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Evaluation of the Composition and Chemistry of Ash and Potash from Various Plant Materials-A Review

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Abstract: The composition and chemistry of ash and potash from various plant materials were assessed. Sequel to unavailability of vital information on the composition and chemistry of ash and potash is the production of potash of low quality, especially by local producers, as well as wrong determination or identification and quantification of components of potash in studying it for various purposes. In this review, both qualitative and quantitative chemistry of ash and potash as well as factors affecting them were evaluated; disparities in observations in previous studies were identified and clarified. The results indicated variable compositions, definite chemistry influenced by several factors and different ideas and observations of various researchers.

Key words: Ash, potash, ash-alkali, non-alkali, potassium, sodium

INTRODUCTION

Ash is the mineral residue obtained after combustion of organic materials. While there is a data gap on the quantities of ash being generated in many countries, Tarun *et al.* (2003) estimated a generation of three million tons of wood ash for United States and about 70% of these was being land-filled. Ash generation potential varies from one plant material to the other. Analysis of some wood species by Misra *et al.* (1993) reveals ash contents of 0.43, 0.45, 0.87, 1.64 and 1.82% for Aspen, Yellow poplar, White oak, White oak bark and Douglas fir bark respectively. Kevin (2003) observed 0.58% for Beech wood. A range of 6.3 to 12.0% ash content was observed in some varieties of Musa species (Babayemi *et al.*, 2010a). Adewuyi *et al.* (2008) recorded a range of 1.25 to 8.80% for some African wood species. The composition of ashes depends on the source, species of plant material and the nature of the soil where the plants grow. Ashes from combustion of mixed plant materials (such as wood wastes used as firewood) will have compositions different from those of pure woods. Also, the part of a plant combusted may determine the ash yield and composition. Even in the same plant, metal composition may vary, such as observed in the study of trace element concentrations in the fruit peels and trunks of *Musa paradisiaca* (Selema and Farago, 1996).

Temperature of combustion is another important factor that determines the ash yield of a plant material (Misra *et al.*, 1993). The presence of black particles (charred wood particles) in ashes usually indicates incomplete combustion. Combustion at higher temperatures (usually not exceeding 600°C) may hasten and ensure complete combustion, though this depends on the particle size and/or the nature of plant material. Combustion of plant materials at higher temperatures may result in decomposition of some inorganic components and weight loss (Misra *et al.*, 1993). The solubility of ash is a function of the amount of alkali metal components and other soluble salts (like chlorides and sulphates of K and Na) present in the ash, which depend on the species of plants combusted.

Lack of knowledge of the composition and chemistry of ash and potash often leads to failure in producing potash of good quality from ashes, especially by local producers; it may also lead to wrong determination and/or identification of components of potash in studying them for various purposes. Hence, the composition and chemistry of ash and potash are evaluated in this review.

Potash: The word potash is said to be conventionally derived from pot-ash-the ash residue after combustion of organic material (plant materials) (Wikipedia, 2007) and sometimes, it is so-called because K is the main alkali metal in the ash. However, current researches have shown that only a fraction of ash is potash. The earlier literatures reported the determination of potash in ripe plantain peels (Ankrah, 1974). Several other researchers have attempted to study the potash content of various plant materials (Kevin, 2002; Afrane, 1992; Nwoko, 1980). Over the years, in a traditional way, attempt has been made to obtain the real potash by leaching the ash with water. The extract

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Table 1: Purity and amount of KOH, K_2CO_3 and Non-Alkali (NA) contents (%) of crude potash

Wood species	Purity	KOH	K_2CO_3	NA
Irvingia gabonensis	4.50	0.41	4.09	95.50
Celtis zenkerii	45.60	0.00	45.60	54.40
Albizia zygia	61.50	0.00	61.50	38.50
Annogissus celocarpus	93.00	1.22	91.78	7.00
Terminalia superba	44.00	0.42	43.58	56.00
Cola gigantia	4.50	0.00	4.50	95.50
Cordia millennii	64.50	0.39	64.11	35.50
Funtumia elastica	65.00	0.39	64.61	35.00
Ceiba pentandra	46.50	0.00	46.50	53.50
Ficus exasperata	96.50	0.41	96.09	3.50

Source: Adewuyi *et al.* (2008)

Table 2: Ash (AC) and potash (PC) contents of some different wood (sawdust) samples (WS)

Content (kg m^{-3})	WS_1	WS_2	WS_3	WS_4	WS_5	WS_6	WS_7	WS_8	WS_9
AC	3.22	5.52	4.17	4.24	1.42	4.93	1.62	15.18	3.45
$^aPC_1$	4.74	53.76	25.41	9.25	17.85	16.58	15.55	11.09	9.19
$^bPC_2$	0.36	1.53	0.43	0.35	0.30	0.33	0.21	0.44	0.25

Source: Adewuyi *et al.* (2008). [a]Weight per volume of ashes; [b]Weight per volume of sawdust

obtained traditionally may be coloured (usually brown) and may contain a lot of impurities. Potash yield depends on the type of plant material, the nature of soil where the plants grow and the efficiency of extraction technology used (Babayemi *et al.*, 2010b). Taiwo and Osinowo (2001) recorded 56.73±0.16% for cocoa pod, 43.15±0.13% for palm bunch, 16.65±0.05% for groundnut shell and 12.40±0.08% for sorghum chaff. Afrane (1992) recorded 40 to 60% for cocoa pod and Adewuyi *et al.* (2008), 2.77 to 26.88% for various African wood species (Table 1). The potash content in the peels of some varieties of Nigeria grown plantain and banana as reported by Babayemi *et al.* (2010a) ranged from 69.0 to 81.9% (of ash) and 4.7 to 9.6% (of dry peel). Beech wood ash yields 20.69% potash (Kevin, 2003).

Estimation of ash and potash contents by volume of sample: Volumetric estimation may portray a better picture of ash and potash yield potentials of plant materials. When wood (in form of sawdust) is combusted to ashes, on average the volume is reduced by 95% (Babayemi and Adewuyi, 2010), the values of ash content range from 1.42 to 15.18 kg m^{-3} (weight per volume of sample); potash contents range from 4.74 to 53.76 kg m^{-3} (weight per volume of ashes) and 0.21 to 1.53 kg m^{-3} (weight per volume of sample) (Table 2).

Alkali and non-alkali components of potash: Potash content refers to the water-soluble content of the residue obtained after complete evaporation of the extract solution leached from ashes. The potash is supposed to be mainly carbonates and/or hydroxides of alkali metals (Na or/and K); but in most cases, it contains other water-soluble non-alkali substances such as some chloride and sulphate salts. In some studies, certain plant materials gave higher non-alkali content than the alkali content. Examples were *Irvingia garbonensis* with non-alkali content of 95.5%: a whitish water-soluble salt and *Cola gigantia* with non-alkali content of 95.5%: a brownish water-soluble salt (Adewuyi *et al.*, 2008). With appropriate separation methods (especially recrystallization), different components in the crude potash can be separated and obtained in pure form.

Determination of potash content: To determine the potash content of a plant material, a known weight of the material is completely combusted to ashes. The ash is leached with a known volume of water. The leachate contains all water-soluble inorganic compounds, forming the impure (crude) potash. The resulting potash could be obtained in dry form by evaporating the leachate to complete dryness and drying the residue to constant weight in an oven at 105°C. If weight w_1 of ash is extracted with water of volume v and after evaporation of volume v_1 to complete dryness, a residue with constant weight w_2 is obtained, Potash Content (PCa) (% of ash) is derived as:

$$v_1 \text{ yields } w_2$$

Then v yields:

$$\frac{w_2}{v_1} \times v \text{ (unitweights)} \tag{1}$$

$$PC_a = \left(\frac{w_2}{v_1}\right) \times \frac{1}{w_1} \times 100 \tag{2}$$

Non-Potash Content (NPC_a) (% of ash) is given by:

$$NPC_a = 100 - \left(\frac{w_2}{v_1} \times v\right) \times \frac{1}{w_1} \times 100 \tag{3}$$

If sample of weight w has yielded the ash w_1, the potash content (PCS) (% of sample) is given by:

$$PC_a = \left(\frac{w_2}{v_1} \times v\right) \times \frac{1}{w_1} \times 100 \tag{4}$$

Non-potash content (NPCs) (% of sample) is given by:

$$NPC_a = 100 - \left(\frac{w_2}{v_1} \times v\right) \times \frac{1}{w_1} \times 100 \tag{5}$$

Metal content of potash: The insoluble components of ashes consist of silicates and compounds of other metals

Table 3: Concentration (mg kg^{-1}) of Metals in some varieties of banana and plantain

Metals	Cavendish banana	Paranta	Plantain	Omini banana	Red banana	Lady finger
K	513.40	330.10	374.90	112.70	720.00	350.20
Na	37.40	113.50	191.80	187.60	109.00	61.60
Mg	7.60	49.90	105.80	109.20	174.60	270.60
Ca	31.20	31.20	30.10	20.10	30.10	23.40
Cu	20.10	20.10	4.10	2.60	3.20	11.20
Fe	1.30	26.40	8.80	30.90	5.90	15.10
Zn	2.90	20.90	31.10	10.10	21.10	12.10
Pb	2.80	3.50	3.10	5.30	6.10	8.60

Source: Babayemi *et al.*(2010a)

Table 4: Concentration of metals in some wood species

Metals	Pine (wt. % of ash)	Aspien (wt. % of ash)	Poplar (wt. % of ash)
K	16.24	11.25	7.93
Na	0.06	0.06	2.30
Mg	7.03	3.55	9.09
Ca	29.05	21.17	25.67
Cu	0.04	0.03	0.03
Fe	0.58	0.26	0.32
Zn	0.36	0.34	0.04

Source: Misra *et al.* (1993)

which are not soluble or are sparingly soluble in water. Hence when ash is leached with water, only the carbonates and perhaps chlorides and sulphates (if present) of alkali metals go into solution, including a minute fraction of those other metals which are not or are sparingly soluble. This was evident in the findings of Babayemi *et al.* (2010a) in which the metal ion concentrations in the leachate were very low compared to the values observed in the corresponding analysis of the crude ash, except the alkali metals and Mg and Ca. Table 3 show typical analysis of alkali and some other metals in some varieties of Musa species, the values range from 37.40 to 720 mg kg^{-1} for Na and K and from 1.30 to 270.60 mg kg^{-1} for other metals. The lowest concentrations were observed for Pb and the highest for K, followed by Na and Mg. Variations in metal concentrations also occur in wood species (Table 4); as observed by Misra *et al.* (1993), the values ranged from 0.04 to 29.05% (of ash) for pine; 0.03 to 21.17% (of ash) for aspen and 0.03 to 25.67% (of ash) for poplar. The lowest values were observed for Cu and Na, while the highest values were observed for Ca, followed by K. Expressed in a better way, K, Na and Mg dominate in Musa species; while Ca and K dominate in wood species. Further studies are suggested to establish if these observations for Musa and wood species are generally true.

Determination of alkali content: The alkali content of potash consists of the potassium and/or sodium carbonates. It was reported in some literatures to be hydroxide of K and/or Na (Kuye and Okorie, 1990). Usually this is determined by acid-base titrimetry, using methyl orange and/or phenolphthalein indicator(s). Some weight (about 3.45 g) of the crude potash is dissolved with distilled water in a 250 mL volumetric flask and made up to mark. An aliquot is titrated with 0.1 M HCl. If total alkali content is of interest, methyl orange is used as the indicator and if only the hydroxide content is of interest, phenolphthalein indicator is used. The individual hydroxide and carbonate contents may be determined by using the double-indicator (phenolphthalein and methyl orange) method. The phenolphthalein indicator is first added to the aliquot and the point of change in colour indicates the neutralization of the whole of hydroxides and half of the carbonates:

$$X_2CO_3(aq) + XOH_{(aq)} + 2HCl_{(aq)} \rightarrow 2XCl_{(aq)} + HCO^-_{3(aq)} + H_2O_{(l)} \quad (6)$$

where, X is the alkali metal.

The methyl orange is then added to continue the titration and the point of change in colour indicates the completion of neutralization of the other half of the carbonates (that is, bicarbonates):

$$XHCO^-_{3(aq)} + HCl_{(aq)} \rightarrow XCl_{(aq)} + CO_2(g) + H_2O_{(l)} \quad (7)$$

Hence, the use of only phenolphthalein indicator to determine the molarity of ash-alkali extract (Onyegbado *et al.*, 2002) assumes the ash-alkali extract to be alkali metal hydroxides only (Nwoko, 1980; Onyekwere, 1996; Kuye and Okorie, 1990); but the facts have been established (Adewuyi *et al.*, 2008; Kevin, 2003) that the ash-alkali extract contains both alkali metal carbonates and hydroxides, though the hydroxide content may be very small.

Ash-alkali extract of Na and K: The supposition that the ash-alkali extract is alkali hydroxide could have been brought about by the explanation that K_2O and/or Na_2O is/are formed during the combustion of a plant material and these dissolve in water during extraction to form hydroxides (Onyegbado *et al.*, 2002). But it may be said that the formation of K_2O or Na_2O could just result from the burning of pure metals (K or Na) in air; since the K or Na in the plant material is bound in the organic matrix of the plant matter, the excessive release of CO_2 gas in the combustion system will rather favour the formation of carbonates of these metals than their oxides (Adewuyi *et al.*, 2008; Kevin, 2002).

Table 5 shows ash-alkali extract of Na and K in some agro-wastes as reported by Taiwo and Osinowo (2001). The levels of hydroxides are lower than carbonates and both the hydroxides and carbonates contents of K are higher than those of Na. this implies that the main alkalis are carbonates and they are those of K.

Table 5: Ash-alkali due to K and Na in some agro-wastes

Alkali	Cocoa-pod ash	Palm-bunch ash	Sorghum chaff ash	G. nut shell ash
K_2CO_3	56.73±0.16	43.15±0.13	12.40±0.08	16.65±0.05
KOH	16.07±0.05	15.91±0.10	5.22±0.06	9.80±0.05
Na_2CO_3	0.17±0.03	0.36±0.04	0.22±0.02	0.24±0.02
NaOH	0.07±0.02	0.13±0.03	0.08±0.02	0.09±0.02

Source: Taiwo and Osinowo (2001)

Alkaline property of potash: Potassium and sodium belong to group I in the periodic table of elements and one major property of group I elements is the formation of soluble salts and bases. Hence, the hydroxides and carbonates of K and Na are soluble in water. Applying the explanation of Kevin (2003), the alkaline character of potash (a crude form of potassium carbonate) when dissolved in water is summarized by Eq. 8-9 below:

$$H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)} \quad (8)$$

$$K_2CO_{3(aq)} \rightarrow 2K^+_{(aq)} + CO^{2-}_{3(aq)} \quad (9)$$

$$H_2O_{(l)} + CO^{2-}_{3(aq)} \rightleftharpoons HCO^-_{3(AQ)} + OH^-_{(aq)} \quad (10)$$

$$H^+_{(aq)} + CO^{2-}_{3(aq)} \rightleftharpoons HCO^-_{3(aq)} \quad (11)$$

Self ionization of water produces equal number of OH^- and H^+ ions. When potash is introduced, it also ionizes into K^+ and CO_3^{2-} ions. The CO_3^{2-} ion abstract H^+ ion from water, resulting in a decrease in H^+ ion but an increase in OH^- ion, which leads to increase in pH (alkaline condition).

Relationship between ash and potash contents: It would be expected that the higher the ash content the more the potash yield; that is, an existence of highly linear relationship between the two; but this may not be true in all cases. In Fig. 1, the ash content is strongly correlated with the potash yield (% of dry sample) (that is, R^2 = 0.893) for varieties of Musa species; whereas poor correlation is observed for sawdust of some wood species (R^2 = 0.0324) (Fig. 2). This sharp disparity could perhaps be a reflection of the degree of variation in intra-species chemical composition of plant materials, which seems to be low in Musa species (may be because of high content of soluble metal compounds) and high in wood species (perhaps as a result of high content of silicate and other insoluble metal compounds). In other words, relationship between ash and potash content varies with the species of plants.

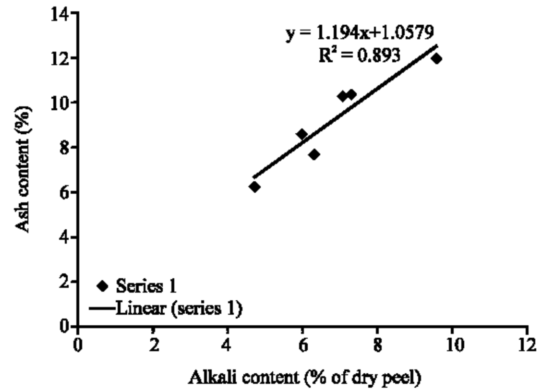

Fig. 1: Correlation between ash contents and alkali contents (% of dry peel of Musa species). Source: The data used are taken from Babayemi *et al.* (2010a)

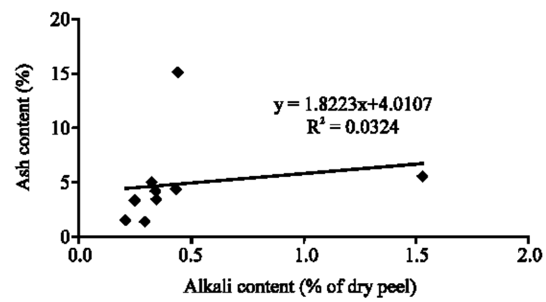

Fig. 2: Correlation between ash content and alkali content (% of sawdust of wood samples). Source: The data are taken from Adewuyi *et al.* (2008)

CONCLUSION

Ash and potash have compositions which vary with plant materials used. Potassium carbonate is the main ash-alkali and it is a fraction of the crude potash, since other non- alkali substances may be present in substantial amount. Plant species, nature of soil where the plant grows, application of appropriate chemistry and technology are some of the factors which influence both qualitative and quantitative determinations of components of ash and potash.

REFERENCES

Adewuyi, G.O., N.O. Obi-Egbedi and J.O. Babayemi, 2008. Evaluation of ten different African wood species for potash production. Int. J. Phys. Sci., 3: 63-68.

Afrane, G., 1992. Leaching of caustic potash from cocoa husk ash. Bioresour. Technol., 41: 101-104.

Ankrah, E.K., 1974. Chemical studies of some plant wastes from Ghana. J. Sci. Food Agric., 25: 1229-1232.

Babayemi, J.O. and G.O. Adewuyi, 2010. Assessment of combustion and potash production as options for management of wood waste. J. Applied Sci. Environ. Manage., 14: 73-75.

Babayemi, J.O., K.T. Dauda and A.A.A. Kayode, 2010a. The ancient alkali production technology and modern improvement. Asian J. Applied Sci.,

Babayemi, J.O., K.T. Dauda, A.A.A. Kayode, D.O. Nwude, J.A. Ajiboye, E.R. Essien and O.O. Abiona, 2010b. Determination of potash alkali and metal contents of ashes obtained from peels of some varieties of Nigeria Grown Musa species. Bioresource, 5: 1384-1392.

Kevin, M.D., 2002. A primitive alkali: Potash. Caveman Chem.,

Kevin, M.D., 2003. Caveman Chemistry: 28 Projects, from the Creation of Fire to the Production of Plastics. Chapter 8, Universal Publishers, Australia.

Kuye, A.O. and C. Okorie, 1990. Factors affecting the lixiviation of palm bunch ash as a source of alkali for soap production. Ife J. Technol., 3: 33-37.

Misra, M.K., K.W. Ragland and A.J. Baker, 1993. Wood ash composition as a function of furnace temperature. Biomass Bioenergy, 4: 103-116.

Nwoko, V.O., 1980. Chemical processing development. Proceedings of the 10th Annual Conference of the Nigerian Society of Chemical Engineers (NSCE'80), Nigeria, pp: 40-53.

Onyegbado, C.O., E.T. Iyagba and O.J. Offor, 2002. Solid soap production using plantain peels ash as source of alkali. J. Applied Sci. Environ. Manage., 6: 73-77.

Onyekwere, C., 1996. Cassava peels ash: An alternative source of alkali in soap production. B.Eng. Thesis, Department of Chemical Engineering, University of Port Harcourt, Port Harcourt, Nigeria.

Selema, M.D. and M.E. Farago, 1996. Trace element concentrations in the fruit peels and trunks of *Musa paradisiaca*. Phytochemistry, 42: 1523-1525.

Taiwo, O.E. and F.A.O. Osinowo, 2001. Evaluation of various agro-wastes for traditional soap production. Bioresour. Technol., 79: 95-97.

Tarun, R.N., N.K. Rudolph and S. Rafat, 2003. Use of wood ash in cement-based materials. http://www4.uwm.edu/cbu/abstracts/03-513.pdf.

Wikipedia, 2007. Potash. Free Encyclopedia, http://en.wikipedia.org/wiki/potash.