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The Effect of Source and Thermal Combustion of Maize Plant for the Production Maize Stover Ash Potash (MSAP)

Ogunwede O. I.
Assistant Director, Department of Mechanical Engineering,
Federal University of Technology, Nigeria
Abolarin, M. S.
Professor, Department of Mechanical Engineering,
Federal University of Technology, Nigeria
Abdulrahman, A. S.
Senior Lecturer, Department of Material and Metallurgical Engineering,
Federal University of Technology, Nigeria
Olugboji, O. A.
Senior Lecturer, Department of Mechanical Engineering,
Federal University of Technology, Nigeria
Agboola, J. B.
Senior Lecturer, Department of Mechanical Engineering,
Federal University of Technology, Nigeria

Abstract:
The effect of source and thermal combustion of maize plant for the production of MSAP was investigated. MSAP is a maize stover ash potash which is majorly a potassium based salt. This salt could be chlorides, sulphates and nitrates, but the qualities and properties of potassium in potash differ due to the source of such plants and the temperature of combustion into ash. The combustion of stover into ash for the production of potash can either be done in open air or closed system such as furnace. This study investigated the quality of potash derived from the ashes of maize Stover, dried to a constant weight and thermally combusted in the open and closed systems. The result showed that the potash has varying qualities of potassium salts due to source and mode of combustion. The analyses of the properties of MSAP by NAA and XRD showed that the qualitative and quantitative elements present include K,Na, Cl, Ca, Mn and other trace elements. These elements appear as a eutectic mixture, and the potash revealed as Halite, K-rich syn.

Keywords*: Potash, temperature, maize Stover, ash, MSAP*

1. Introduction

Potash denotes a variety of mined mineral ore or manufactured salts derived from leached alkaline water from the ashes of plants, all of which contain potassium as the major element (Kelvin, 2003, Joyce, 2007). The word "potassium" was derived from potash, and potash, equivalent to "pot ash", which refers to plant ashes soaked in a water pot, as the primary means of manufacturing the product via traditional techniques before the industrial era (EML, 2012). It was reported that there are a number of such mined or manufactured minerals with varying potassium contents, but only those that are water-soluble are of significant commercial interest (Joyce, 2007). The most common commercial product is potassium chloride (KC1), which is also known as muriate of potash ("MoP") or sylvite, which is principally used for the production of agricultural fertilizers (Joyce., 2007, EML., 2012). Various chemical compounds containing potassium have the word potash in their traditional names. Meanwhile, some common potassium containing minerals have been grouped as chlorides, sulphates and nitrates (Ipini., 2012). The use of potash has been found in different areas such as fertilizer, soap production, bleaching textiles, glass making, food seasoning and for consumption, to control hypertension by patients with hypertensive diagnosis to mention but a few. The properties and the quality of potash derived from leached ashes are predicated on the type of plant ashed, its geological source (PDA., 2012), and the temperature of ashing; to this end, the characteristics of potash are numerous. Meanwhile, John., (2012) reported that when two cations have the same charges and a similar radius, a mineral that contains one of the cations may contain the other as well, thus forming a solid solution of eutectic mixture. Common examples include Mg^{+2} and Fe^{+2} as in olivine, Na^{+1} and K^{+1} as in alkali feldspar, Al^{+3} and Fe^{+3} as in garnet etc. In this study, the focus is on the effect of thermal combustion on the ash and the geological location of maize stovers for the production of potash with respect to its quality via NAA and XRD analysis.

2. Quality of Maize Stover Ash Potash

Maize Stover Ash Potash (MSAP) is a derivative of potash from maize plant ashes derived specifically from dried maize Stover, thermally combusted into inorganic activated ash, dissolved in water, filtered and its alkaline water evaporated into crystals. The crystalline compound formed is referred to as "potash". Bisyplan, (2015) revealed that EN15297 and EN15290 standards recorded there are two main groups of elements in the ash, the "minor and the major elements". The minor elements include: As, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, V, and Zn with small concentrations, while the major elements are Al, Ca, Fe, Mg, P, K, Si, Na, and Ti, but the most important of the major elements are: Si, Ca, K, Na, and P. The interaction of these elements in any potash will determine its qualities and properties. In addition, the temperature for the thermal combustion of the ash plays a major role in the quality and quantity of potash derived which can be analyzed with the use of modern equipment. The composition of the ashes also depends on the sources, species of plant materials and the nature of the soil where the plants grow; similarly, the part of the plant combusted may also determine the ash yield and its compositions (Babayemi et al., 2010). Primarily, the potash extracted from the alkaline of ash of plants is supposed to be mainly carbonates and/or hydroxides of alkali metals (Na and or K)(EML., 2012), but in most cases, it could contain other water-soluble non-alkali substances such as some chloride and sulphate salts (Babayemi., et al, 2010). For total ash determinations, ashing is completed in a muffle furnace with a controlled temperature ranging between 400^oC to 700^oC, but 550^oC is most satisfactory to avoid loss of important elements (Yeshajahu, and Clifton., 2004). Meanwhile, traditional producers of potash do carryout the ashing at lower temperature in the open atmosphere where it is difficult to regulate the ashing temperature that varies between 300^oC to 400^oC. To this end, the quality of potash produced is found to be different from the one produced under regulated temperature.

3. Materials and Methods

Three samples of maize stovers were used in this study. Two samples were collected from the same source on a maize farm at Industrial development Centre (IDC), Sabon Gari local government area, Zaria Kaduna State, and a third sample of maize stover was obtained from a maize farm at Michika local government area, Adamawa State. One of the samples from IDC was thermally combusted in a muffle furnace at a controlled temperature of 550^oC into total ash; while the other two samples, the second from IDC and the third from Adamawa were thermally combusted in the open atmosphere until the ash was completed at 367^oC respectively. The ashes of the three samples were dissolved in water, filtrated, and the alkaline filtrate was evaporated until crystals of potash formed. The three samples of the potash produced were analyzed. The qualitative and quantitative mineralogical analyses of the samples were determined using Neutron Activated Analysis (NAA) and X-ray Refractive Diffractometer (XRD). The NAA was used to determine the elemental composition and quantification of the samples, while the XRD was used to determine the molecular structure, empirical formula, chemical formula, compound name and mineral type present in the samples taken. NAA was conducted at the Centre for Energy Research and Training (CERT), Ahmadu Bello University Zaria, using NRR-1, model MNSR, 2004, while the XRD was carried out with PAN alytical X'pert Pro Mrd PW2040 XRD Diffractometer at Tshwane University of Technology, Pretoria South Africa. The results obtained were used to corroborate each other.

4. Results and Discussion

Table 1 shows the chemical composition of the three MSAP salts analyzed using Neutron Activated Analysis (NAA), indicating the plants source and ash temperature. The result showed that the compounds are potassium-based salts with the following qualitative compositions such as Na, K, Mn, Cl, Ca, V, Al, but the quantitative compositions of the compounds were found to be different from each other. The result is reported in percentage concentration.

		Ash of Plant from Same Source (IDC)		**Ash of Plant from Other Source (Michican)**
S/No	Elements	Potash from Ash of Sample A at 550^oC (%)	Potash from Ash of Sample B at 367^oC (%)	Potash from Ash of Sample C at 367^oC (%)
1	Na	0.026	0.014	0.037
2	K	50.750	23.070	27.430
3	Mn	0.001	0.000	0.000
4	Cl	29.009	15.210	26.960
5	Ca	0.601	BDL	BDL
6	V	BDL	0.001	BDL
7	Al	BDL	BDL	0.053
8	Others	BDL	BDL	BDL

Table 1: Source of Plant, Ash Temperature and Chemical Composition of MSAP Salt by NAA
BDL = Below Detection Limit

Samples A and B were materials from the same source location but were ashed under different atmospheric conditions. The ashes of sample A were thermally combusted in a muffle furnace at 550^{o}C, while the ashes of samples B and C were done in the open ambient atmosphere and their ashing completed at 367^{o}C. While sample A had potassium concentration of 50.750%K, sample B had 23.070%K and sample C had 27.430%K. Similarly, sample A has 0.601%Ca, while calcium was completely absent in Sample B, but sample B showed traces of vanadium (0.001%) in its concentration. This has pointed out that ashing temperature plays an important role in the quality of potash compositions derived. In the same logic, comparing samples B and C that were thermally combusted under the same ambient atmospheric temperature but having their plants from different sources, were found to have different compositional values. The result also shows that the samples are potassium based salts. While sample B contains 23.070%K, sample C has 27.430%K. In addition, sample B has traces of vanadium (0.001%V) without the presence of aluminum, while sample C contains some level of aluminum (0.053%Al) but without the traces of vanadium. This also proved that sources of location of the plant ashed are a contributing factor in determining the qualitative and quantitative value of the potash produced. Corroborating the three samples, it is noted that thermal temperature can affect the calcium in the potash produced if the plants are thermally combusted in the open atmosphere. Likewise, the source of the plant can determine whether there is the presence of aluminum or vanadium in the final product or not. It could therefore be inferred that thermal temperature and source location of the plants ashed are contributing factors in determining the qualitative and quantitative value of the potash produced from maize stover ash. Looking at the quality of the potash formed, sample A reflects a better quality having a higher quantitative value of potassium, chloride, calcium, sodium and traces of manganese present in the eutectic salt than the other two samples B and C. However, sample C could be of good use in some other areas of applications since it contains about 0.05%Al.

4.1. Compositional Analysis of MSAP Using XRD

From the XRD analysis of the MSAPs, Figure1 is the spectra for the chemical names for the MSAP sample A derived from the ash that was thermally combusted in a controlled atmosphere in a muffle furnace at 550^{o}C.The spectrum revealed that the MSAP of sample A contained different phases of minerals.

It was observed from Tables 2 and 3, for the same ample A, that the major diffraction peaks are 28.29^{o}, 29.85^{o}, 30.69^{o}, 31.64^{o}, 38.84^{o} and 40.52^{o} and their inter-planar distances are 3.15Å, 3.00Å, 2.91Å, 2.83Å, 2.32Å and 2.22Å respectively. The relative intensity of the X-ray scattering is 100.00, 9.19. 38.14, 46.96, 9.92, and 83.90 respectively, and their phases at these peaks after matching are Sylvite, syn (KCl.Ca), Sodium Potassium Chloride (NaKCl), Sodium Potassium Chloride (NaKCl), Calcium Chloride ($CaCl_2$), Hydrophilte, syn ($CaCl_2$), and Sylvite, syn (KCl.Ca) respectively. The minerals contained in this potash are the chlorides of potassium, sodium and calcium. This is in conformity with the NAA analysis reported in Table 1. It has been highlighted in Table 1 that the quantitative value of Calcium is 0.601%, therefore it could be inferred that the minerals present in the potash of sample A are chlorides of Na, K and that of Ca, which proved that the potash is a combination of eutectic salts.

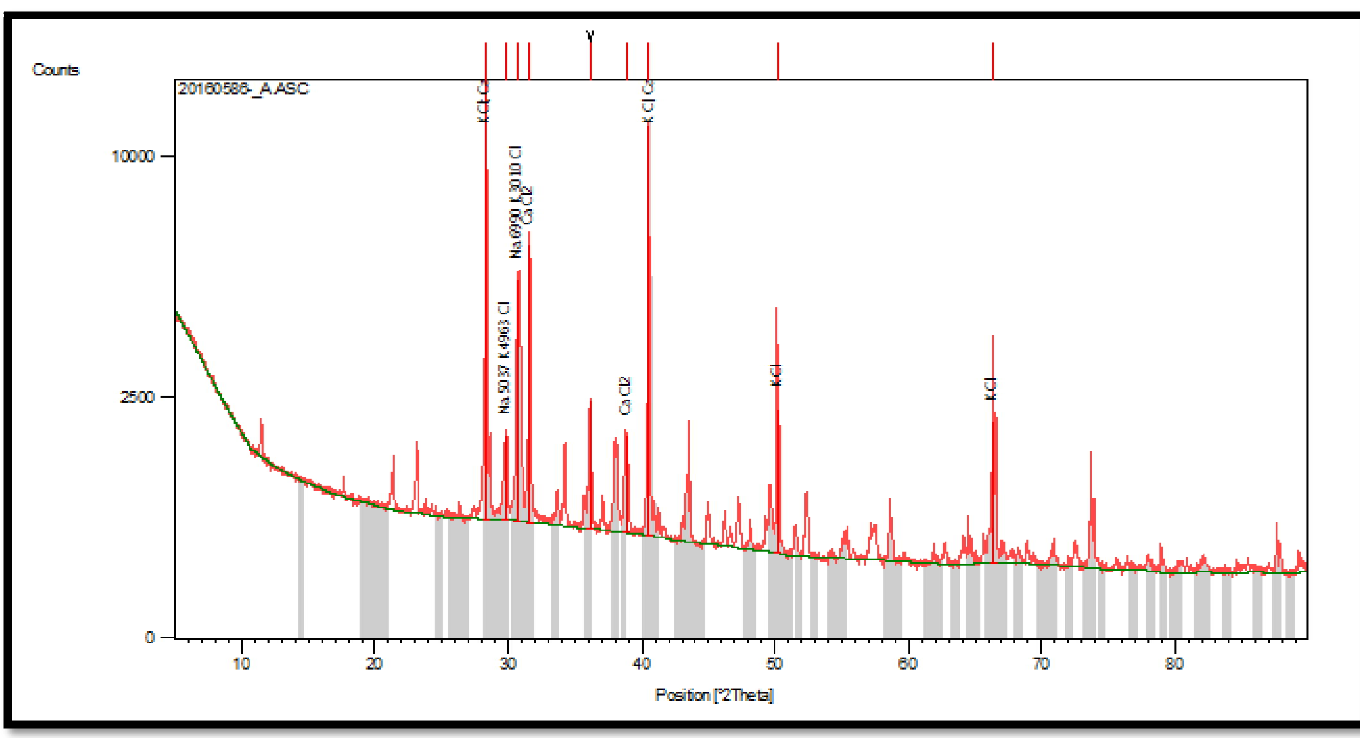

Figure1: Sample a XRD Spectra: Chemical Name

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-spacing [Å]	Rel. Int. [%]	Tip width [°2Th.]	Matched by
28.2891	12954.28	0.0836	3.15481	100.00	0.0850	04-0587; 10-0348
29.8463	1191.10	0.2676	2.99366	9.19	0.2720	75-0301
30.6871	4941.14	0.1673	2.91352	38.14	0.1700	75-0303
31.6364	6082.98	0.1338	2.82824	46.96	0.1360	49-1092
36.1349	1901.19	0.1673	2.48580	14.68	0.1700	
38.8403	1284.50	0.3346	2.31866	9.92	0.3400	01-0338
40.5194	10868.06	0.0669	2.22637	83.90	0.0680	04-0587; 10-0348
50.2182	1945.81	0.2007	1.81678	15.02	0.2040	04-0587
66.4042	1769.73	0.4896	1.40670	13.66	0.4080	04-0587

Table 2: Peak List of Sample A
1 Å = $1x10^{-10}$m

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	04-0587	*77	Sylvite, syn	0.000	1.080	K Cl.Ca
*	75-0301	*30	Sodium Potassium Chloride	0.000	0.046	Na.5037 K.4963 Cl
*	75-0303	*27	Sodium Potassium Chloride	0.000	0.028	Na.6990 K.3010 Cl
*	75-0297	*26	Sodium Potassium Chloride	0.000	0.058	Na.1002 K.8998 Cl
*	49-1092	21	Calcium Chloride	0.000	0.209	Ca Cl2
*	01-0338	17	Hydrophilite, syn	0.000	0.024	Ca Cl2
*	26-0918	16	Halite, K-rich, syn	0.000	0.168	K0.2 Na0.8 Cl
*	10-0348	*39	Calcium	0.000	0.736	Ca

Table 3: Identified Patterns List of the XRD of Sample A

Figure 2 is the spectral for MSAP sample B.The ash for the potash of MSAP sample B was thermally combusted in an open ambient atmospheric conditions at 367^{o}C.The spectral revealed that the MSAP of sample B contained different phases of minerals. And the major diffraction peaks as detailed in Tables 4 and 5 are 27.95^{o}, 42.63^{o}, 49.70^{o}, 66.01^{o}, and 73.26^{o} and their inter-planar distances are 3.19Å, 2.12Å, 1.83Å, 1.42Å and 1.29Å respectively. The relative intensity of the X-ray scattering is 70.63, 78.19. 35.21, 53.85, and 37.16, and their phases at these peaks after matching are Potassium (K), Potassium Sodium (K. Na_2). Sodium Potassium Chloride (NaKCl), Potassium Chloride (KCl), Halite (NaCl) and Halite, K-rich syn, (KNaCl). The minerals contained in this potash are the chlorides of potassium and sodium. This is in conformity with the NAA analysis reported in Table 1. Therefore, it could be inferred that the minerals present in the potash of sample B are chlorides of Na and K, which proved that the compound is a combination of eutectic double salts.

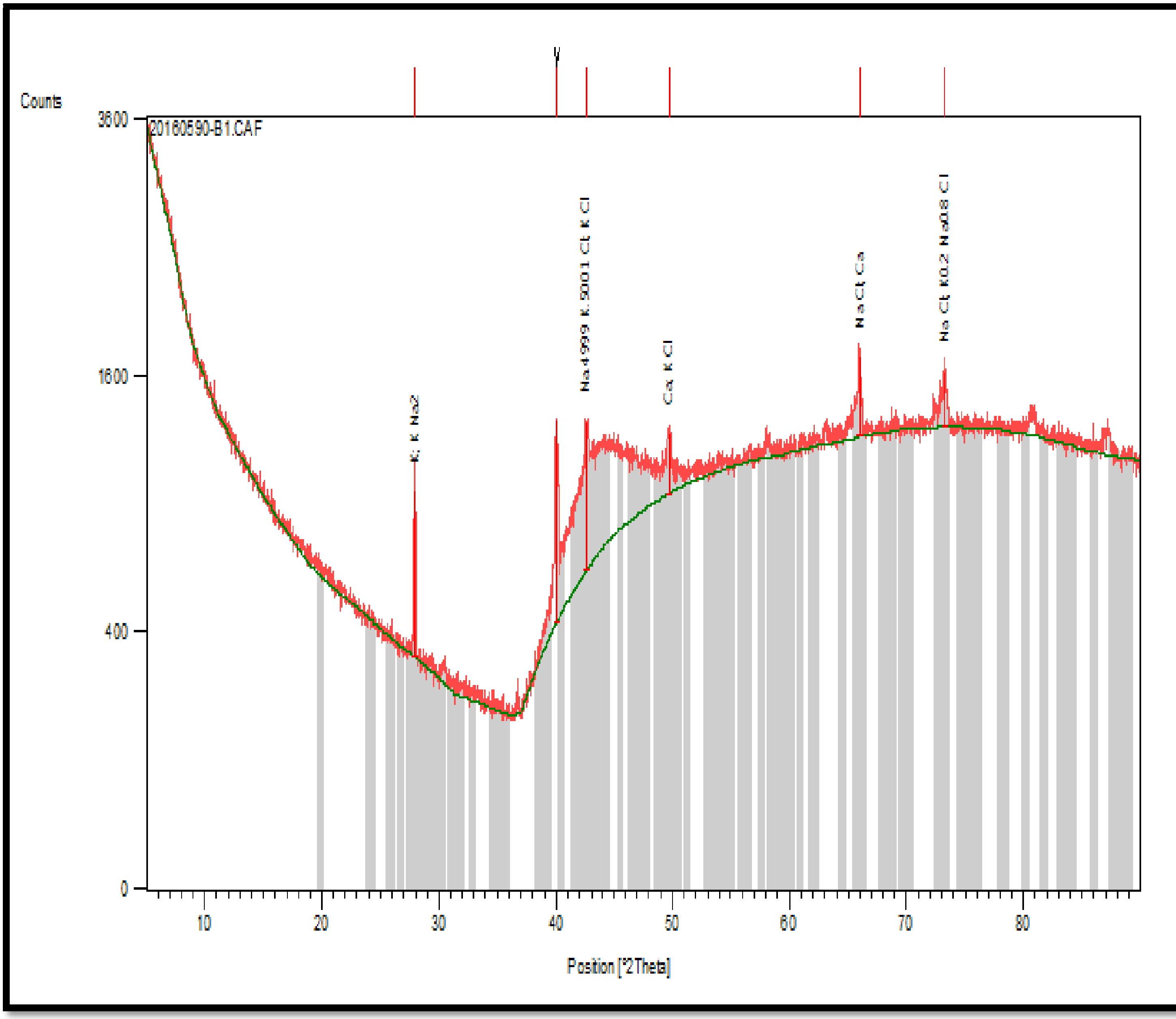

Figure 2: Sample B XRD Spectra: Chemical Name

Pos. [°2Th.]	Height [CTS]	FWHM [°2Th.]	d-Spacing [Å]	Rel. Int. [%]	Tip Width [°2Th.]	Matched by
27.9522	638.23	0.1673	3.19206	70.63	0.1700	39-1051; 10-0244
40.0999	903.66	0.0816	2.24682	100.00	0.0680	
42.6278	706.56	0.2676	2.12101	78.19	0.2720	75-0300; 77-2121
49.7006	318.19	0.4015	1.83448	35.21	0.4080	10-0348; 77-2121
66.0144	486.65	0.2676	1.41523	53.85	0.2720	01-0994; 10-0348
73.2624	335.76	0.3264	1.29101	37.16	0.2720	01-0994; 26-0918

Table 4: Peak List of Sample B
1 Å = 1x10^{-10}m

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	39-1051	24	Potassium	0.000	0.309	K
*	40-0994	21	Potassium	0.000	0.088	K
*	02-0621	18	Hydrophilite	0.000	0.154	Ca Cl2
*	01-0994	18	Halite	0.000	0.216	Na Cl
*	75-0300	16	Sodium Potassium Chloride	0.000	0.982	Na.4999 K.5001 Cl
*	83-1728	14	Sodium Chloride	0.000	0.117	Na Cl
*	10-0348	13	Calcium	0.000	0.197	Ca
*	26-0918	14	Halite, K-rich, syn	0.000	0.842	K0.2 Na0.8 Cl
*	10-0244	15	Potassium Sodium	0.000	0.246	K Na2
*	77-2121	0	Potassium Chloride	0.000	0.065	K Cl

Table 5: Identified Patterns List of the XRD of Sample B

Figure 3 is the spectra forthe MSAP of sample C.The ash for the potash of MSAP sample C was also combusted in an open ambient atmospheric conditions at 367^{o}C.The spectral revealed that the MSAP of sample C also contains different phases of minerals. Tables 6 and7 showed the major diffraction peaks after matching as 28.07^{o}, 30.46^{o}, 31.37^{o}, 35.85^{o}, 38.18^{o}, 40.25^{o}, 42.64^{o} and 80.74^{o} and their inter-planar distances are 3.18Å, 2.93Å, 2.85Å, 2.51Å, 2.36Å, 2.24Å, 2.12Å and 1.19Å respectively. The relative intensity of the X-ray scattering is 12.50, 19.27, 28.96, 8.05, 88.96, 30.39, 100.00 and 28.89, and their phases at these peaks are [Calcium (Ca), Potassium (K), Potassium Sodium ($K.Na_2$)], [Sodium Potassium Chloride (Na.K.Cl), Potassium Calcium Chloride ($K.CaCl_3$), Halite, K-rich syn, (KNaCl)], [Sodium (Na), Potassium (K), Sodium Potassium Chloride (Na.K.Cl), Hydrophilite ($CaCl_2$)], [Potassium (K)], [Hydrophilite ($CaCl_2$)], [Calcium (Ca), Hydrophilite ($CaCl_2$)], [Sodium Potassium Chloride (Na.K.Cl), Potassium Calcium Chloride ($K.CaCl_3$)] and [Sodium (Na), Potassium Chloride (KCl)]. The minerals contained in this potash are the chlorides of potassium, sodium and Hydrophilite. This is in conformity with the NAA analysis reported in Table 1, with the presence of aluminum. Even though calcium is below detection limit, The XRD has revealed that some level of traces of calcium is present in the sample. Therefore, it could be inferred that the minerals present in the potash of sample C are chlorides of Na, K and Ca which proved that the potash is a combination of eutectic double salts with traces of aluminum.

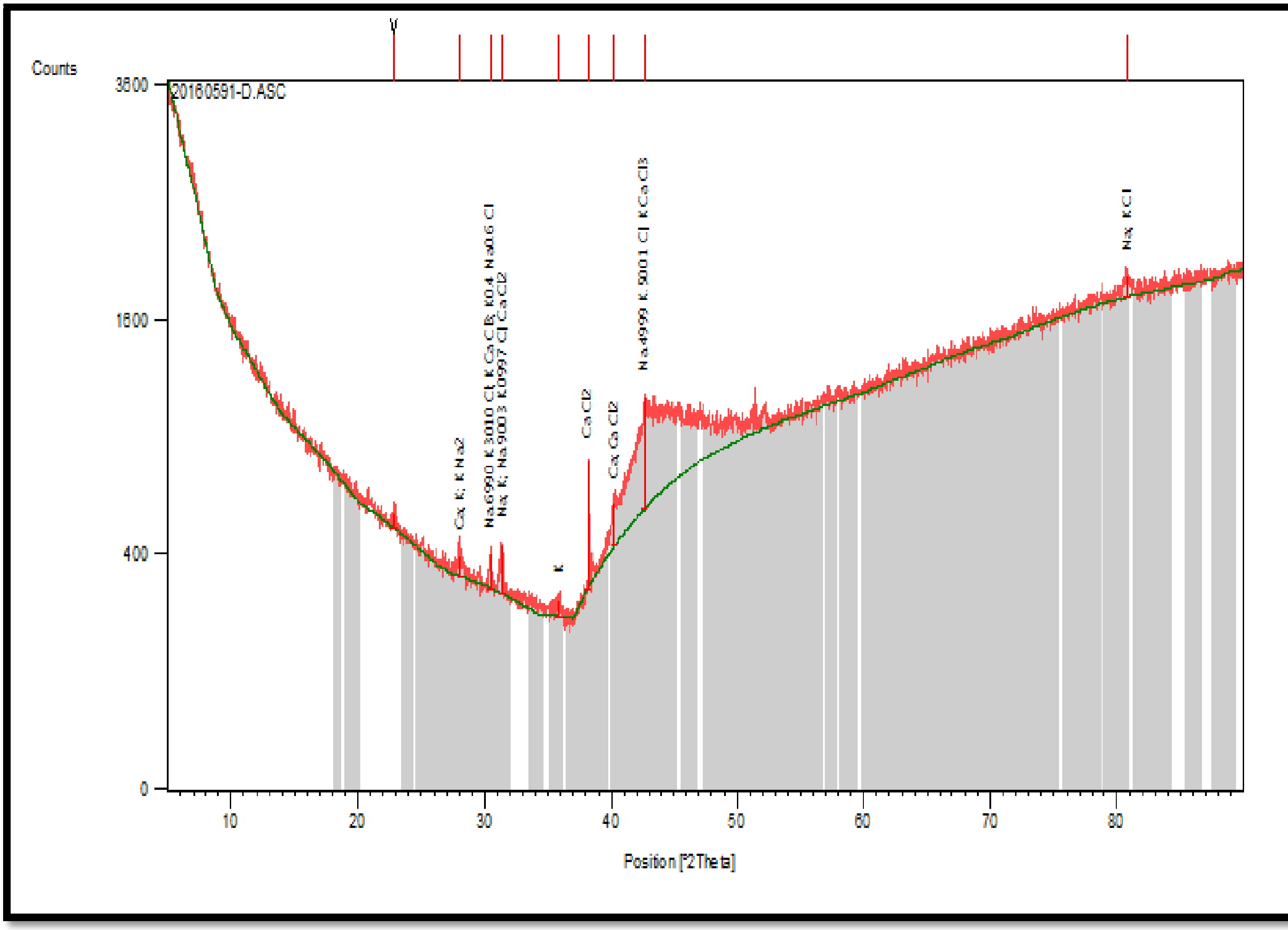

Figure 3: Sample C XRD Spectra: Chemical Name

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-Spacing [Å]	Rel. Int. [%]	Tip Width [°2Th.]	Matched by
22.8761	59.30	0.4015	3.88757	10.86	0.4080	
28.0770	68.25	0.4015	3.17815	12.50	0.4080	10-0348; 39-1051; 10-0244
30.4614	105.26	0.2007	2.93460	19.27	0.2040	75-0303; 25-0625; 26-0919
31.3655	158.14	0.1673	2.85204	28.96	0.1700	09-0188; 40-0995; 75-0305; 24-0223
35.8469	43.99	0.5353	2.50511	8.05	0.5440	39-1051
38.1764	485.83	0.0612	2.35549	88.96	0.0510	24-0223
40.2548	165.94	0.4015	2.24039	30.39	0.4080	10-0348; 24-0223
42.6383	546.13	0.2007	2.12051	100.00	0.2040	75-0300; 25-0625
80.7350	157.78	0.6528	1.18931	28.89	0.5440	09-0188; 78-0656

Table 6: Peak List of Sample C
1 Å = 1x10^{-10}m

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	75-0303	31	Sodium Potassium Chloride	0.000	0.296	Na.6990 K.3010 Cl
	10-0348	27	Calcium	0.000	0.242	Ca
	09-0188	28	Sodium	0.000	0.180	Na
*	40-0995	23	Potassium	0.000	0.325	K
*	78-0656	12	Potassium Chloride	0.000	0.083	K Cl
*	39-1051	20	Potassium	0.000	0.394	K
*	75-0300	17	Sodium Potassium Chloride	0.000	1.281	Na.4999 K.5001 Cl
*	75-0305	17	Sodium Potassium Chloride	0.000	0.320	Na.9003 K.0997 Cl
*	10-0244	18	Potassium Sodium	0.000	0.327	K Na2
*	01-0786	0	Sylvite	0.000	0.108	K Cl
*	25-0625	17	Potassium Calcium Chloride	0.000	0.191	K Ca Cl3
*	75-0304	11	Sodium Potassium Chloride	0.000	0.268	Na.8243 K.1757 Cl
*	75-0299	13	Sodium Potassium Chloride	0.000	0.725	Na.3835 K.6165 Cl
*	01-0500	8	Potassium	0.000	1.246	K
*	26-0919	17	Halite, K-rich, syn	0.000	0.266	K0.4 Na0.6 Cl
*	24-0223	19	Hydrophilite [NR]	0.000	0.296	Ca Cl2

Table 7: Identified Patterns List of the XRD of Sample C

5. Summary and Conclusion

In this work, the potash produced from the alkaline of the ashes from maize stovers was presented. Two maize stover from the same source and the third maize stover from a different source were thermally combusted under different atmospheric conditions. One was thermally combusted under a controlled atmosphere while the other two maize stovers were thermally combusted in the open atmosphere. The potash from the alkaline from the three different ashes were all analyzed to determine the effect of temperature on the derived potash, and also to know if the sources of the plants ashed have significant effect on the potash quality produced. The analyzed result using NAA and XRD revealed that the quality of the potash of the plants from different sources differs, likewise the qualities of the potash of the plants from the same source were different when thermally combusted under different atmospheric conditions.The one under controlled atmosphere yielded the highest percentage concentration of potassium. It can therefore be concluded that production of ash under controlled atmosphere gave the highest potassium concentration with optimum quality of potash.

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