> (kg/m <sup>3</sup> )	0.36	1.53	0.43	0.35	0.30	0.33	0.21	0.44	0.25

<sup>a</sup>Weight per volume of ashes; <sup>b</sup>Weight per volume of sawdust**Table 4.** Amount of KOH compared to K<sub>2</sub>CO<sub>3</sub>, expressed as a percentage.

Wood species	KOH	K <sub>2</sub> CO <sub>3</sub>
<i>Irvingia gabonensis</i>	9.21	90.79
<i>Celtis zenkerii</i>	0.00	100.00
<i>Albizia zygia</i>	0.00	100.00
<i>Terminalia superba</i>	0.95	99.05
<i>Cola gigantia</i>	0.00	100.00
<i>Cordia millennii</i>	0.61	99.39
<i>Funtumia elastica</i>	0.60	99.40
<i>Ceiba pentandra</i>	0.00	100.00
<i>Ficus exasperate</i>	0.43	99.57

Figure 1: Traditional Potash Extraction setup

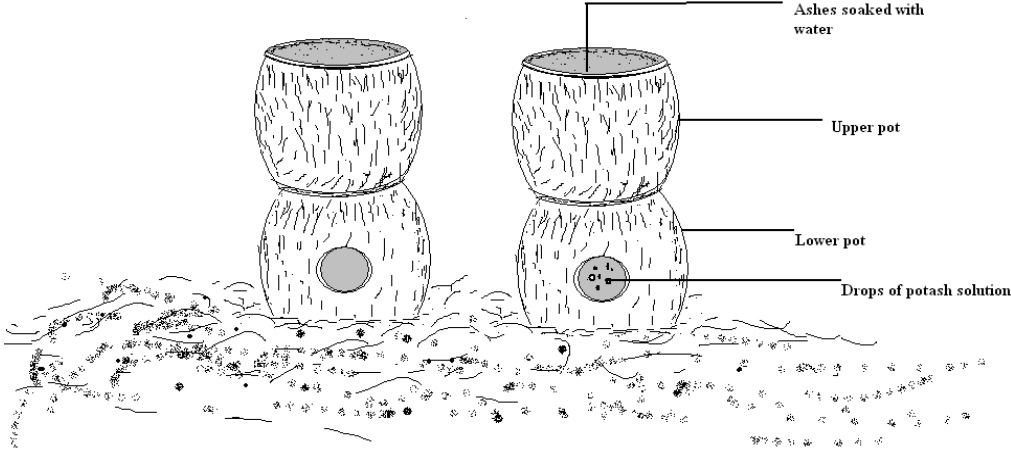
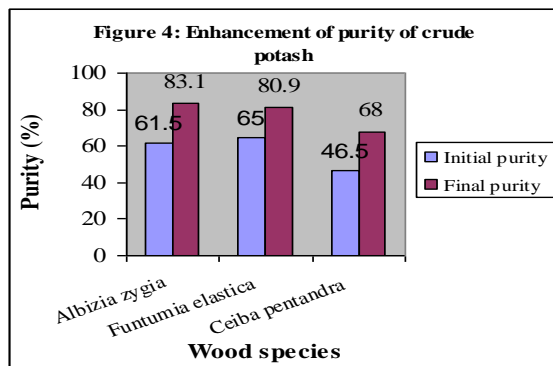
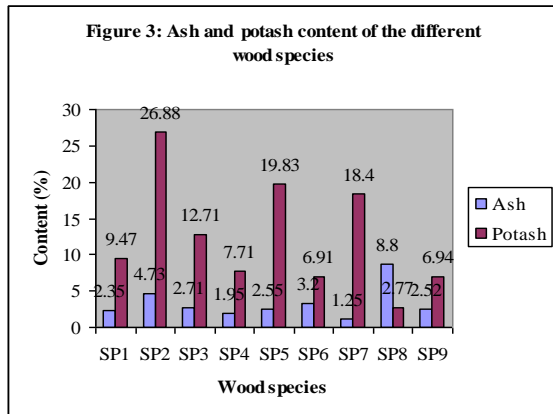
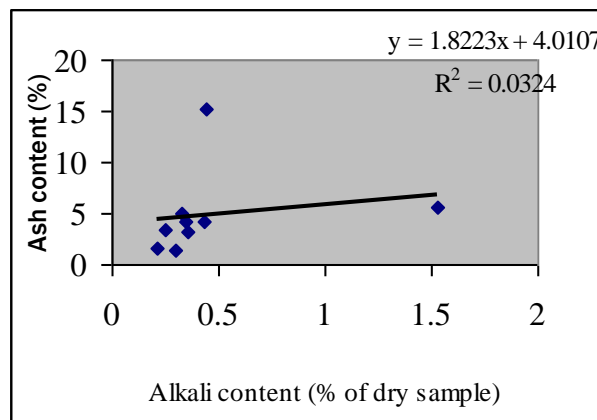


Fig. 2 Laboratory potash extraction set-up (Kevin, 2002)





**Figure 5: Correlation between ash content and alkali content (% of sawdust of wood samples)**



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