



CHARACTERISATION OF RICE HUSK AND WOOD ASH AS CONSTITUENTS FOR PRODUCTION OF PHOSPHORUS AND POTASSIUM

D. J. Malgwi^{1*}, A. N. Jones² and M. A. Musa²

¹ Department of Civil Engineering Technology, Ramat Polytechnic, Maiduguri, Borno State, Nigeria

² Department of Civil and Water Resources Engineering, University of Maiduguri, Maiduguri, Borno State, Nigeria

*Corresponding author's email address: deborah2james@yahoo.com

ARTICLE INFORMATION

Submitted 26 November, 2023
Revised 02 May, 2024
Accepted 24 May, 2024

Keywords:

Phosphorus
Potassium
Carbonization
Extraction

ABSTRACT

This study investigated the potentials of rice husk and wood ashes from various species (Mahogany, Iroko and Mghelina) as sustainable sources of phosphorus (P) and potassium (K). The raw rice husk sample was obtained from Dala rice mill while different wood species such as Mahogany, Iroko and Mghelina, were obtained from Baga road timber shade both in Maiduguri, Borno State. Both raw materials were carbonized at different temperatures ranging between 350-750°C respectively. The laboratory analysis of the ash samples was conducted using atomic absorption spectrophotometer (AAS) to determine the presences of K, and P. The result shows that rice husk ash contains a mean value in terms of mg/100g of K₂O (3.593) and P₂O₅(1.382). Also, Mahogany wood ash contains 4.48mg of K and 0.55 mg of P. Similarly, Iroko wood ash was found to consist of 5.14g of K and 0.56g of P. In addition to Mghelina wood ash(Beech wood), it was found that compounds present has a mean values in terms of g/100g of K (10.4) and P (0.96). It is noteworthy that P was highest in wood ash (mghelina) amongst the materials tested. Therefore, the presence of these compounds in wood and rice husk ashes could be a potential low-cost resource for the production of inorganic fertilizer.

© 2024 Faculty of Engineering, University of Maiduguri, Nigeria. All rights reserved.

1.0 Introduction

Growing concerns about global environmental degradation and energy insecurity has intensified the quest for sustainable alternatives. Biomass resources, particularly forestry and agricultural wastes like rice husk and wood ash, have emerged as promising renewable energy sources. characterizing these waste materials as constituents for producing phosphorus and potassium offers a compelling solution. Rice husk and wood ash with their abundant availability and have low operating costs, can be harnessed to generate essential nutrients for agricultural applications, unlocking their eco-friendly fertilizers, minimizing waste disposal issues while supporting sustainable development (Yin *et al.*, 2008). However, one major issue arising from the use of forestry and timber biomass is the generation of ash as a by-product and its monumental environmental and health concern which could be challenging and highly expensive to curtail (WHO, 2015). Additionally, majority of biomass ash generated in thermal plants which includes materials such as wood, rice husk, bagasse and agricultural waste are burned to generate electricity or heat and the end products either disposed of in landfill or uncontrolled agricultural fields.

However, due to scarcity of waste disposal or management facilities, growing environmental concerns, and increasing volume of ash generated from various sources poses significant environmental and management challenges in recent years (Prakash *et al.*, 2007). The burning of the biomass releases Carbon monoxide to the atmosphere (which is poisonous) with resultant consequential and undesirable atmospheric pollution. However, in Maiduguri, the population relies heavily on limited alternative energy sources, rapid urbanization, climate changes and insufficient waste management facilities. There are three main categories of nutrients required by plants which includes macronutrients, micronutrients and heavy metals (Priyadharshini *et al.*,2009). Macronutrients include elements such as phosphorus, potassium, calcium and magnesium while micronutrients include iron, sodium, manganese and copper (Masso *et al.*, 2017). The contents of macro- and micronutrients also indicate that the ash is a valuable fertiliser, but the content of heavy metals precludes use in circumstances where these substances might enter the human food chain (Masso *et al.*, 2017). The potential negative impact

Corresponding author's email address: deborah2james@yahoo.com

on the forest ecosystem and the surrounding environment due to an increased utilization of biomass for energy needs should be mitigated (Wang *et al.*, 2013). To obtain a more sustainable utilisation of biomass fuels, the ash obtained from the combustion of the biofuel could be recycled back to the soil for amendments as valuable forest and tree/shrub fertiliser (Wang *et al.*, 2013).

This paper characterised carbonized rice husk and some wood species under control environment (pyrolysis) for extraction of P and K as constituents for the production of inorganic fertilizer.

2. Materials and Methods

2.1 Materials

In this study, the materials and equipment used for the processing of rice husk and wood ashes includes the following. The materials included raw rice husk, Mahogany, Iroko and Mghelina samples (grinded), while the equipment used included Fabricated oven, Thermometer, Sieve and Digital scale.

2.1.1 Sample preparation

The raw materials were collected manually and spread to dry prior carbonization. 20g of rice husk and 150g of woodchips were placed into the fabricated kiln under low oxygen supply which was ignited and burnt into ashes at varying temperature ranges of 350-750°C for rice husk and wood respectively. The burnt ashes were allowed to cool before collection. The ash samples were collected and labeled in plastic containers prior to use and then transported to Chemistry Department, Yobe State University for laboratory analysis. The Buck Scientific 210VGP Atomic Absorption Spectrophotometer (AAS), UK 2005 was then used to analyze the ash samples. The elements analyzed were Sodium (Na), Potassium (K), Magnesium (Mg), Manganese (Mn), Calcium (Ca), Zinc (Z), Phosphorus (P), Silicon (S), Iron (Fe) and Aluminum (Al).

2.1.2 Rice Husk Preparation

Approximately, 20g of rice husk was placed in a prefabricated kiln and fired at a temperature of 500 to 750°C to avoid environmental pollution as reported by Rao *et al.* (1992). Cremation time was 15 hours after carbonization was reached, the rice husk ashes were allowed to cool in the kiln. Combustion was then recorded visually by opening the oven and collecting the rice husk ash in an airtight polyethylene bag. The samples were analyzed in the laboratory to determine the elemental composition of Rice Husk ashes.

2.1.3 Wood Ash Preparation

The wood ash formulation uses three species of wood samples such as Mahogany, Iroko and Mghelina. Approximately 150g of woodchips were pyrolyzed in a prefabricated kiln by heating to 500°C. At the end of degassing, the lid of the vessel was removed and the remaining char burnt at 350°C. It took 5-8 hours to burn completely at this low temperature. The low temperature ash formed by the above process was used for laboratory analysis. Samples were allowed to heat at the required temperature to ensure adequate heating time and complete any conversion that may have been initiated at the sample holding temperature.

2.2 Determination of Elemental Composition

2.2.1 Digestion Method

The ash samples were digested prior to analysis. The ash samples were moisturized with few drops of distilled water. Thereafter, it was mixed with 2ml concentrated Hydrochloric Acid (80% HCL), and then dried on hot plate at 100°C. Furthermore, it was mixed with 5ml nitric acid (20%) and filtered using Whatman filter paper of size 10µm into volumetric flask of 100ml. The extract was then ready for analysis using the analytical machine. They were determined using the Buck Scientific 210VGP Atomic Absorption Spectrophotometer (AAS), UK 2005. The procedure was as follows: you Press and hold ON button until the spectrophotometer turns on. Then, you Scroll up and select all tests from the testing menu. Scroll and then select the tests to be conducted - chloride, Nitrate, sulphate, phosphate, dissolved oxygen and others, from the menu depending on parameters to be tested and select programmed tests then rinse a clean tube with sample water and fill it to the 10th line with the sample. then you insert the filled tube into the chamber and close the lid after which you will select scan blank after that you remove it from the spectrophotometer and add the content of one packet or tablet of reagent that is chloride – TT, Nitrate reducing reagent, sulphate reagent, phosphate acid reagent, then reinsert the cap and shake until the powder dissolves completely. Wait for 5 minutes for full colour development. Then at the end of 5 min waiting period mix and insert tube into chamber. Close lid, select scan sample and record result. Press OFF button to turn spectrophotometer OFF or press exist button to exit to a previous menu or make another menu selection. The procedures were repeated three times and their mean values obtained.

3. Results and Discussion

3.1 Elemental Composition of Rice Husk Ash

The results from the characterization of rice husk ash are shown in Table 1. The results show that the various compounds present in the samples have mean, standard deviation and individual values in terms of mg/100g. The results show that RHA is primarily composed of silicon dioxide (SiO₂) accounting for approximately 79.757% of the total elemental components. The mean value of 3.593 K₂O, 1.382 P₂O₅, 1.025 CaO, 0.626 MgO, 0.069 MnO, 0.045 ZnO, 0.367 Fe₂O₃ and 0.558 Al₂O₃. This is consistent with previous studies. The major elements in this study P and K compared with research by *Iara et al.* (2016) revealed similarity in compounds present with 0.23% P₂O₅ and 0.69% K₂O which are lower than those obtained in the present work.

Table 1: Elemental Composition of Rice Husk Ash in oxide

S/No.	Elements (mg/100g)	Sample 1	Sample 2	Sample 3	Mean	SD
1	Na ₂ O	0.174	0.174	0.174	0.174	0.000
2	K ₂ O	3.775	3.107	3.898	3.593	0.426
3	MgO	0.456	0.715	0.708	0.626	0.148
4	MnO	0.069	0.069	0.069	0.069	0.000
5	CaO	0.989	1.143	0.943	1.025	0.105
6	ZnO	0.011	0.08	0.045	0.045	0.035
7	P ₂ O ₅	1.238	1.192	1.716	1.382	0.290
8	SiO ₂	79.85	78.805	80.616	79.757	0.909
9	Fe ₂ O ₃	0.396	0.383	0.323	0.367	0.039
10	Al ₂ O ₃	0.699	0.617	0.358	0.558	0.178

3.2 Elemental Composition of Mahogany Wood Ash

The results from the characterization of Mahogany Wood Ash as presented in Table 2 below shows significant amounts in mean, standard deviation and individual values in terms of g/100g with 5.90 calcium, 8.16 silicon, 4.48 potassium, 0.55 phosphorus, 1.67 zinc, 2.07 iron and 0.50 manganese. It was observed that compounds of interest P and K are 4.48 and 0.55 respectively. The findings correlate with the results reported by *Ngassam et al.* (2021) in their study on mahogany bark.

Table 2: Elemental Composition of Mahogany Wood Ash

S/No.	Elements (g/100g)	Sample 1	Sample 2	Sample 3	Mean	SD
1	Sodium	0.19	0.21	0.18	0.19	0.02
2	Potassium	4.57	4.43	4.45	4.48	0.07
3	Magnesium	0.30	0.32	0.31	0.31	0.01
4	Manganese	0.51	0.49	0.51	0.50	0.01
5	Calcium	5.90	5.61	6.20	5.90	0.29
6	Zinc	1.60	1.74	1.68	1.67	0.07
7	Phosphorus	0.48	0.50	0.69	0.55	0.11
8	Silicon	8.20	8.28	8.01	8.16	0.14
9	Iron	2.17	2.00	2.04	2.07	0.09
10	Aluminum	1.48	1.48	1.52	1.50	0.02

3.3 Elemental Composition of Iroko Wood Ash

Table 3 presents the results from the characterization of Iroko Wood Ash shows significant amounts in mean, standard deviation and individual values in terms of g/100g with 15.30 calcium, 0.58 silicon, 5.14 potassium, 0.56 phosphorus, 1.67 zinc, 2.54 iron and 0.83 manganese.

Table 3: Elemental Composition of Iroko Wood Ash

S/No.	Elements (g/100g)	Sample 1	Sample 2	Sample 3	Mean	SD
1	Sodium	1.93	1.97	1.75	1.88	0.12
2	Potassium	5.06	5.08	5.26	5.14	0.11
3	Magnesium	1.30	1.30	1.27	1.29	0.02
4	Manganese	0.85	0.84	0.81	0.83	0.02
5	Calcium	15.15	15.33	15.43	15.30	0.14
6	Zinc	2.65	2.36	2.61	2.54	0.16
7	Phosphorus	0.57	0.58	0.53	0.56	0.02
8	Silicon	0.57	0.59	0.58	0.58	0.01
9	Iron	0.30	0.33	0.35	0.33	0.03
10	Aluminum	0.14	0.14	0.15	0.14	0.00

3.4 Elemental Composition of Mghelina Wood Ash (Beech Wood)

The results from the characterization of Mghelina Wood Ash (beech wood) are shown in Table 4. shows significant amounts in mean, standard deviation and individual values in terms of g/100g with 36.91 calcium, 7.93 silicon, 10.40 potassium, 0.96 phosphorus, 0.47 zinc, 1.23 iron and 0.09 manganese.

It was observed that the compounds present of interest P and K are 0.96 and 10.40 respectively. Annune et al. (2020) validates these findings.

Table 4: Elemental Composition of Gmelina Wood Ash (Beech Wood)

S/No.	Elements (g/100g)	Sample 1	Sample 2	Sample 3	Mean	SD
1	Sodium	2.52	2.54	2.52	2.53	0.01
2	Potassium	10.38	10.42	10.42	10.40	0.02
3	Magnesium	0.72	0.78	0.68	0.73	0.05
4	Manganese	0.09	0.09	0.09	0.09	0.00
5	Calcium	39.95	32.77	38.01	36.91	3.72
6	Zinc	0.47	0.47	0.47	0.47	0.00
7	Phosphorus	0.96	0.97	0.96	0.96	0.00
8	Silicon	7.95	7.96	7.87	7.93	0.05
9	Iron	1.25	1.11	1.33	1.23	0.11
10	Aluminum	1.51	1.47	1.49	1.49	0.02

3.5 Mean Value of P And K From Rice Husk and Wood Ashes

Table 5 presents the Mean Values of Phosphorus (P) and Potassium (K) in RHA and three types of WA: Mahogany, Iroko and Mghelina. It was found that the ashes have reasonable content. The P and K content found in the Rice husk ash was 1.38 mg/100g and 3.59 mg/100g, whereas P and K of Wood ash for Mahogany were 0.55g/100g and 4.48g/100g, Iroko were 0.56g/100g and 5.14g/100g and mghelina (beech) were 0.96g/100g and 10.40 g/100g respectively. In comparison of P values mghelina > iroko > mahogany > rice husk indicating that WA has higher content of P, while K values mghelina > iroko > mahogany > rice husk indicating that Mghelina WA has higher content of K.

Table 5: Mean Value of Phosphorus (P) and Potassium (K) from Rice Husk and Wood Ashes

S/No.	Elements	RHA(mg/100g)	WA (g/100g)		
			Mahogany	Iroko	Mghelina
1	Phosphorus	1.38	0.55	0.56	0.96
2	Potassium	3.59	4.48	5.14	10.40

4. Conclusion

The analysis of the result indicates that the concentration of P and K are highly significant with $p < 0.01$. The presence of high contents of P from wood ash(mghelina), 10.4 g/100g and K from Rice husk, 3.59 mg/100g signifies its potential for NPK blend.

References

- Annune, JE., Nwafor, C., Shawon, MC. and Ahmed, YA. 2020. Production and Characterization of Wood Ash Pozzolan of Melina and Cashew Tropical Woods. International Journal of Scientific & Engineering Research, 11(10): 2229-5518.
- Iara, JF., Daiane, C., Amanda, GK., Carlos AMM., Tatiana, LAC., Rocha, FA., Brehm, D., Regina, CE. and Modolo, D. 2016. Characterization of rice husk ash produced using different biomass combustion. Techniques for Energy, 165: 351-355.
- Krishna, R. 1992. Studies on the formation of Sic whiskers pulverised rice husk ashes. Ceramic International, 18 (1): 35-42.
- Masso, C., Nziguheba, G. and Mutegi, J. 2017. Soil fertility management in sub-Saharan Africa. Sustainable Agriculture Reviews, 25: 205–231.
- Ngassam, I., Walda, M., Dodoo-Arhin, D., Kühne, HC. and Schmidt, W. 2021. Characterization of mahogany bark ash for its use as supplementary cementitious material and its behavior in a cement paste at its earlier age. Concrete Beton, Journal of Cement and Concrete, 167:19-22.
- Prakash, NB., Nagaraj, H., Guruswamy, KT., Vishwanatha, BN., Narayanswamy, C., Gowda, NAJ., Vasuki, N. and Siddaramappa, R. 2007. Rice hull ash as a source of silicon and phosphatic fertilizers: effect on growth and yield of rice in coastal Karnataka, India. International Rice Research Notes, 32: 34–36.
- Priyadharshini, J. and Seran, TH. 2009. Paddy husk ash as a source of potassium for growth and yield of cowpea (*Vigna unguiculata*). Journal Agricultural Science, 4 (2): 67-76.
- Wang, M., Zheng, Q., Shen, Q. and Guo, S. 2013. The critical role of potassium in plant stress response. International Journal of Molecular Sciences, 14(4): 7370–7390.
- World Health Organization. 2015. World report on ageing and health. World Health Organization. <https://iris.who.int/handle/10665/186463>
- Yin, C., Rosendahl, LA. and Kaer, SK. 2008. Grate firing of biomass for heat and power production program. Energy and Combustion Journal, 34:725-754.