Determination of Combustion Characteristics of some Agricultural Wastes in Niger State, Nigeria.

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ABSTRACT

Agricultural wastes cannot generally be called so because if they are properly managed,they can be sources of income generation. This paper intends to determine the combustion characteristics, combustion rate, ignition point, highest heating value, peak temperature, percentage weight loss, and proximate analysis of some agricultural biomass using Thermo Gravimetric Analysis (TGA). Forty milligram (40mg) of each samples of pre-determined moisture content are reduced to particles size of 25mm using an electric powered blending machine before transferred into muffle furnace. The temperature was raised from ambient to 850k with a linear heating rate of 25^0C/ min. Results showed that the energy generated by the rice husk, cowpea shell and corn cob were 20.88KJ/g, 18.68KJ/g and 19.51KJ/g respectively when combusted separately. Peak burning profile varied from 630k to 780k while the combustion rate varied from 0.5 mg/min to 2.75 mg/min and ignition temperature also varied from 385k to 600k. These results are useful to design of incinerator, briquette production and production of biofuels from the studied biomass.

Keywords: Thermo-gravimetric analysis, Agricultural biomass, Burning profile and Combustion characteristics.

1. INTRODUCTION

Several literatures have described agricultural wastes resources to include wood and wood wastes, agricultural crops and their waste by-products, municipal and solid wastes, waste from food processing and aquatic plants and algae (Brems *et al,* 2011; Miljkovil 2015). Although the chemical constituents and moisture content of agricultural wastes materials vary, they all contain low amounts of polluting elements and ash, which is the major difference between the agricultural waste fuels. Agricultural wastes cannot be denoted as wastes because of substantial benefits that can be explored from them. These benefits have been reported to include their use as fuel, its conversion into biofuel use as feeds, compost fertilizer and use in production of particle board. (Demirbas, 2008).

Combustion is one of the most important thermal treatment methods for agricultural wastes. Although the fundamental combustion behaviour of agricultural wastes fuels has received increasing attention of late, there remains no comprehensive compilation of their combustion (Demirbas 2000). Although burning agricultural wastes in order to produce heat energy is as old as mankind, though this kind of fuel is different from coal in its combustion characteristics and, due to its high volatile content and alkali content of ash, it can cause various problems (Miljkovi, 2015). The heating value of a fuel indicates the energy available in the fuel per unit mass while the net heating value is the actual energy available for heat transfer. The difference in available energy is explained by the fuel's chemical composition, moisture and ash content. For the purpose of properly designing and operating straw fired power plant, it is important to have detailed knowledge of the characteristics of fuel combustion and the effects of varying operating conditions. Considering the role of Niger State in agricultural activities, volume of agricultural waste generated annually in each local government area of the state and of course, the nuisance it causes, this research intends to determine the thermal properties of selected agricultural waste with a view to suggesting better ways of managing them to prevent environmental pollution.

2. MATERIALS AND METHOD

Niger State is one of the North-central states in the Guinea Savannah Zone of Nigeria. It is at sometimes called the food basket of the nation owing to the abundant potentials for all year round farming. Geographically, it is located on Latitude 10º 00' 00'' N, 06º 00' 00'' E, occupying a total area of 76,363 km^2. It is characterized by two distinct seasons; rainy and dry seasons. Short grasses and scattered trees in its extreme north and dense forest towards the south are features of its vegetation with mean maximum and minimum temperatures of 37ºC and 20ºC respectively. Politically, the state is sub-divided into three (3) zones viz: A, B and C., with a total of 25 Local Government Areas in all as indicated in figure 1. Records were obtained from the Niger State Ministry of Agricultural and Rural Development as well as Agricultural Development Project (ADP) on the annual food production in (tonnes/hectare) by each political zone of the state.

The sample of the biomass, maize cob, cowpea and rice husks were collected from milling points in Minna, Niger state capital and their grain/husk ratio determined. With the aid of a Muffin furnace, blender and in accordance with ASTM 2395 standards. A non-isothermal thermo-gravimetric analysis was performed using a furnace analyser. The samples were reduced to < 25mm particle size and 40mg each of the sample was spread on the bottom of the crucible before subjected to constant heat in an oxygenated furnace from a temperature of 400K through 1200K. With constant measurements of weight using the digital weighing balance, proper timing using stop watch and their respective temperatures change in the pace of 50k, and finally held for 30 minutes at constant weight. After every marked temperature each sample was put into the desiccator to allow to cool to temperature of zero kelvin before reweighing, which is in accordance with the ASTM 2395 standard. Burning profile was plotted using the Microsoft excel and behaviours of the different waste matter compared.

Fig. 1: GIS map of Niger State showing Local Government Areas.

3. RESULTS AND DISCUSSIONS

3.1 Annual waste generated in from each political zone of the state

The production of maize among the Zones has little difference based on the data obtained from ADP and the state ministry for agriculture and rural development, though Zone C is slightly higher with the value of 3,937 tonnes/year followed by Zone B with 2,619 tonnes/year. Zone A is the highest in rice production with the estimated value of 5,453 tonnes/year followed by Zone C with 3,032 tonnes/year and Zone B with 2,031 tonnes/year. Zone C is the centre known for cowpea production because of moderate weather condition. Records shows it has an estimated cowpea production of 4,746 tonnes/year followed by Zone A with 2,612 tonnes/year and zone B with 2,440 tonnes/year. The explanations above is clearly shown in figure 2 below. Meanwhile, the waste generated in each political zone for each of the crops under study was determined using grain/husk ratio. The result obtained indicated that Zone C is slightly higher with an estimated value of 2,619 tonnes/year, Zone B with 2,297 tonnes/year and Zone A with 2,054 tonnes/year. Zone A has the highest in rice production with an estimated value of 1,818 tonnes/year followed by Zone C with 1,010 tonnes/year and Zone B with 677 tonnes/year. Zone C as the centre for cowpea production has an estimated value of waste generation as 1,438 tonnes/year followed by Zone A with 792 tonnes/year and Zone B with 739 tonnes/year.

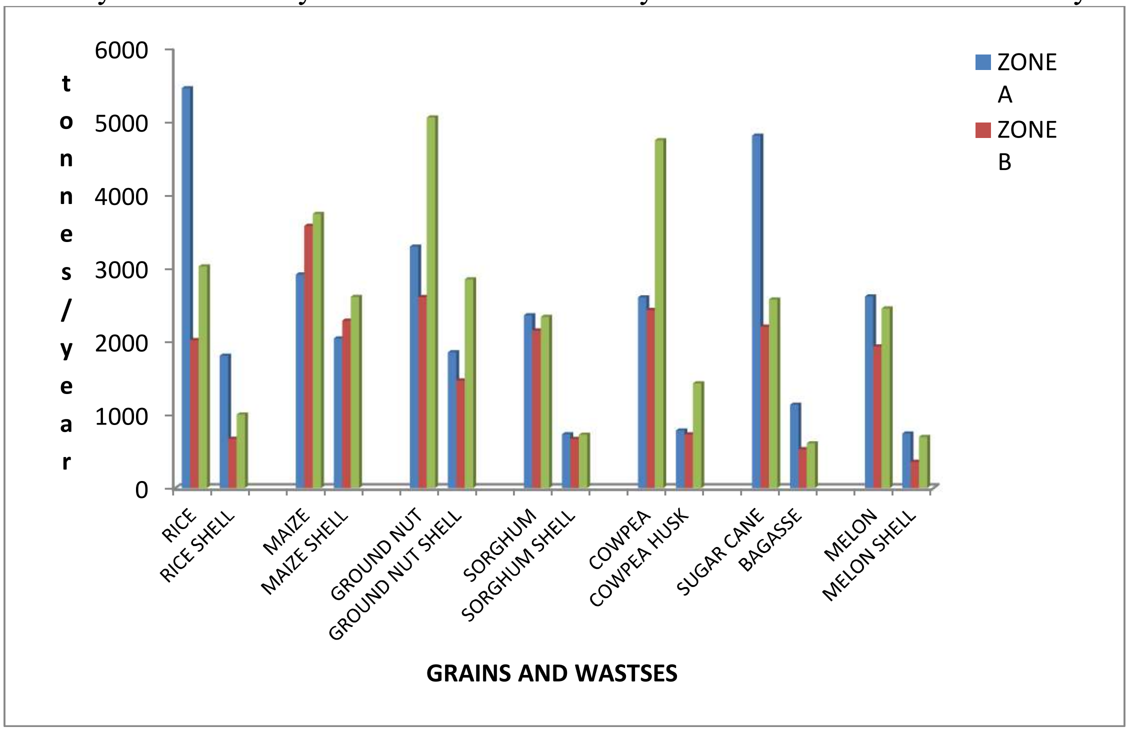

Fig. 2: Annual food production in tonnes/year – (ADP, 2018)

3.2 Result of Proximate Analysis of the Different Agricultural Wastes under Study

The result of the proximate analysis of the agricultural wastes under study at moisture content of 5 % after the non-isothermal thermo-gravimetric test is presented in figure 3. The volatile matter for the agricultural wastes ranges averagely from $80.275 \pm 1.525\ \%\ to\ 26.82 \pm 0.3\ \%$. After the volatile phase come the fixed carbon (FC) phase. This is the part that is quantified as the part of materials that is used to estimate the heat values or energy content in calories or KJ. From the study, the FC ranges from $35\%\ to\ 11.725\ \pm 1.525\%$ and the value of the energy Higher Heat Value (HHV) of $16.42\ \pm 0.3 KJ/g\ to\ 20.98\ KJ/g$.

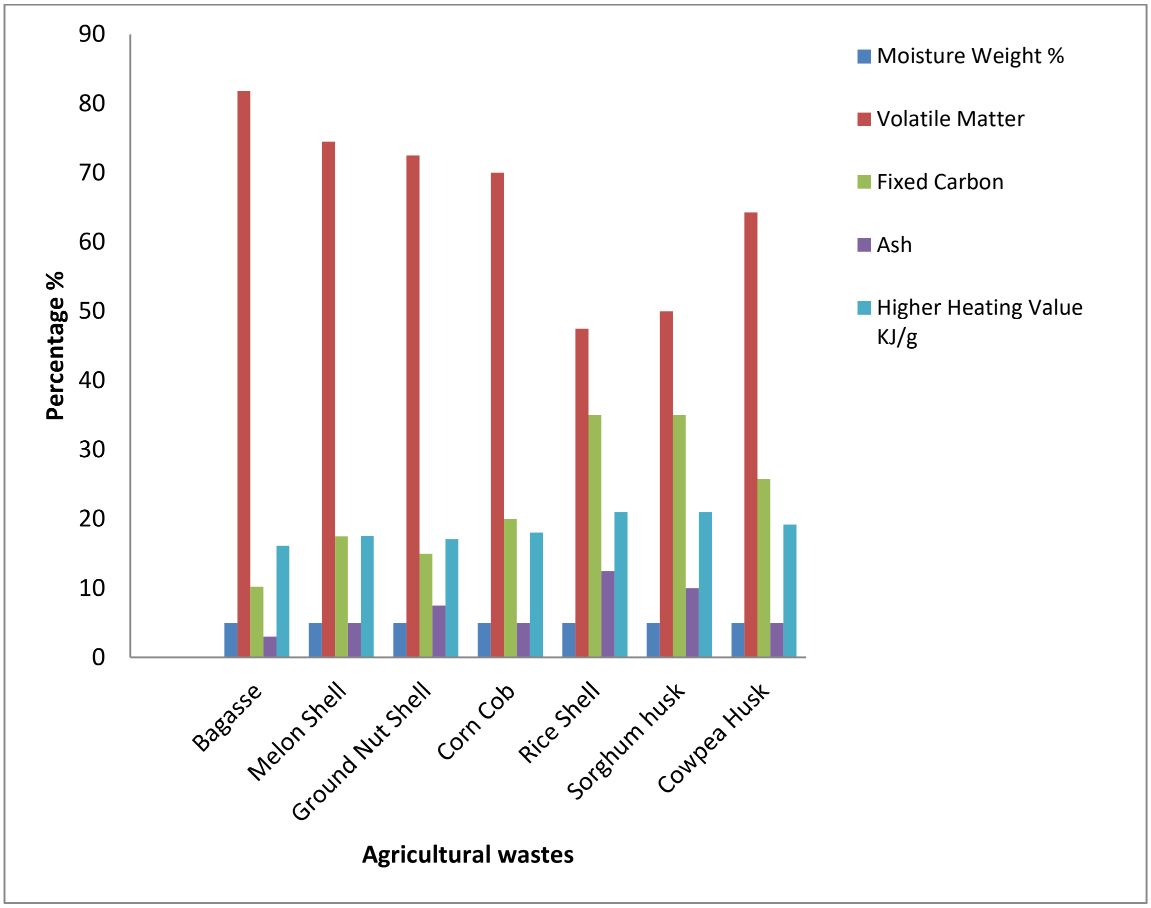

Fig. 3: Result of proximate analysis of the different agricultural wastes under study

The ash phase, the final phase is assumed as harmless to the environment and useful as soil nutrient. The ash content ranged from 12% to 3% from rice shell > cowpea husk > corn cob. The energy content of corn cob was 19.51KJ/g which is slightly higher than the standard which is 17.0KJ/g. The energy generated by the rice husk was 20.88KJ/g while the cowpea shell gives 18.68KJ/g. This cowpea energy value is close to 19KJ/g which is the standard. Mixture of rice shell and that of cowpea gives 18.68KJ/g which is slightly less than the energy generated by the two different agricultural wastes when treated individually.

3.4 Result of burning profile of the various agricultural waste

A plot of the rate of weight loss against temperature while burning a sample under an oxidizing atmosphere is referred to as the ‘‘burning profile’’ (Haykırı *et al.,* 2000). Figure 4 is the burning profile of corn cob, cowpea husks and their combinations. It can be seen from the profile that the ignition temperature of their combination is 200K compared to that of just corn cob and cowpea only which are 400K and 300K respectively. This indicates that the mixture has a combustive advantage over their individual component. The characterization of the carbon content shows a mass loss of 2 mg/min which is also faster than that of corn cob and cowpea husks which are 1.6mg/min and 1.7 mg/min respectively.

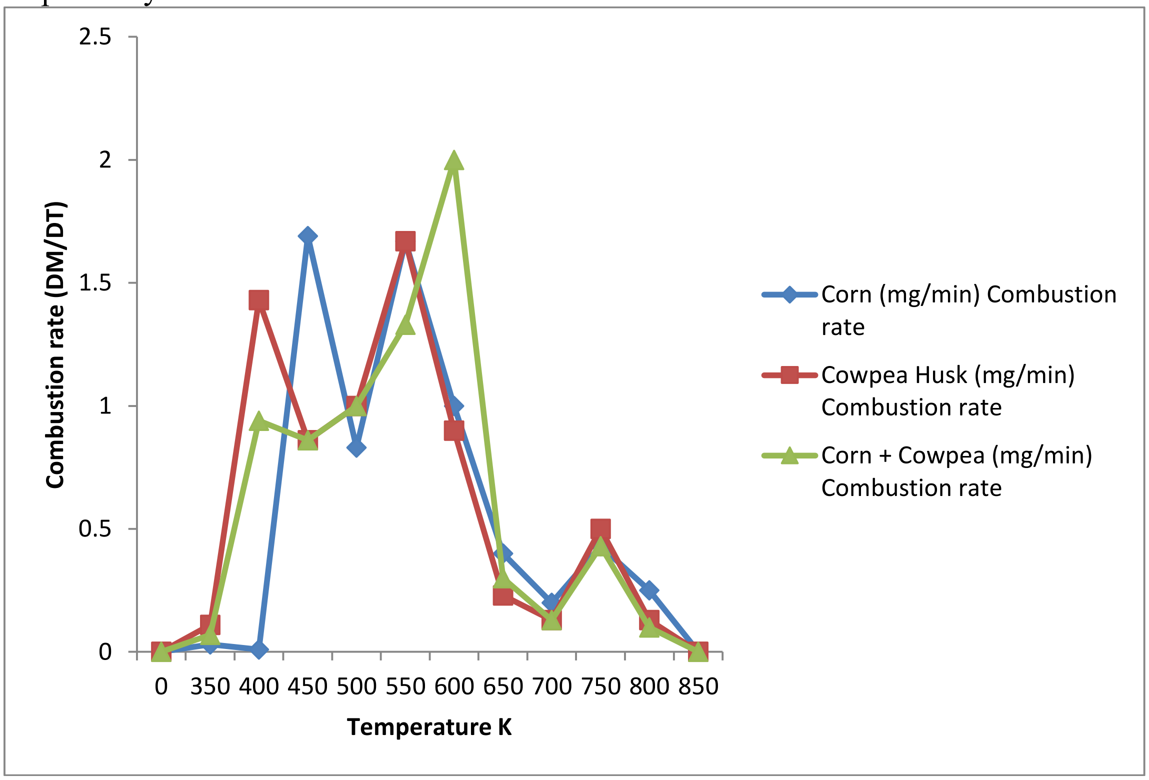

Fig. 4: Burning profile of corn cob, cowpea husk and their combination

The burning profile of cowpea husks, rice shell and their combination took a different behaviour as can be seen in figure 5. The burning temperature for their combine form starts at 100K, which is faster than that of rice shell alone which is 395K and cowpea husk which is 300K. The rate of combustion was 2.6mg/min at 300K which is faster than cowpea husk (i.e. 1.7mg/min at 500K), but slightly slower than rice shell (2.75mg/min at 600K). With a very low peak temperature of 300K and burning rate when compared with the individual components, it is very plausible to mix rice and cowpea for faster incineration of the waste.

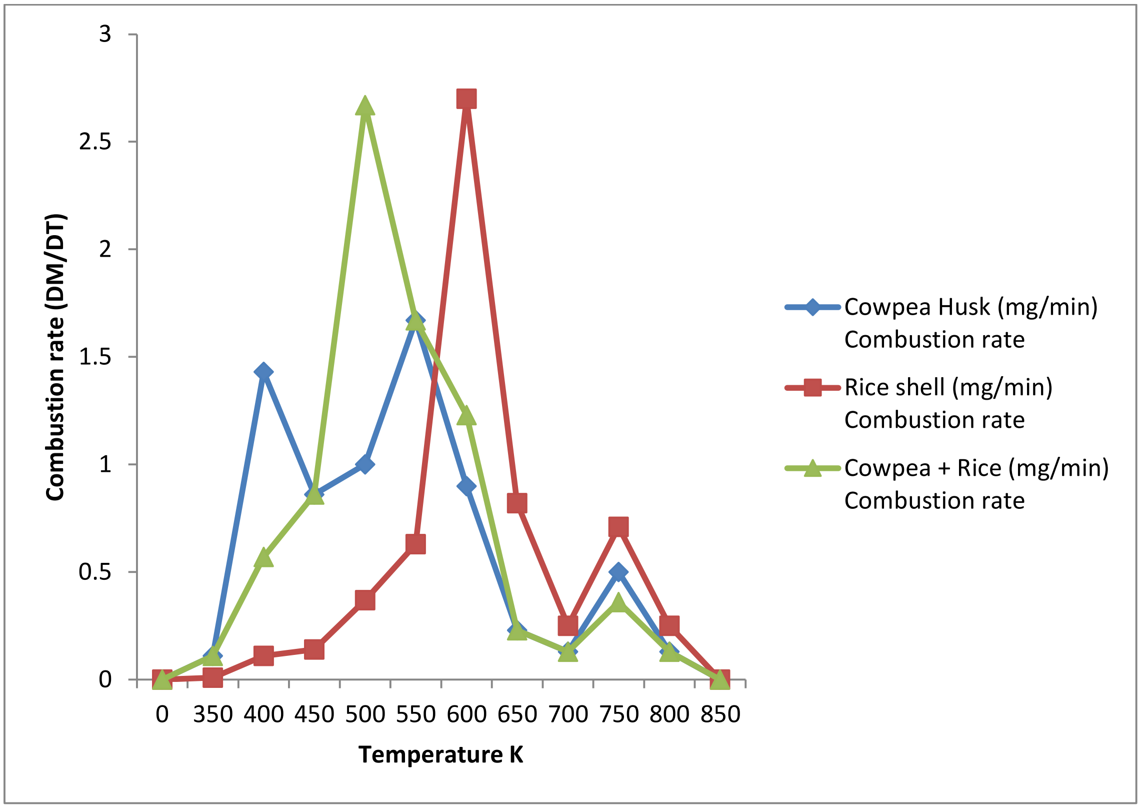

Fig. 5: Burning profile of cowpea husk, rice shell and their combination

The burning characteristics for rice shell and corn cob gave a different pattern as shown in figure 6. From the profile, the ignition temperature for the combine was at 200K compared to that of just corn cob alone that was 400K and rice which was 375K. This result also point out that the mixture has a combustive advantage over their single. The temperature of 600K is almost similar to the separate peak of the individual samples. The characterization of the carbon content show the mass loss of 2 mg/min which is also faster than that of only corn cob which was 1.6mg/min but not as fast as that of rice shell which is 2.75 mg/min.

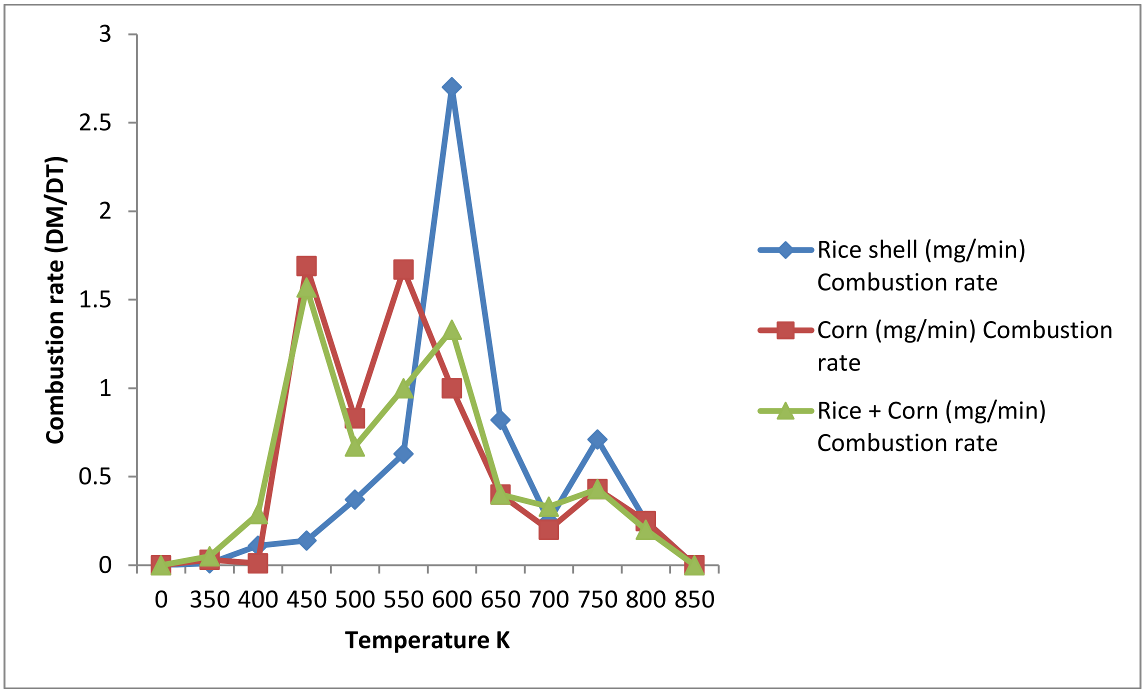

Fig. 6: Burning profile of corn cob, rice shell and their combination

4. CONCLUSION

The analysis of combustion characteristics of corn cob, rice husk, groundnut shell and melon husk in Niger state was successfully carried out. The results indicated that waste generation are not the same throughout the political zones of the state with cowpea production highest in zone C while zones A is leading in rice production and its waste generation. Proximate analysis of the various waste matter was also conducted and individual component fractions determined. Most importantly, the burning profiles for both the individual waste and their combinations were also plotted and studied. It is however recommended that more agricultural waste be looked into, and the analysis be done with more than two agricultural biomasses combined as this may give a better result.

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