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FUEL WOOD SYSTEMS: REDUCTION OF GREENHOUSE GAS EMISSIONS

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ABSTRACT

Fuel wood systems offer significant possibilities for reducing greenhouse gas emissions when bio-energy replaces fossil fuel in energy production. This research paper provide analysis of calorific value, wood density, moisture content and ash content of commonly used fuel woods in Girei local government area of Adamawa state-Nigeria to determine the fuel-woods which are suitable as energy source. Nine (9) commonly used wood species of interest were selected for test evaluation. Test result show that Tamarindus Indica, Dalbergia Melanoxylon and Prosopis African have relatively high wood density, high calorific value and low percentage ash content when combusted. Their low ash content is also desirable as fuel since only non-significant part of the volume cannot be converted into useful energy. These wood species should be planted as a source of fuel-wood while efficient wood burning stoves should be develop and adopted in local communities. It is recommended that thermal test performance and emission characteristics of these wood species should be conducted.
Key words: Calorific value, Wood density, Ash content, Moisture content, Greenhouse gas emissions

INTRODUCTION

Biomass has been a major source of energy throughout the world. It refers to the energy of biological systems obtain from animals and plants. It is an indirect form of solar energy because it arises due to photosynthesis of plants. It is the primary source of energy for nearly 50% of the world's population (Kithyoma et al, 2006). Wood biomass is a major renewable energy source in the developing world representing a significant proportion of the rural energy supply (Hashiramoto, 2007). The resources that make up biomass can be classified into wood biomass, forge, grasses and shrubs; residues and waste (forestry, agricultural, municipal and industrial) as well as aquatic biomass. Organic materials, including cultivated products, solid agricultural waste, urban and rural material waste are abundant in most developing countries of the tropics. The biomass which is considered most significant in terms of energy source is wood and wood waste. Wood is a traditional fuel and about

50% of the wood harvested in the world is used as fuel (Doglas, 1994). The reasonable energy from wood compares favorably with other classes of energy sources such as solar, wind, tidal and geothermal. Wood is cheap, abundant and renewable as it could be grown consistently for energy utilization as long as there is land, water and sunshine. Wood energy provides an alternative to fossil fuels, a means to combat a changing global climate, and an environmentally sound sustainable energy future. Wood provides about 2.4% of Australia's total primary energy needs while developing countries such as Nepal, Ethiopia and Kenya obtain majority of their energy needs from the burning of wood, animal dung and other biomass (Badcock *et al.*, 1978). Nigeria uses 80 million cubic metres of fuel wood annually for cooking and other domestic purposes (Sambo, 2005).

Most woods burn readily but some species are fire retardant and will not burn except in the mixture of more flammable woods. While some woods burn readily, they may not be suitable for fuel woods because of excessive spark production, toxic or irritating smoke. The wood of Sesbania grandiflora for example is not highly regarded as fuel because of the excessive smoke it produces when burning (Hegde, 1990). Fuel wood properties include calorific value, wood density and wood moisture content. The importance of these factors for domestic fuel wood use depends on the type of stove used, cooking methods and the adequacy of ventilation. Local preferences may also be important depending on the effects of the fuel wood on the flavour of the cooked food. Gross calorific value is not an important property since there is little variation among species (Harker *et al.*, 1982). However, the total energy contained in wood is not converted completely to available heating energy since this includes heat generated by the combustion of hydrogen (about 6% of wood mass). Heat is also lost in vapourising moisture contained in the wood. The result obtained from the research is to used to recommend the fuel wood species with better energy value and characteristics value for plantation so as curtail indiscriminate the felling of trees in Girei local government area of Adamawa state.

MATERIALS AND EQUIPMENTS

The commonly used wood species in Girei local government of Adamawa state, Nigeria were used for the study. Young fresh branches of the trees species were obtained from the sudan savannah forest. Table 1 gives the botanical, English and Hausa names of the woods species. The equipments used for the tests were Cusson's bomb calorimeter set consisting of Bomb Calorimeter vessel of double walled outer vessel, Beckman thermometer, thermocouple, Galvanometer Crucibles porcelain, low wide form 3ml, covers numbered with furnace-proof ink. Other equipments were Muffle furnace with pyrometric controller, Analytical balance of sensitive 0.1mg, desiccators, drying oven, wood cutting machine, a digital weigh scale, and Venier caliper and oxygen cylinder.

Table 1: Names of commonly used wood species

S/No	Botanical	English	Hausa
1	Ficus Thonningii	Strangler	Chediya
2	Vitex Doniana	Black Plum	Dinya
3	Prosopis African	Iron wood	Kiriya
4	Balanites Aegyptiaca	Soap Berry	Aduwa
5	Piliostigma Reticulatum	Camel's foot	Kargo
6	Danlella Oliver	Copaila Balsam	Maje
7	Dalbergia Melanoxylon	African Black wood	Karye Gatari
8	Parki Biglobosa	African locust bean	Dorowa
9	Tamarindus indica	Tamarin	Tsamiya

METHODOLOGY

Sample preparation

The wet branches of the woods species were split into medium size mostly used for fuel wood and air-dried for 90 days to reduce the moisture content. The dried wood samples were then sawed using the wood cutting machine and the dust collected for the test.

Determination of Calorific Value

The calorific values of the wood species were determined using Cusson's bomb calorimeter. One kilogram of the sawdust of each sample was loaded into the bomb calorimeter crucible. To initiate the burning process of the saw dust wood, a 50mm long cotton thread was inserted between the Nichrome firing wire coils and the center of the test sample specimen in the crucible. The sealing of the bomb calorimeter was positioned in its groove avoiding surface flows of the seal ring. The knurled locking of the ring of the calorimeter was raised and bomb body lowered into the ring and the body rotated until its threads fully engage the thread of the ring. The sealing ring was then tightly screwed on the thermocouple plugged into position through the top of the bomb calorimeter. Oxygen was then passed into the interior of the bomb calorimeter from a cylinder through the top valve on the calorimeter to a pressure of about 25bars. The indicator on the galvanometer was adjusted to zero and left to stabilize for about 30 seconds to check the stability of the ambient temperature within the bomb calorimeter. The bomb calorimeter content was then ignited for the combustion process. The maximum temperature for the combustion process was then noted through the thermometer inserted on the bomb calorimeter.

The calorific value of each wood species was calculated using equation 1

$$\text{Calorific Value}\left(\frac{Q}{M}\right) = C\Delta t \quad \text{...1}$$

Where;

Q=Quantity of heat released during combustion (KJ)

M=Mass of wood burnt (kg)

C=heat capacity of bomb calorimeter 1238KJ/°C

Δt =temperature rise

Determination of percentage Ash content

The air-dried wood samples were weighed to 5g each. The crucible with covers were dried for 2-hours at 100°C in an oven and removed from the oven to the desiccators. They were cooled and weighed with their covers to the nearest 0.1mg and the result recorded as M_1 while the 5g earlier weighed was recorded as M_0. The crucibles and the samples were weight together and the result recorded as M_2. The sample was then Ash in furnace at 600°C for 2-hours. The crucibles with covers were allowed to cool in furnace to a temperature of less than 200°C and placed in desiccators with vented top. The crucibles were then weighed with covers and the ash content to the nearest 0.1mg and recorded as M_3. The percentage ash content of the wood species was calculated using equation 2

$$\text{Percentage Ash content} = \frac{M_3 - M_1}{M_O} \times 100 \quad \text{..2}$$

Where:

M_O=weight of the sample

M_1=weight of the crucible

M_2=weight of crucible and dry wood sample
M_3=weight of the crucible and ash

Determination of Density

The wood species were cut into cuboids and the mass of each pellet was obtained using a digital weighing scale. The mass was recorded as M. The dimensions of the cuboids shaped pellet were obtained by measurement using a vernier caliper. The dimensions were recorded as length (l), breadth (b) and width (w) and the volumes of the wood species obtained through calculation. The density of the wood species were calculated using equation 3

$$\text{Density, } \rho = \frac{M}{V} \qquad \ldots\ldots 3$$

Where:
ρ is the density of wood species
M is the mass of wood species
V is the volume of wood species

Determination of Moisture Content

The wood species were cut into pellet and the mass of the wet pellet measured and recorded as M_{wet}. The wet wood specimens were placed in an oven at a temperature of 103°C for 24 hours. Then the mass of the oven dried woods specimen were measured and recorded as M_{od}. The moisture content of the wood species were calculated in percentages using equation 4.

$$\text{Moisture content (M)} = \frac{M_{wet} - M_{od}}{M_{od}} \times 100\% \qquad \ldots\ldots 4$$

Where
M_{wet} is the mass of wet wood species
M_{od} is the mass of oven dried wood species

RESULTS AND DISCUSSION

Table 2 shows the calorific value, density, ash content and moisture content of the nine most commonly used fuel woods species in Girei local government area of Adamawa state.

Table 2: Calorific value, Density, Ash content and Moisture content of the nine tested woods species.

S/No	Wood species	Calorific Value (KJ/Kg)	Density (Kg/m^3)	Ash Content (%)	Moisture Content (%)
1	Ficus Thonningii	19.30	440.0	5.20	9.10
2	Vitex Doniana	21.22	606.1	7.40	13.35
3	Prosopis African	21.47	1034.4	3.00	11.35
4	Balanites Aegyptiaca	21.47	894.3	5.60	12.01
5	Piliostigma Reticulalum	22.18	636.4	8.20	14.35
6	Danlella Oliver	20.76	746.2	15.00	11.60
7	Dalbergia Melanoxylon	22.50	1420.4	7.20	11.20
8	Parki Biglobosa	22.14	782.1	5.00	12.06
9	Tamarindus Indica	23.12	1061.9	4.20	10.05

Percentage of Ash Content

High ash content of wood is less desirable for fuel wood as it is characterized as non combustible products and reduces heat of combustion (Klasnja *et al.,* 2002). Higher ash content signifies that higher percentage of the wood is not combusted. This shows that Danlella Oliver and Piliostigma Reticulalum are less desirable wood species for combustion process due to their high percentage ash content while Prosopis African and Parki Biglobosa have low ash content and could yield high level of useful energy when combusted.

Density of Wood Species

The density of wood determines its duration in fire when combusted. A higher wood density will sustain combustion for a long duration of time and produces long-lasting coals and thus more desirable. It can also be used as a parameter in determining the softness or hardness of wood species. Dalbergia Melanoxylon, Tamarindus Indica and Prosopis African have high densities of more than 1000kg/m^3 and are most likely to be hard woods. Since hard woods are known for sustaining long lasting combustion process as well as long lasting coals, they are more economical where heating requires steady concentrated long heat production.

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Calorific Value

When choosing wood for burning there are three factors which have an effect on the calorific value (CV) or the amount of available heat per unit of fuel (type of species, wood density and the moisture content). Hard woods give higher net kilo-Watt hour (kWh) of heat from a cubic-metre, m^3 of wood than soft woods. Thus, Dalbergia Melanoxylon, Tamarindus Indica and Prosopis African will give a higher calorific value than Ficus Thonningii, Piliostigma Reticulalum and Vitex Doniana. As show in the table of results, the moisture content and wood density has considerable effect on the calorific value of the wood when combusted as higher moisture content and low wood density tend to gives a lower calorific value.

Moisture Content

There is variation in calorific value between wood species due to the amount of water naturally present in the wood when felled. Thus, fresh woods have lowered calorific as part of the useful heat is used in vapourising moisture contained in the wood. Similar wood species dried to the same moisture content will have similar calorific value. From the table of results, it can be inferred that less heat would be lost to vaporizing the moisture in Ficus Thonningii and Tamarindus Indica than the other wood species. In practical term, if the combustion process of these woods species takes place in an open air where the heat of combustion will not be completely capture, then the heating value of these woods would be less than the value shown in result table. From literature it was recorded that if the moisture content of wood is less than 20% it will burn without smoking. It can also be inferred from Figure 4 that the woods under study will burn without smoking and are considered as good candidate for usage without polluting the environment

CONCLUSION AND RECOMMENDATION

The use of fuel wood is not an ideal intervention method when addressing energy crises due to poor indoor air quality associated with biomass combustion and negative effect of deforestation on the environment. However, when choosing wood for burning, three factors are of paramount interest; wood species, wood density and moisture content are to be establish. Hardwoods (deciduous, broadleaved tree species) tend to be denser and hence making a ton of hardwood logs to burn for a longer period of time than softwood softwoods (evergreen, coniferous species) which contain more resins. From literature, the moisture content of wood has the greatest effect on calorific value than any of the variables. Water moisture left in the timber has to be evaporated away before the wood will burn. This reduces the net energy released as useful heat. Generally, density of wood biomass, calorific value and percentage ash content are important wood fuel variables that affect the burning characteristics (combustion) and energy released of the fuel including the type of combustion equipment used. The choice of fuel wood in the local government area is not governed by factors like the burning duration, the maximum obtainable temperature and ash content of the wood species and thereby using whatever fuel wood is available. Indiscriminate clearing of land and exploitation of trees for fuel wood without replacement is a major problem today most especially in developing countries. If deforestation and its associated environmental degradation effects are to be curtailed, then only efficient wood burning species should be used as fuel wood. Improve efficient wood burning stoves should be develop and the thermal performance and emissions characteristics of the stove using the wood species should be carryout to select the most efficient wood species while at the same time government should embark on afforestation programmmes.

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