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ELEMENTAL ANALYSIS AND COMBUSTION CHARACTERISTICS EVALUATION OF NIGERIAN BIOMASS RESOURCES

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ABSTRACT

*An investigative work was done to analyse the elemental composition and the combustion characteristics of some biomass resources that is, agricultural and forestry samples. The method of analysis was according to Association of Official Analytical Chemists (AOAC). The results shows that the higher heating value (HHV) for Sorghum husk, Araba (*Ceibo pentandra*), were 17.2MJ/kg, and 18.0MJ/kg respectively. The analysis also reveals the presence of carbon, hydrogen, nitrogen, sulphur and oxygen in significant amount. These biomass wastes can be transformed in to valuable energy products in form of solid, liquid or gaseous fuels for either domestic or industrial applications.*

Key words: biomass, combustion, elemental analysis, heating value, Nigeria.

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1. INTRODUCTION

Bioenergy research and development in developed economies has reached an advanced stage and its deployment is on a gradual increase [1]. A number of power plants, namely, the Gelderland power station [2] in the Netherlands, German power plants [3], Varnamo demonstration plant in Central Sweden [4] and the 75MW Bay Front plant in Wisconsin [5], are all existing and functional models. On the contrary, in many developing nations, the utilization of biomass resources is still very primitive and mostly limited to domestic purposes [6].

Generally, the enormous availability and diversity of biomass residues in the form of agricultural or forestry by-products make the bioenergy option an attractive renewable energy source. For instance crop and wood processing residues available in the United States of America annually is estimated to be 278 million and 107.3 million dry tons respectively [7]. Sadly, the huge biomass residues in Nigeria are either burnt in open air or disposed off into the waterways or drainage systems [8, 9]. This represents a huge potential for energy generation that could expand the country's supply energy mix and ensure environmental sustainability. Typically, biomass is reputed for its zero net CO_2 contribution to the environment and this is a major boost to reverse the devastating global warming phenomena [10, 11]. Again, it has a merit of being suitable for establishment as an off-grid small scale plants in rural and semi-rural areas. Furthermore, the use of biomass emits low levels of NO_x and SO_2, reduces the occurrence of acid rain, conserves natural resource and mitigates some ecological challenges.

The elemental properties and energy contents of various biomass resources have been researched into widely. Chinnawala [12] undertook a proximate and ultimate analysis, and also evaluated the energy values of several agricultural and forestry samples, while Jekayinfa and Omisakin [13] determined the chemical composition of some agricultural wastes and subsequently used it to evaluate their higher and lower heating value. Enweremadu *et al.* [14]; Fapetu [15]; Singh *et al.* [16] evaluated the energy potentials of soy-bean and cowpea, charcoal, and rice husk respectively. Research, design and development of biomass driven energy systems is often necessarily preceded by investigation into the chemical and combustion properties of biomass resources. This work therefore sought to undertake an analysis of the chemical composition and an evaluation of the combustion characteristics of some tropical agricultural and forestry resources.

2. MATERIALS & EXPERIMENTAL PROCEDURES

2.1. Sample Collection and Preparation

The biomass waste samples, Araba (*Ceibo pentandra*) and Sorghum husks, were gathered from a wood processing plant and farm site in Ilorin, Nigeria. The forestry material was processed in to particle sizes less than 1 mm using a Planing machine and Sieve, while the agricultural materials were ground using a Grinder incorporated with a 2mm sieve. The elemental analysis and determination of the combustion characteristics were carried out at a laboratory in Moor Plantation, Ibadan, Nigeria.

2.2. Methods

2.2.1 Elemental Analysis

The elemental analysis is the weight fraction of the following elements; carbon, hydrogen, nitrogen, sulphur and oxygen. The methods used were according to Association of Official Analytical Chemists (AOAC, 1998), Walkley [17] and Jekayinfa and Omisakin [13].

2.2.2. Combustion Characteristics

The parameters under the thermal energy evaluation were determined using the recommended guidelines provided by the Association of Official Analytical Chemists (AOAC, 1998). The pieces of equipment used were a Muffle furnace, an Oven, an Analytical balance, crucibles, and desiccators.

2.2.2.1. Ash Content

For the ash content determination, 2.0g of the sample was combusted at a temperature of 550°C in a Muffle furnace for 4 hours.

2.2.2.2. Moisture Content and Dry Matter

The moisture content and dry matter were determined by measuring 2.0g of sample in to a crucible, which had been previously ignited and weighed, and was placed in an oven for 24hours at a temperature of 100°C. This was allowed to dry to a constant weight. The moisture content was calculated as the difference between 100% and the percentage of dry matter.

2.2.2.2. Thermal Energy Content

The energy values of the samples were determined using a Gallenkamp Ballistic Bomb Calorimeter. A calibration constant was obtained using the value of heat released by Benzoic Acid. This was subsequently used in determining the calorific value of the sample after which 0.25g of the sample was burnt off in excess oxygen.

3. RESULTS AND DISCUSSIONS

3.1. Elemental Analysis

The elemental analysis provides useful information about the elemental composition of biomass, which includes %Carbon (C), %Hydrogen (H), %Oxygen (O), %Sulphur (S), and %Nitrogen (N).

Table 1: Elemental Analysis of Agricultural and Forestry Samples

	Agricultural Samples	Forestry Samples
	Sorghum Husk	Araba (*Ceibo pentandra*)
C	31.60	15.20
H	5.80	4.53
N	2.94	1.33
S	0.14	3.07
O	55.52	73.11

The results for the chemical composition of some agricultural and forestry resources are presented in Table 1. The table shows that the hydrogen content for all the biomass resources ranges between 4 – 6%. These values, particularly for the wood species, agree with the limits presented in other research publications [12, 18].

The nitrogen content in each of the biomass type under study is less than 3%. Relatively, they are comparable with the value obtained for some coal, 1.2% [19, 20]. They are also in conformity with results from similar studies for some agricultural wastes [13]. The significance of the amount of nitrogen in biomass is hinged on the fact that fuel bound nitrogen is a major culprit in the liberation of oxides of nitrogen NO_x from biomass combustion processes [21, 22].

The table also shows that Sorghum husk has the lower sulphur content, 0.14%, while *Ceibo pentandra* has 3.07%. Sorghum husk has a promising prospect for bioenergy purposes because of its relatively low Sulphur content that makes it environmentally compatible.

Table 2: Combustion Characteristics of Agricultural and Forestry Samples

	Agricultural Samples	Forestry Samples
	Sorghum Husk	Araba (*Ceibo pentandra*)
Higher heating value (MJ/kg)	17.2	18.0
% Ash content	4.00	2.76
Moisture content	9.00	6.87
Dry matter	91.00	93.13

Table 2 shows the combustion characteristics of the agricultural and forestry resources under investigation. Sorghum husk has the lower higher heating value, 17.2 MJ/kg, while *Ceibo pentandra* has the higher value. The heating values obtained for *Ceibo pentandra* is comparable to that of Casuarina, 18.77MJ/kg and that of Sorghum to that of Sudan grass, 17.39MJ/kg [12]. By implication, any of the forestry resources can be propagated with the aim of utilizing them for energy generating purposes, while Sorghum husk, hitherto waste materials, can be turned to energy producing raw materials.

The ash content for Sorghum husk, 4%, is the relatively higher and it is typical of most agricultural wastes (2 – 7%) as reported in literature [20]. High ash content is a major drawback from the view point of energy related applications. The results of ash content value 2.76% for Araba lie within the limit (about 5%) published for wood grown in the tropics.

The hydrogen to carbon ratio for Sorghum husk, and Araba, are 5.45, and 3.36 respectively as shown if Figure 1. In some bio-oil production through thermochemical processes such high H/C ratio are undesirable and makes bio-oil upgrade and/or feedstock pretreatment a necessity.

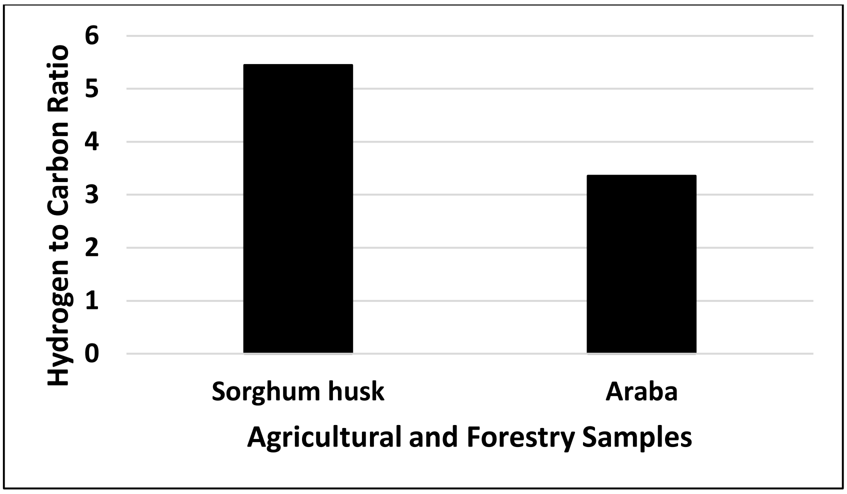

Figure 1: Hydrogen to Carbon (H/C) Ratio of Some Agricultural and Forestry Samples

4. CONCLUSION

The calorific values obtained, 17.2 MJ/kg and 18.0 MJ/kg, for the biomass samples make them attractive renewable fuel source. Though the ash content for the agricultural residue is slightly high, that of the forestry sample is quite moderate make it a viable feedstock for thermal processes. It can also be concluded that carbon, hydrogen, sulphur, nitrogen and oxygen are present in the biomass resources under study at amount comparable to existing values in literature. The sulphur content for all biomass resources is less than 5%, while nitrogen content is less than 3%. These analyses add to the data base of energy generating potentials of agricultural and forestry resources.

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