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Investigation on the Effects of Addition of Binder and Particle Size on the High Calorific Value of Solid Biofuel Briquettes

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Abstract
The effects of biomass particle size and addition of binder on the high calorific values (HCVs) of five (5) selected biomass briquettes is studied. Analyses of the experimental results show that finely grinded particles (about 1.75mm and 2.00mm) had low calorific values as the grinding resulted in a loss of some heat and made the sample vulnerable to air oxidation.Addition of gum Arabic binder greatly inceases the high calorific value of all samples followed by starch and top-glue binder tend to decerease the HCVs for the range of biomass tested in the order 25.3201> 23.2985>20.0023 respectively.Thus indicating gum Arabic and starch improves the caloric value while top glue and polyvinyl Chloride (PVC) decreases the calorific value of the samples. An extensive investigation on the PVC dissolved in Toluene compound(organic) as chemical binder was observed to decrease the calorific values of all the briquette samples except those made of coconut shell and rice husk.
Keywords: Biomass, Biofuel, Binder, Briquette, High heating value

1. Introduction

To address the various energy challenges associated with non-renewable fuels, many countries have indicated commitment to Biofuel production that are renewable, sustainable, cheap, safe and geographically diversified (Abdullahi *et al*, 2011; McKendry, 2001 and Hodgson, 1999).. Solid Biofuel in the form of briquettes, logs, bales, chips, pellets, etc had become an important source of energy even in the rural communities. The main advantage of the Biofuel briquettes are its domestic origin, potential for reducing total dependence on oil and gas economy, jobs creation to the rural dwellers and help in the waste management by changing waste to wealth. Biofuel briquettes for utilization as energy source for domestic and industrial heating processes can significantly reduce emissions of air pollutants (El-Shinnawi et al., 1989; Fabian, 2003). The bush biomass and agricultural waste that are largely produced daily in the country could be employed as raw-materials for both small and large scale solid Biofuel production. Ismail et al 2013, investigated biomass briquettes as energy source in relation to their elemental contents. The major challenges associated with the use of oil as energy source includes economic loses, destruction of the environment, marine plants and animals (Hischberg et al., 2004). Another problem with oil as fuel is sustainability and projected depletion with time. Analysis by Hodgson(1999) showed that the energy consumption in the decade 1984-1994 rose by 1.6% per year worldwide but in Africa by 2.3% while in China it increased by 4.3% etc. This increase in energy demand requires a study to add to the existing sources of energy.

The use of wood as fuel in large scale without replenishing poses serious environmental consequence in many countries, desertification being the most important. The increase in Nigerian population places more demands on energy, to the extent that the increase use of wood exposes the country to hazards of desertification and flooding. To address the various energy challenges associated with non-renewable fuels and desertification, there is the need to perfect the production of biofuel briquettes. Yakubu(2009) reported that gum Arabic enhances/increases the calorific value of briquettes while starch decreases or retards the combustion of biomass. This work aims at investigating the required grain size and types of chemical additives that enhances the heating value of the biofuel briquettes.

In order to determine the effect of biomass grain size and addition of binder on the solid Biofuel preparation, this work investigated the key effects of particle (grain) size and addition of binder on the calorific values (thermal value) for various Biofuel samples. It was an experimentally based project that employed the used of oxygen bomb calorimeter (Parr 6100 model) in determining the calorific values of the samples directly. Kumar and Pratt,(1996) estimated the high heating values from elemental composition of biomass fuel. McKendy(2002) found out that the actual amount of energy recovered from a given biomass source vary with conversional technology, as will the form of energy used.

2. Materials and Methods

2.1 The Raw Materials

The raw materials used in this work are biomass from herbaceous plants (perennial crops) and agricultural residues locally produced in Nigeria's community. These materials are collected from farmlands and local community around 'Yar Adua University, Katsina, Nigeria in October, 2011. They were kept under a room temperature and used in this experimental work without any pretreatment so as to represent the actual scenario (condition) by which they are used as fuel.

2.2 Sample Preparation

The samples were cut to approximately 1cm size using stainless steel scissors and used for analysis. The dried samples were carefully pounded in a wooden mortar with wooden pestles and then sieved to 1mm mesh size samples. The powdered samples were mixed with known mass of different adhesives and 200ml of water and then prepared into a pellet (of about 2.5g mass) by means of a pellet press; this is done to prevent scattering of material during the combustion, with consequent incompleteness of combustion. These pellets were sundried and kept in a polyethylene bags to prevent moisture absorption before experiment. The screening procedure recommended in the instrument's manual for determining the calorific values using bomb calorimeter was observed.

2.3 Experimental Procedure and Equipments

The direct determinations of the high calorific values (HCV) of the samples were made using a bomb calorimeter (model 6100 series manufactured by Parr Instrument Company) in the chemical engineering department, Ahmadu Bello University, Zaria. The calorific value from this machine is the high heat value (HHV), which includes the latent heat of the vapor emitted from the specimen. The machine consists of a small cup to contain the sample, a 1108 oxygen bomb with an oval bucket which fits into the insulating water jacket, a built-in semi-automatic system for charging the bomb with oxygen, high precision electronic thermometer, a bright, color, touch screen display for data entry and operation control, Special communication ports for printer, computer and network (LAN) connections, the Dewar (to prevent heat flow from the calorimeter to the surroundings), ignition circuit connected to the bomb and a removable compact flash memory card slot for simple program updates and test report archiving. All steps in the test procedure are managed by a microprocessor control system programmed to operate the calorimeter in either the conventional equilibrium mode or in a faster dynamic mode. All data is handled automatically by a dedicated microcomputer. The only calibration necessary prior to burning the samples, is that the heat of combustion measured by the apparatus must be calibrated using 1g mass (99.5% purity) of benzoic acid. As the calorific value of the benzoic acid is determined, the bomb is standardized, and is ready for use to calculate heat of combustion of any compounds.

Electrical energy is used to ignite about 0.140g of the fuel; as the fuel is burning, it will heat up the surrounding air, which expands and escapes through a tube that leads the air out of the calorimeter. When the air is escaping through the copper tube it will also heat up the water outside the tube. The temperature change in the water is then accurately measured. This temperature rise, along with a bomb factor (which is dependent on the heat capacity of the metal bomb parts) is used to calculate the energy given out by the sample burned.

3. Results and Discussion

3.1 Effect of Addition of Binder on HCV

The results listed in tables 1 and 2 reflect the effect of the addition of binder on the calorific value of biomass. Top-burnt glue, starch, gum Arabic and Polyvinyl Chloride(PVC) dissolved in Toluene (organic binders) were used in this work. Addition of binders in the preparation of biomass is important for transport, ease of forming briquette and storage purposes.

It can be seen from table 1 and figure 1 above, the addition of gum Arabic binder greatly increases the gross calorific values of most samples when compared with the results without binder followed by starch. Addition of top-burnt glue binder decreases the calorific values of most samples except for stalks. Decrease in calorific value would not be acceptable since the whole aim of biomass combustion research is to enhance its heating values. It is therefore important to consider the effect of binder to be added in the solid Biofuel preparation as briquettes, pellets, bales, chips, etc. For sawdust, the calorific value without binder is greater than that with binder. This is due to the fact that the effect of binder greatly depends on the elemental composition of the fuel in question. In the earlier work of Yakubu (2009), it was reported that briquettes produced from sawdust with gum Arabic binder are quite better in terms of calorific value, combustion characteristics, quality and ecological friendliness than does produced from sawdust-starch and it was also confirmed in this work. The effect of PVC dissolved in Toluene as an organic binder is shown in Table 2. This class of organic binder greatly decreases the heating value of most biomass when used as fuel. The calorific values is observed to decrease by a half when compared with the values of the same briquettes without the organic binders

Table 1: Effect of Addition of Binder on GCV

S/N	Fuel Name	GCV (MJ/kg) Without binder	GCV (MJ/kg)*	GCV (MJ/kg)**	GCV (MJ/kg)***
1	Saw dust	18.1725	17.1785	16.4218	-
2	Maize Stalks	18.7302	16.3155	19.0243	-
3	Husk?	-	19.1932	18.7401	23.3341
4	Paper	20.7841	20.0023	23.2985	25.3201
5	Stalks?	15.5741	18.0125	18.9540	19.9841

- Top-burnt Glue ** Starch *** Gum Arabic

Table 2: Results of the Effect of PVC Binders on Gross Calorific Value (HHV)

Fuel Name	Mesh Size (µm)	HHVs (MJ/Kg) Briquettes without Binders	HHVs (MJ/Kg) Briquettes With PVC Binder
Cocoanut Shells	212	18.73625	26.16468
Groundnut Shells	212	51.8665	23.0233
Coffeeweed(Senna Obtusifolia)	212	41.49233	17.76208
Coffee senna (Senna Occidentalis)	212	17.07803	10.05858
Rice Husks	212	9.403375	23.5233
Bagasse	212	33.66293	15.57563
Maize Cobs	212	37.39783	13.4173
Rice Straw	212	33.9892	24.0586
Cotton Stalks	212	26.33613	16.46235
Sawdust	212	37.58613	14.89713
Flamboyant	212	42.1115	16.6632
Maize Husks	212	39.21535	15.18025
Corn Stalks	212	34.8391	10.97908
Switch Grass	212	29.02033	14.70883

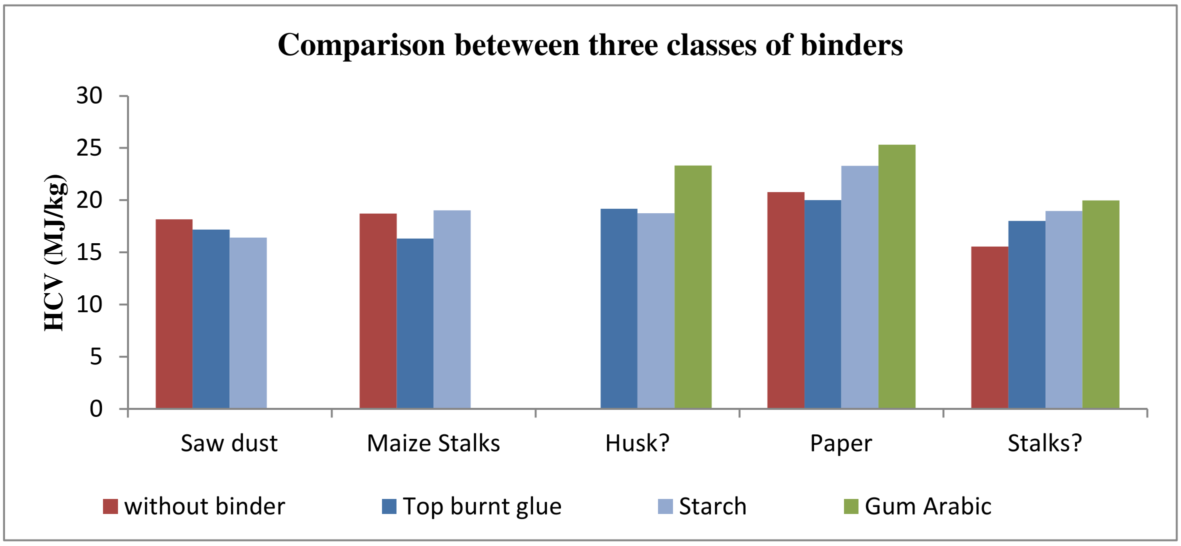

Figure 1: Comparison between three classes of organic binders

3.2 Effect of Particle Size on HCV

The effect of particle size on the measured heating values of biomasses is presented in table 3 and figure 2 represent the bar chart of the results. It can be seen by comparison of the three mesh sizes; the bigger size of 3.35mm has high calorific values than smaller (1.75mm and 2.00mm) mesh sizes. The fine size (2.00mm) gives the smallest heating values in all the samples except for paper. The fine grinding resulted in a loss of some heat and made the sample vulnerable to air oxidation. This result agrees with that obtained by Kumar and Pratt (1996) when the effect of particle size on three plant biomass was analyzed. Ismaila *et al* (2013) also obtained the same

results when the effect of grain size on the fourteen selected plant biomass was investigated.
It was observed that the measured calorific values for all sizes are generally within the widely reported values in the range of 17-21 MJ/Kg for biomass materials. In all the sizes, 3.35mm gives a better result that is quite comparable to ASTM results.

Table 3: Effect of Particle Size on GCV

S/N	Fuel Name	Size (1.70mm)	Size (2.00mm)	Size (3.35mm)
1	Saw dust	19.0043	18.7495	-
2	Maize Stalks	18.6254	-	20.0748
3	Husk	20.1466	19.6025	19.7541
4	Paper	18.7005	19.9948	-
5	Stalks	13.0015	12.7431	13.4321

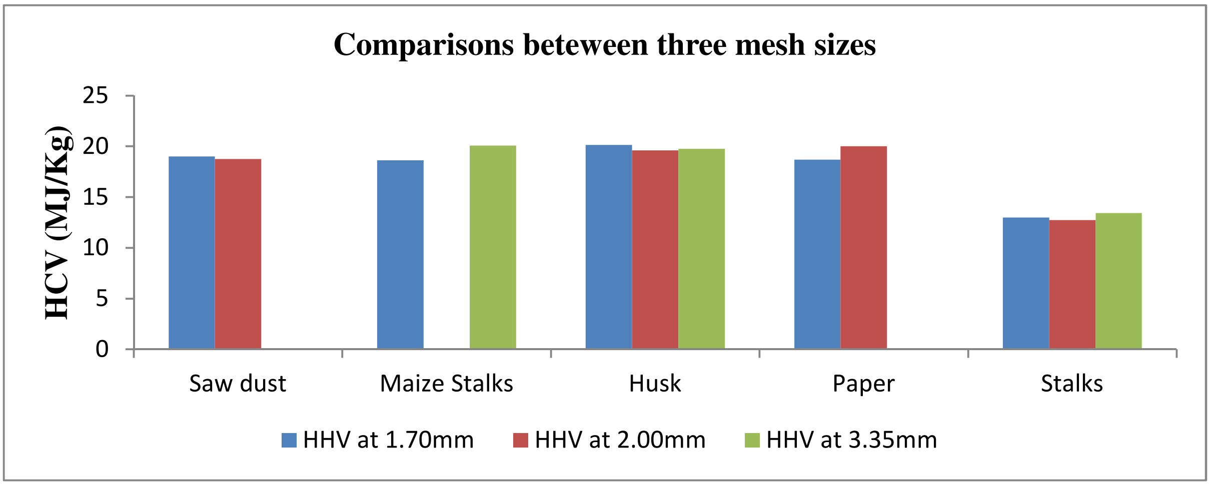

Figure 2: Effect of Particle Size on the HCV

4. Conclusion

The results of the investigation reveals that finely ground particles (about 2.00mm) had low calorific values when compared with 3.35mm grain size. That the grinding resulted in a loss of some heat and made the sample vulnerable to air oxidation. Also the grain size effect is dependent on the type of biofuel material. Addition of top-burnt glue and PVC dissolved in Toluene as organic binder greatly decreases the heating value of most fuels but gum Arabic binder increases the high heating value of all samples followed by starch. The negative binding chemical effect on the high heating value would not be acceptable as the prime aim of biomass combustion research is the enhancement of its heating values. Again the binding effect is observed to depend on the nature of biofuel material. The method of our analysis may have played a role in the observed results as reported by McKendy(2002) but the consistence of the results with that of other reports (Kumar and Pratt, 1996 and Yakubu,2009) validates the work.
It is recommended that different particle sizes should be tested in order to obtain an optimum particle size with a different technique, so as to improve on the HHVs. Also other organic or chemical binders should be tested in order to come up with a better and improved binding agent that adds to the calorific value of biomass briquettes when used as fuel. Else if a choice be made from our investigation, a biomass briquette of particle size 3.35mm is a choice when bound with gum Arabic.

4.1 References

Abdullahi, I., Ismaila, A., Musa, A.O., and Galadima, A. (2011). Effect of Kinetic Parameters on Biogas Production from Local Substrate Using a Batch Feeding Digester. *European Journal of Scientific Research*, Vol. 57 No.4, pp.626-634
Burgher, P., 2007. In-depth analysis of accidental oil spill form tankers in thee context of global oil spill trends from all sources, Journal of Hazardous materials, 140, 245-256
El Shinnawi M. M, El Tahawi B.S, El Housein M, Falony S.S 1989 Changes of organic constituents of crop residues and poultry waste during fermentation of biogas production. Applied Microbiology Biotechnology, Vol. 5 pp475-486

Fabian M, 2003 An introduction to anaerobic digestion of organic wastes. Scotland Remade.

Hischberg S, Bergher P, Piekerman G, Dones R 2004. Severe accidents in the energy sector, comparative prospective. Journal of Hazardous Material 111, 57-65

Hodgson, P.E., (1999). *Energy and environment.* England: Imperial College Press, Chap 1 and 2.

Ismaila, A., Zakari Y I, Nasiru R, Tijjani B.I, Abdullahi I, and Garba N.N (2013). Investigation of Biomass Briquettes as Energy Sources through their Calorific Values in Relation to their Total Carbon/Hydrogen Content for Efficient Biofuel Utilization, Advances in Applied Science Research., 4(4): 303-309 .

Kumar, J., and Pratt, B.C., (1996). Determination of Calorific Values of Some Renewable Biofuels. Elsevier, *Thermochimica Acta,* 279, 111-120.

McKendry, P., (2001) Energy Production from Biomass (part 1): Overview of Biomass, *Bioresource Technology* 83 (2002) 37–46

Yakubu, I.,A. (2009). Briquetting Sawdust for Solid Fuel, PGD Thesis, Ahmadu Bello University, Zaria, Nigeria.