# Determination of Heating Value of Five Economic Trees Residue as a Fuel for Biomass Heating System

Adeyinka Adekiigbe,

Department of Civil Engineering (Mechanical Unit), Osun State Polytechnic, P. M. B. 301, Iree, Nigeria
deyinka25@yahoo.co.uk

**Abstract:** The concerns about carbon emission and daily rise in prices of fossil fuel has increase the attention on biomass derived fuels which is affordable and environmentally safe fuel source for energy facilities, industrial boilers, pulp and paper industry, and cement industry. The higher heating value (HHV) of residues of five biomass sample (*Gmelina Arborea, Terminalia Superb, Milicia Excelsa, Triplochiton Seleroxylau and Tectonia Grandis*) obtained from Nigerian sources were determine experimentally and estimated from proximate analysis. The measured HHV of the sample varied between 20MJ/kg and 27MJ/kg, the estimated higher heating value varied between 16MJ/kg and 19MJ/kg which are quite low when compared with those obtained from bomb calorimeter test. It is economic estimation that based on only proximate analysis. Findings from the study established that *Terminalia Superb* appear the most clean and efficient sample among those tested, though the combustion characteristic of other samples are attractive. The results have very important implication in designing biomass heating system for a production industry which can eventually leads to reduction in cost of energy required in processing. Suggestions are made about ways to guide biomass energy towards effective achievement of government and stakeholder goals for renewable energy, climate change mitigation and natural resource sustainability.

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## 1. Introduction

One essential component of rapid economic and social development is energy. In other words, it is impossible for any country to achieve social and economic progress without a safe sustainable, reliable and reasonable affordable supply of energy to meet demand (Zaney, 2001). One of the acute problems facing mankind today is shortage of energy (Abraha, 1984); in which Nigeria is not an exception. The world's energy markets rely heavily on the fossil fuel, coal, petroleum crude oil, and natural gas as sources of energy, fuels and chemicals. Since millions of years are requires to form fossil fuels in the earth, their reserve are finite and subject to depletion as they are consumed (Klass, 2004). With fossil fuel prices rising daily and the adverse impact of it usage on the environment, the only substitute for fossil fuel is biomass (Balat and Ayar, 2003). Biomass is renewable in the sense that only a short period of time is needed to replace what is used as an energy resource (Balat and Ayar, 2003).

Biomass is obtained from living or once living material including wood or suitable waste material (Beck, 2003). Wood wastes of all types make excellent biomass fuels (Hurst Boiler, 2012). It can be used in a wide variety of biomass technologies. Combustion of woody fuels to generate steam and heat is a proven technology (Beck, 2003). To efficiently use wood residue as fuel, there is need to study its combustion properties which is important in designing furnace or burning device to ensure efficient utilization (Fuwape, 1985).

The present study is confined to determine the higher heating value of residues of five economic trees, and also to determine the proximate analysis and use the results to estimate the higher heating value by applying a unified correlation. It is expected that the information from this study will expose the energy potentials that are stocked in the residues of economic trees, and it will also provide a good basis on which the government and other stakeholder will plan and implement a safe, clean, and affordable energy.

## 2. Material and Methods

### 2.1 Material Description and Selection

Every country of this world has its peculiar distribution of tress and vegetation (Okonomo and Egho, 2010). In Nigeria, this is not different. This basis of selection was their economic importance, distribution, characteristic, origin, ecology and agro-forestry potential. They provide many products, including food for humans and animals, timber, fuel and medicine (Okonomo and Egho, 2010). The artists, wood carvers, casket builders, furniture workers and mortal makers' preferred to use them. The table 1 below shows the five economic trees.

The materials for the study were collected for major sawmill in Ikire, Nigeria. Since there are no standard sampling procedure specified for biomass materials (Channiwala and Parikh, 2002), samples were collected with due care to get the most representative sample and were kept in polythene bags. Preparation of samples was carried out in accordance with ASTMD 2013-86 (1989). The procedure required sample to be in powder form up to 250mm grain size.

Table 1. List of economic trees used in the study

| Botanical name | Common name |
|---|---|
| *Gmelina Arborea (Roxb)* | Gmelina/White Teak |
| *Terminalia Superb* | Afara |
| Milicia Excelsa | Iroko |
| *Triplochiton Scleroxylau* | Obeche |
| *Tectoni Grandis L.F* | Teak |

Source: Okonomo and Egho, (2010)

**2.2 Experimental Method**

The moisture in test sample was determined according to ASTM D2016-74 (83) method. The specific gravity was determined in accordance with ASTM D2395-93 standard. The proximate analysis of sample was carried out in accordance with ASTMD3172-73 (1984) standard. The volatile matter contents in the test sample were determined according to ASTMD3175-89. Determination of ash content in the test sample was carried out according to ASTMD3174-89 method in the electric furnace. The fixed carbon content of the test sample was calculated by difference. The higher heating value of these samples was determined according to ASTM D2015-(1985) method in a oxygen bomb calorimeter. The estimating higher heating value of sample was also computed by applying correlation based on proximate analysis information.

The percentage moisture content (MC) was calculated as follows:

$$\% M.C = \frac{w_w - w_d}{w_w} \times 100 \%$$

where, $W_w$ = weight of the sample as received, $W_d$ = weight of the sample after oven-drying.

The percentage specific gravity (S.G) was determined as follows:

$$\% S.G = \frac{w_{wd}}{w_{wt}}$$

where, $W_{wt}$ = weight of the wood sample, $W_{wd}$ = weight of water.

The percentage volatile matter (V.M) was determined as follows:

$$\% V.M = \frac{m_s - m_{fd}}{m_s} \times 100 \%$$

where, $m_s$ = mass of air dried sample, $m_{fd}$ = mass of sample after 10 mins in furnace at 900$^o$C.

The percentage ash content (A) was determined as follows:

$$\% A = \frac{m_{ar}}{m_s} \times 100 \%$$

where, $m_{ar}$ = mass of ahs residue (g), $m_s$ = mass of air dried sample (g).

The percentage fixed carbon (F.C) was determined by subtracting the sum of percentage volatile matter and ash content from 100.

$$\% F.C = 100 - \% (V.M + A)$$

The measured higher heating value (HHV) of fuel sample was determined as follows:

$$HHV = \frac{(q_2 - q_1)C}{m} \text{ (kcal/g)}$$

where, $q_2$ = galvanometer reading with sample, $q_1$ = galvanometer reading without sample.

C = calibration constant, m = mass of fuel sample.

The estimated higher heating value (HHV) of fuel sample was computed as follows:

$$HHV = 0.3536(F.C) + 0.1559(V.M) - 0.0078(A)$$

(MJ/kg) (Parikh, Channiwala and Ghosal, 2005).

**3. Results**

Form Table 2 the air-dried samples obtained varies widely in moisture content, from 7.9% to 38.00%. Most of the samples were however in moisture content levels lower than 24.60%. This implies that they must have been stored for long periods before being collected. Most of the sample has moderate specific gravity except *Tripochiton Scleroxlau* that has the lowest specific gravity of 0.44% and it's reflected in heating value.

Table 2: Physical properties of samples tested.

| Sample | Physical | | |
|---|---|---|---|
| | Condition of test sample | Moisture content (%) | Specific gravity (%) |
| *Gmelina Arborea Roxb* | Air dried | 24.60 | 0.50 |
| *Terminalia Superb* | Air dried | 7.90 | 0.53 |
| *Milica Excelsa* | Air dried | 38.00 | 0.53 |
| *Triplochiton Sclerxylau* | Air dried | 12.50 | 0.44 |
| *Tectonia Grandis* | Air dried | 12.80 | 0.61 |

The result of proximate analysis on Table 3 show that all the samples contained more volatile matter than fixed carbon and more fixed carbon than ash forming minerals. The *Milicia Excelsa* has highest value of 85.77% while *Gmelina Arborea* has the lowest volatile matter of 83.00%.

Table 3: Proximate analysis of samples tested

| Sample | Proximate analysis | | |
|---|---|---|---|
| | Volatile matter (%) | Ash content (%) | Fixed carbon (%) |
| *Gmelina Arborea Roxb* | 83.00 | 0.58 | 15.80 |
| *Terminalia Superb* | 82.09 | 0.73 | 17.18 |
| *Milica Excelsa* | 85.77 | 2.49 | 11.74 |
| *Triplochiton Sclerxylau* | 84.50 | 4.89 | 10.61 |
| *Tectonia Grandis* | 83.19 | 1.83 | 4.96 |

Table 4: Higher heating value of samples tested

| Sample | Higher heating value | |
|---|---|---|
| | Measured (kJ/kg) | Estimated (kJ/kg) |
| *Gmelina Arborea Roxb* | 25,650 | 18,522 |
| *Terminalia Superb* | 27,866 | 18,866 |
| *Milica Excelsa* | 22,806 | 17,503 |
| *Triplochiton Sclerxylau* | 20,208 | 16,887 |
| *Tectonia Grandis* | 24,151 | 18,244 |

The result of proximate analysis on Table 3 show that all the samples contained more volatile matter than fixed carbon and more fixed carbon than ash forming minerals. The *Milicia Excelsa* has highest value of 85.77% while *Gmelina Arborea* has the lowest volatile matter of 83.00%.

**4. Discussions**

On the basis of the physical properties, the *Milica Excelsa* is the poorest species tested. Moisture in the fuel samples severely reduce available heating value, a low moisture level in the fuel is usually preferable (Lucas and Fuwape, 1984). All most of the samples have low moisture content; this implies that they must have been stored for long periods before being collected. Wood with high density is normally preferred as fuel because of its high energy content per unit volume when compared with low density. A high specific gravity is desirable for fuel, it increase with decrease in growth rate (Lucas and Fuwape, 1984). All the samples have low specific gravity and it is reflected in their heating value.

The results of the proximate analysis shows that all the samples contained more volatile matter than fixed carbon and more fixed carbon than ash forming minerals. The quantity of hydrocarbon in all the samples tested are highly, which indicate that they may burn with long smoke, to reduce amount of smoke, the heating system temperature should be high and small quantities of fuel should be fed at regular interval. The percentage ash-forming minerals in *Gmelina arborea roxb* residue are small but high in *Triplochiton sclerylau* is high. The need to clean out the combustion chamber of burning device would be much reduced when ash content is low (Lucas & Fawape, 1982).

The higher heating value determines the quantitative energy of the fuels (Fawape, 1985). The residue of *Terminalia superb*, with heating value of almost 27,866 kJ/kg is the best fuel among the trees residue tested. Its heating value approaches the heating value of carbon which is about 32,000kJ/kg. The more the hydrogen and carbon content of the residue of the tree, the greater the heating value. The figure obtained for higher heating value using the results of proximate analysis with correlation are quite low when compared with those obtained from the bomb calorimeter test. The calometric method measured the total heat generated when a unit mass of sample is completely burnt in 25bars of oxygen while the unified correlation method estimated heating value of combustion. The assumption on which unified correlation equation based is on economic estimation of energy content per sample volume and does not account for energy loss in bond breakage as well as heat of formation when element combine chemically. All the result samples are quite high heating value make them suitable as a fuel for biomass heating system.

**5. Conclusion**

This experimental study has provide a useful framework for determine the most suitable sample for fuel among the five economic trees residue tested that have low moisture content, high specific gravity, low ash content, and a substantial heating value rating. *Terminalia Superb* appears the most efficient among those tested. *Gmelia Arborea* and *Tectonia Grandis* would be of good use as fuel. The use of their residues in raising steam in boiler house and producing the heat in production industry would considerably cut down the cost of energy required in processing; thereby reduce the overall cost of production. They can also be used for domestic cooking, heating and for keeping the surrounding warm, instead of relying on depleting fossil fuel, highly cost gas and electricity. Government should formulate policy that will consider biomass energy technology as a tool for integrated development, and also encourage large commercial forestry operation for economics tree growth in order to span benefits like erosion prevention, employment creation, reduction of pretentious gases, and protection of wildlife and other components of biodiversity.

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**Corresponding Author:**
Engr. Adeyinka Adekiigbe
Department of Civil Engineering (Mechanical Unit)
Osun State Polytechnic, P. M. B. 301, Iree Nigeria
E-mail: deyinka25@yahoo.co.uk

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