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Analyzing the Elemental Chemical Composition and Inorganic Minerals of Woody Biomass for Alternative Energy Generation: A View Point of Nigerian Sawdust

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Abstract- Energy is one of the most vital requirements for human existence and development and it is imperative to explore the various sources of its generation and maximize the numerous opportunities that is accrued in its abundance and diversity. This study therefore was done to analyze the elemental chemical composition and inorganic minerals of Ghana Obeche softwood sawdust and its importance in alternative energy generation in Nigeria. The outcome of the elemental analysis of the chemical composition were as follows Carbon 52.8wt%, Hydrogen 4.60wt%, Nitrogen 0.19wt%, Oxygen 37.4wt% and Sulphur 0.206wt%. The experimental results obtained for the inorganic minerals that is Sodium, Magnesium, Calcium and Potassium of the studied sample were 91.8 ppm, 102.4 ppm, 526.1 ppm and 337.6 ppm respectively. The results of the analysis showed that the sawdust sample has suitable values of inorganic minerals and some specific alkali metals that are very useful during the fast pyrolysis process since they act as catalysts and can influence the decomposition behavioral pattern of sawdust and that will bode well for the aim of generating alternative energy source.

Keywords- *Woody Biomass, Inorganic Minerals, Chemical Composition, Alkali Metals and Energy*

I. Introduction

As the global economy grows on a daily basis, energy requirements and utilization have tremendously increased particularly in developed and some developing countries like Nigeria. Presently, the world is being challenged by huge shortages and unstable price of fossil fuels at the international market, a potential solution to the rapid energy demand is the use of lignocellulosic materials such as wood sawdust as renewable source of energy. Although, Africa constitutes about 12% of the world population, it utilizes only 4% of global energy (Ardayfio-Schandorf, 1996). Considering the fact that the fossil fuel as the major source of energy is on the decline and fast becoming a topical issue that requires an urgent attention as a result of environmental danger and hazards associated with its exploration and production and judging by the projection that the wood fuel demand would rise to about $213.4x10^3$ metric tonnes by year 2030. As a result of this, a transition to renewable energy alternative is urgently needed in a developing nation like Nigeria (Stout and Best, 2001). Some of the dangers and threats associated with fossil fuel include climate change which is related to carbon emissions into the atmosphere, depletion of ozone layer which results to the emission of ultra-violet radiation of the sun that is harmful to both human and aquatic lives, air and water pollution as a result of release of oxides of sulphur and carbon and other gases into the atmosphere which may cause acid rain and so on. The quest for alternative source of energy has attracted considerable interests in the last decades on the need for the development of environmental friendly renewable sources like wood sawdust and new technologies such as fast pyrolysis process through which organic components of wood sawdust that is, cellulose, hemicelluloses and lignin are thermally decomposed when subjected to a high temperature. The product of the fast pyrolysis process is Bio-oil which is a dark brown viscous, acidic with distinctive smoky odor used as fuel for boilers, gas turbines, diesel engines, furnaces and stationary engines (Elliot, 2007, Ozbay and Putun, 2006).

A. Chemical Composition of Wood Sawdust

There are three major components that constitute wood sawdust namely cellulose, hemicelluloses and lignin and some minor composition of compounds such as lipids, proteins, simple sugar, water, starches, and hydrocarbons and ash (Cheng et al, 2011, Dagnino et al, 2013).

B. Inorganic Minerals

Wood sawdust also contains some inorganic minerals of varying content that comprises pyrolytic liquid and solid products as ash. These inorganic minerals and some specific alkali metals are very useful during the process of fast pyrolysis since they act as catalysts and influence the decomposition behavioural pattern of sawdust (Nowakowshi et al, 2008). Examples of the Alkali earth metals include magnesium, calcium and inorganic compounds like chlorine and sulphur also have influence during the process (Falimi et al, 2008, Oasmaa et al, 2010).

The most common inorganic elements in sawdust include Potassium (k), calcium (ca), magnesium (Mg), and silica(si) while concentrations of other elements like sodium (Na), manganese (Mn), phosphorous (P), Iron (Fe) Titanium (Ti) and copper (Cu) are minor (Boman et al, 2004). According to the metal composition in sawdust, it has been shown that Ca has the highest value in the feedstock followed by K, Mg and Na in succession order (Di Blasi et al, 2009). Table 1 show some of the alkali and alkali earth metal concentrations of various type of sawdust obtained from literature.

C. Constituents of Wood Sawdust by Ultimate Analysis

Apart from the concentrations of alkali and alkali-earth metals, sawdust also consists of carbon, hydrogen, oxygen, nitrogen and insignificant amount of sulphur (Jung and Park, 2008, Yaman, 2004, Calonaci and Desisto, 2010). The presence of large amount of oxygen and carbohydrate structure in sawdust makes it highly oxygenated. Table 2 shows a comprehensive summary of elemental analysis of the chemical compositions of different sawdust type obtained by various researchers. The percentage compositions of carbon and hydrogen in sawdust help determines its heating values as been reported by researchers.

The ultimate analysis helps us to quantify the various elemental chemical constituents such as carbon, hydrogen, oxygen, sulphur, etc. It is useful in determining the quantity of air required for combustion and the volume and composition of the combustion gases.

TABLE I. ALKALI AND ALKALI EARTH METAL CONCENTRATIONS OF VARIOUS SAWDUST TYPES

Sawdust type/unit	Sodium Na	Magnesium Mg	Calcium Ca	Potassium K	Reference
Japanese larch (ppm)	92.1	103.3	529.5	348.1	Park et al, 2008b
Pine (ppm)	-	239	643	378	Desisto et al, 2010
Bamboo (ppm)	41.6	405.6	3819	344.7	Jung et al, 2008
Beech (Mg/Kg)	74±14	386±3	2160±460	1080±190	Jendoubi et al, 2011
Oriental White Oak (ppm)	66.4	215	6537	1498	Park et al, 2009)
Radiata Pine (ppm)	46.8	165.3	491.4	891.7	Park et al, 2008a

TABLE II. ELEMENTAL ANALYSIS (WT.%) OF THE CHEMICAL COMPOSITIONS OF SAWDUST

Sawdust type	Carbon C	Hydrogen (H)	Nitrogen (N)	Oxygen (O)	Sulphur	Reference
Radiata Pine	44.8	5.90	0.10	46.2	-	Park et al, 2008a
Poplar	45.5	6.26	1.04	47.2	-	Gu et al, 2013
Pine-Spruce	48.7	6.20	-	45.1	-	Calonaci et al, 2010
Pine	45.0	6.80	<0.5	48.0	-	Desisto et al, 2010
Bamboo	46.9	5.85	0.21	47.2	0.02	Jung et al, 2008
Pine	50.3	6.30	0.10	43.3	-	Garcia-Perez et al, 2008
Japanese Larch	50.8	6.80	0.10	42.3	-	Park et al, 2008b
Oriental White Oak	50.3	6.40	0.3	43.0	-	Park et al, 2009
Waste furniture	49.1	6.20	3.00	41.7	-	Heo et al, 2010
Beech	44.3	6.27	0.11	48.75	-	Jendoubi et al, 2011
Pine	50.5	6.40	<0.1	43	-	Oasamaa et al, 2010
Sawdust	49.3	6.39	0.12	44.19	-	Salehi et al, 2009
Sawdust	45.15	4.78	0.39	35.49	0.03	Jung et al, 2010
Larch	44.8	5.98	0.24	48.3	0.02	Lee et al, 2006
White Oak	50.28	5.91	0.17	43.64	-	Jumulune et al, 2012
Spruce	49.1	6.44	0.18	43.9	-	Barmina et al, 2013

D. Carbon

Carbon has been known over the ages as the sixth most abundant element in the universe. It was derived from the Latin word charcoal meaning carbo. Carbon is most naturally obtained from coal deposits, but it normally must be processed into a form suitable for commercial use.

Therefore, there are three (3) allotropes of carbon which occur naturally. These are amorphous, graphite and diamond. Carbon is one of the elements that's that constitute the chemical composition of wood sawdust.

Based on the ultimate analysis carried out by Chaney (2010), it was reported that the composition of the sawdust charcoal briquette analyzed on an 'as-received basis' showed 53.07% carbon.

E. Hydrogen

This is the lightest element and the most abundant in the universe. It is regarded as a highly reactive colorless gas, represented with symbol H. It is available in water and most organic compounds. It is used in industrial processes, production of ammonia and also in the reduction of metal ores to metals.

According to the result of the ultimate analysis (Petura, 1979), all wood species contain about 6% hydrogen. A test conducted on average of 11 hardwoods shows 6.2% hydrogen and average of 9 softwoods shows 6.3% hydrogen (Tillman et al, 1981).

Also, the result of the ultimate analysis on the composition of wood sawdust shows 4.1% hydrogen (Chaney, 2010).

F. *Nitrogen*

This is regarded as a non-metallic element that occurs as a colourless, odourless almost inert gas and makes up four-fifth of the earth's atmosphere by volume. It has the symbol N. It is used for manufacture of ammonia, explosives and fertilizers.

Nitrogen has 0.1% and 0.2% compositions based on the result of the ultimate analysis carried out on different samples of 11 hardwoods and 9 softwoods respectively, (Tillman et al, 1981). This result is similar to the one given by Chaney (2010) where nitrogen has 0.28% composition.

G. *Sulphur*

This is a non-metallic yellow element that occurs alone in nature or combined in sulfide and sulfate minerals. It is represented by symbol S. It is used for the manufacture of sulfuric acid, matches, fungicides and gunpowder.

The result of the ultimate analysis done by Tillman et al, 1981 shows that there is no sulphur content in the various samples of hardwoods and softwoods. But according to the posted by the research of Akowuah et al, (2012), on the physico-chemical characteristics of sawdust charcoal briquette, sulphur contains 0.302% of the overall composition.

II. MATERIALS AND METHODS

The sawdust sample used for this experimental analysis is Ghana Obeche (*Triplochiton scleroxylon)* softwood sawdust. The feedstock was obtained from Iloabuchi sawmill, Port Harcourt, Rivers State, Nigeria.

The equipment and apparatus used for this experimental research are Precision balances, X-Ray Fluorescence Spectrometry (XRF), Elemental Analyzer, Muffle furnace, Soxhlet extractor, Glass wares and Reagents.

The precision balances were used to measure the quality of samples required for the experiment, muffle furnace was used to determine the ash content of biomass sample, while XRF spectrometer and elemental Analyzer were used to determine the quantities and mass concentrations of the major elements.

Several reagents were used to perform analysis on chemical composition and other constituents of the experimental samples.

III. ULTIMATE ANALYSIS

The ultimate analysis was done to determine the elemental chemical composition and various inorganic minerals of the sawdust sample. These include carbon, nitrogen, oxygen, Sulphur, sodium, magnesium, calcium and potassium in accordance with the procedures outlined in European Standard EN 15104: 2011 ("Solid biofuels –Determination of total content of carbon, hydrogen, and nitrogen-instrumental methods") and methods described ASTM 3176 and ASTM 5373.

IV. RESULTS AND DISCUSSION

A. *Analysis of Results*

Table 3 shows the elemental chemical composition of the analyzed sample (GOSS) through ultimate analysis. The following were obtained; carbon 52.8 wt.%, hydrogen 4.60 wt.%, nitrogen 0.19 wt.%, oxygen 37.4 wt.% and sulphur 0.206 wt.% respectively.

TABLE III. ELEMENTAL ANALYSIS (WT.%) OF THE CHEMICAL COMPOSITION OF GHANA OBECHE SOFTWOOD SAWDUST (GOSS)

Sawdust Type	Carbon (C)	Hydrogen (H)	Nitrogen (N)	Oxygen (O)	Sulphur (S)
GOSS	52.8	4.60	0.19	37.4	0.206

When comparing these compositional values with the ones in the Table 2 from various sawdust samples ranging Radiata pine, Poplar, Bamboo etc., it shows that the mass elemental concentrations of the GOSS can produce similar yield of biofuel when used as raw material or feedstock required for the generation of alternative energy.

Similarly, Table 4 shows the inorganic minerals concentration of GOSS which are; sodium (Na) 91.8 ppm, magnesium (Mg) 102.4 ppm, calcium (Ca) 526.1 ppm and potassium (K) 337.6 ppm respectively. These minerals are very useful during fast pyrolysis process, as they act as catalysts and influence the decomposition behavioral pattern of sawdust. The percentage compositions of carbon and hydrogen in sawdust help to determine its heating values and the values obtained for this analyzed GOSS sample are good enough to meet the required standard. Overall ultimate analysis is used in determining the quantity of air required for combustion and the volume and composition of the combustion gases.

TABLE IV. INORGANIC MINERALS CONCENTRATION OF GHANA OBECHE SOFTWOOD SAWDUST (GOSS)

Sawdust Type/Unit	Sodium (Na)	Magnesium (Mg)	Calcium (Ca)	Potassium (K)
GOSS (ppm)	91.8	102.4	526.1	337.6

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V. Conclusion

The outcome of this study which was based on analyzing the chemical composition and inorganic minerals of woody biomass for alternative energy generation as it applicable to Nigerian sawdust. The following conclusions were drawn after the experiment;

The results of the ultimate analysis indicated that the appropriate values of the major elements; carbon, oxygen, hydrogen, nitrogen and sulphur in the sample as outlined in the European Standard EN 15104:2011 and ASTM 3176 and 5373 showed that the sawdust sample has high energy content when used as feedstock.

Also, the result obtained various alkali metals such as sodium, magnesium, calcium and potassium from the experiment showed that the studied sample has adequate inorganic minerals that makes it suitable for use as wood fuel. It could also be concluded that the conversion and use of sawdust as a raw material in biofuel production and alternative energy generation will go a long way in controlling environmental pollution issue especially in a country like Nigeria with dense population of woody biomass.

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