West Indian Journal of Engineering Vol. 25, No. 1, (July 2002) Technical Paper (Adegoke & Mohammed) 1 - 8

Investigation of Sawdust Briquettes as High Grade Fuel

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In an earlier work, some biomass materials such as palm kernel shell, charcoal, coconut shell and coconut fibre were mixed with sawdust in various proportions and the calorific values of the derived briquets found. Briquettes of palm kernel shell and sawdust mixture exhibited the highest calorific value. In this work, briquettes were prepared of sawdust mixed with three particle sizes of palm kernel shell (0.3cm, 0.5cm, 0.9cm diameter respectively), each in the ratio of 1:9, 2:8, 3:7, 4:6 and 5:5 of palm kernel shell to sawdust. The bonding materials used were starch and raw cassava glue. The calorific values were then determined using a Bomb Calorimeter. Results show that starch is a better bonding agent than cassava glue and that calorific value increase with decreasing grain size of palm kernel shell. Furthermore, maximum calorific values obtained were for the 3:7 ratio of palm kernel shell to sawdust.

1. Introduction

Before the Organisation of Petroleum Exporting Countries (OPEC) cartel of 1973, fossil fuels and energy derived from them were cheap, hence there was little or no attention paid to energy management talk less of looking for alternative energy sources. Resulting from the cartel, however, the developed nations started to conserve energy through introduction of emergency measures such as speed restrictions on roads and motor ways, heating restrictions, ban on Sunday driving and limited petrol station opening time [1]. Britain, in particular, took political steps in producing crude oil from their North Sea fields even though the cost of production then was much higher than the cost of buying similar grade of oil from Nigeria. Also, some countries were encouraged (by the developed nations) to produce crude oil without joining the OPEC. These concerted efforts on the part of the developed nations made the gains of the OPEC countries to be short-lived. Hence, within 10 years of the introduction of these measures by the industrialised nations, the OPEC has lost some grounds in their planned control of crude oil prices. Conventional sources of energy such as petroleum, gas and electricity are, therefore, becoming more and more expensive in developing OPEC member countries such as Nigeria. Fossil fuels which include coal, petroleum and gas originated from biomass but there are major physical and chemical differences between these fuels and the original biomass from which they are derived [2].

Fossil fuels provide about 80% of man's energy usage at the present time. Coal was in the local use in the Middle Ages but its exploitation in large quantities was not until the 19th century. Petroleum fuel is predominantly a phenomenon of this century and it is likely to diminish in the next. These fuels upon which our current civilisation is largely based are non-renewable with their limits of availability clearly established. It is for this reason, therefore, that much attention is being given to the search for alternative and supplementary means of fuel supply, with biomass which has the advantage of being renewable as a good candidate [2].

Biomass can generate energy when converted. Biomass energy can thus be derived from plant and animal materials through a variety of conversion and end use processes [3]. Plant biomass in the form of wood was the first and for a long time, the universal

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Pertinent discussion will be published in January, 2003 West Indian Journal of Engineering if received by November, 2002.

and only fuel providing external energy for cooking, space heating and later in manufacturing processes [4]. Examples of biomass include sawdust, wood, charcoal, leaves, bark, tiny branches, rice husk and straw, wheat husk and straw, groundnut shell, coconut fibre, palm kernel shell, carbages and coconut shell [5].

Sawdust which can be used as a biomass fuel is usually burnt off at sawmill sites in the southern part of Nigeria. For many years, sawdust has been used for production of heat and power in gasification plant and for domestic cooking [6]. Following persistent energy crisis in this country within the past four years, sawdust burning stoves have been constructed with a compartment of compacted sawdust. A lot of energy is wasted and the heat released is uncontrolled. In an earlier study, some biomass materials such as palm kernel shell, charcoal, coconut shell and coconut fibre were mixed with sawdust in various proportions and the calorific values of the derived briquettes were found. Palm kernel shell mixed briquette exhibited the highest calorific value [7]. Hence, in this study, briquettes were prepared of sawdust mixed with three particle sizes of palm kernel shell (0.3cm, 0.5cm and 0.9cm diameter respectively), each in the ratio of 1:9, 2:8, 3:7, 4:6 and 5:5 of palm kernel shell to sawdust. Starch and cassava glue were used as binding materials and using Bomb Calorimeter, the calorific values of the derived briquettes were determined.

2. Materials and Methods

2.1 The Test Samples

Resulting from a perennial energy crisis in Nigeria since 1996, kerosine which had been the common man's source of fuel for cooking in the urban areas became scarce and expensive. Attempts are now made to utilise sawdust for cooking purposes.

In this study, palm kernel shell which was found in an earlier study [7], to improve the calorific value of sawdust was ground into small particles of 3mm, 5mm and 9mm average diameter and mixed with sawdust in proportions of 1:9, 2:8, 3:7, 4:6 and 5:5 respectively. A set of briquettes were prepared with starch as the binding agent and another set prepared with cassava glue as binding agent.

The sawdust was collected from sawmills around Akure while the palm kernel shells were collected from Aba Oyo village, also in the outskirt of Akure.

2.2 Description of Apparatus for Measuring the Calorific Values

Figure 1 shows a sectional view of the Gallen Kamp Ballistic Bomb Calorimeter used for measuring the calorific value of the derived sawdust briquettes. The major components are:

(i) The combustion chamber and its support,

(ii) The control box, and

(iii) The thermocouple/galvanometer system.

The combustion outfit consists of a crucible seat D on which crucible is placed. A thin solid shaft (F) supports the crucible seat. At the base of this support shaft, there is a locking with internal threading (G). The locking ring assembly has 'O' ring seals to prevent air leakage into or out of the combustion chamber. The bomb (B), as part of the combustion chamber, covers the combustion part of the equipment and is firmly secured at the base of the support pillar by the elocking ring (G). A hole (A) at the top of the Bomb body (B) provides a means of making good contact by the thermocouple which conducts the heat generated at the combustion chamber to the galvanometer where the reading is translated to ordinary deflection.

The control box houses the Oxygen Pressure Gauge (H) for recording the air pressure inside the calorimeter, the Oxygen Inlet Valve (J); the Galvo-zero knob (K) for setting the galvanometer scale, the Fire Release Button (L) for firing the bomb and the Main Switch (M).

2.3 Experimental Procedure

In determining the calorific value of any sample, the apparatus was calibrated using a sample of Benzoic acid whose calorific value is known to be 6.32Kca/g. A known mass of sample was placed in the crucible. One end of a sewing thread was inserted between the coils of ignition wire and the other end dipped into the centre of the sample in the crucible. The bomb body was placed and tightly screwed into position.

The thermocouple wire was plugged into hole (A) on the bomb body. The pressure release valve (I) was closed and oxygen was admitted into the bomb until the pressure rose to 25 bar, then the valve was closed. The light spot index was set to zero using the

A) CONTACT FOR THERMOCOUPLE	H) PRESSURE SCALE
B) BOMB BODY (COVER)	I) PRESSURE RELEASE VALVE
C) EXTERNAL THREAD	J) OXYGEN INLET VALVE
D) CRUCIBLE	K) GALVO ZERO KNOB
E) IGNITION WIRE	L) FIRE RELEASE BOTTON
F) SUPPORT PILLAR	M) MAINS ON
G) LOCKING RING	N) GALVANOMETER

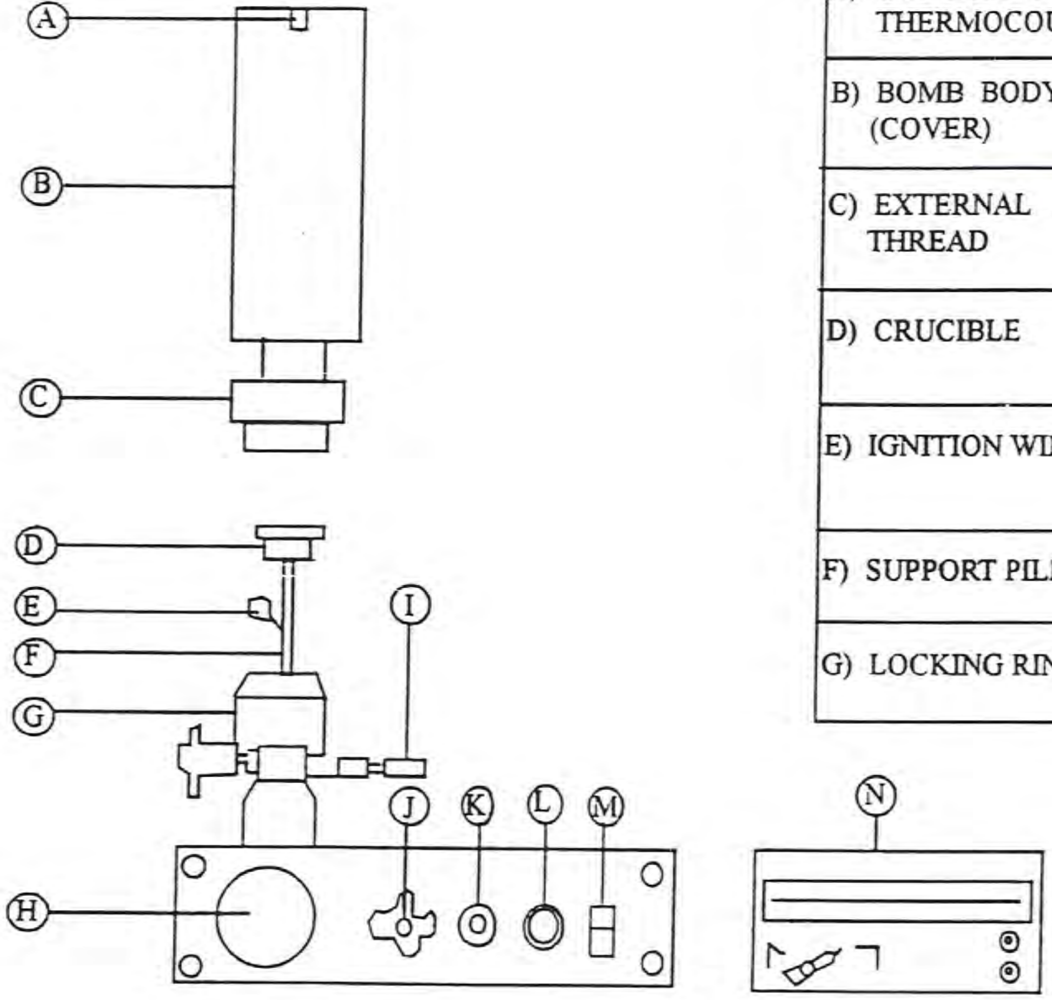

FIGURE 1: *Sectional View of Ballistic Bomb Calorimeter*

galvo-zero knob ensuring a stable temperature before the firing knob was depressed and released to fire the bomb. Heat is released and the maximum deflection of the galvanometer scale was recorded after which the burnt gases were released from the apparatus using the pressure release valve (I).

By comparing the rise in galvanometer deflection with the obtained when a sample of known calorific value such as benzoic acid is burnt, the calorific value of the sample material could be determined.

2.4 Determination of Calorific Values

The calorific value of a fuel is the amount of heat released when a unit mass of it is burnt. Benzoic acid of known calorific value is used to calibrate the Bomb Calorimeter and calorific values of samples are found as follows:

Mass of benzoic acid in crucible = ml (g)
Calorific value of benzoic acid = 6.32kcal/g

Heat release from benzoic acid = 6.32 x ml, kcal if galvo-deflection without sample is γ_1 division, and the galvo-deflection with benzoic acid is γ_2 divisions, then galvo-deflection due to benzoic acid γ_b, will be:

$$\gamma_b = (\gamma_2 - \gamma_1) \qquad \text{..........(1)}$$

Calibration constant: $$\beta = \frac{6.32m_1}{(\gamma_2 - \gamma_1)} \text{ kcal/g} \qquad \text{..........(2)}$$

Six tests were carried out for benzoic acid of mass 0.7g. Hence:

$$\beta = \frac{:\beta_1 +: \beta_2 +: \beta_3 +: \beta_4 +: \beta_5 +: \beta_6}{6} \qquad \text{..........(3)}$$

If the mass of sample equals m_2(g) and the galvo-deflection due to sample equals $(\gamma_3 - \gamma_1)$ divisions, heat release by sample, Q_{RS}, is given as:

$$Q_{RS} = \beta\,(\gamma_3 - \gamma_1)\,\text{kcal} \qquad \text{..........(4)}$$

Calorific value of sample, Q_s is:

$$Q_s = (\beta / m_2)\,[\gamma_3 - \gamma_1]\,\text{kcal/g} \qquad \text{..........(5)}$$

or

$$\frac{(4.186\beta)}{m_2}\ \underline{[\gamma_2 - \gamma_1] kJ/g} \qquad \text{..........(6)}$$

Since 1 kcal = 4.186 kJ

Equation (6) was used to compute the calorific value of the samples. Three experiments were performed for each sample and the average value was taken as the calorific value for the sample.

3. Results and Discussion

Figure 2 shows the relationship between value and the percentage by weight of palm kernel shell in briquette for the different grades of shell and with starch as the binding agent. The result shows that the finer the grain size of palm kernel shell in the briquette, the higher is the calorific value up to a percentage by weight of about 33%. The calorific values for the 5mm and 9mm sizes are about the same, indicating that for grain sizes above 5mm, there is no marked improvement in calorific values. Hence, the grain sizes of palm kernel shell must be below 5mm for improved calorific values.

The result also shows that irrespective of the grain size, calorific value increased with increase in the weight of palm kernel shell in the briquette up to a little above 30% by weight.

Figure 3 shows the same relationship as for **Figure 2** but with cassava glue as the binding agent. Similar behaviours were noticed as the finest grain size (3mm) displayed higher calorific value with no marked difference between the calorific values of the 5mm- and 9mm-sized grains.

For all the different grain sizes, calorific value also increased with increase in mass of palm kernel shell in the briquettes up to about 33% by weight. The drop in calorific value after this point of maximum value was more gradual for the 3mm grain size than in the case of the starch binder.

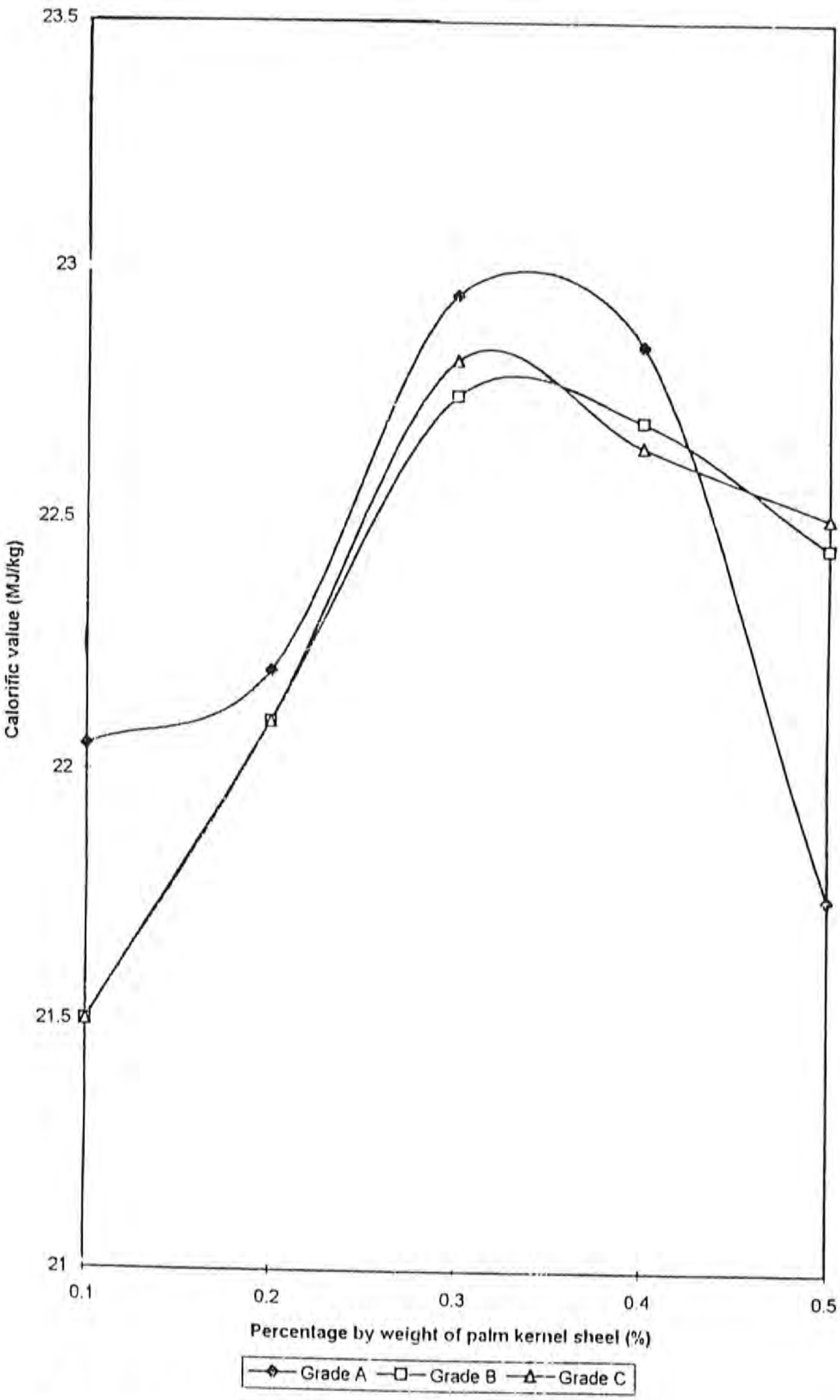

FIGURE 2: *Relationship between Calorific Value and Mass of Palm Kernel Shell for Various Grades of the Shell and Starch as the Bonding Agent*

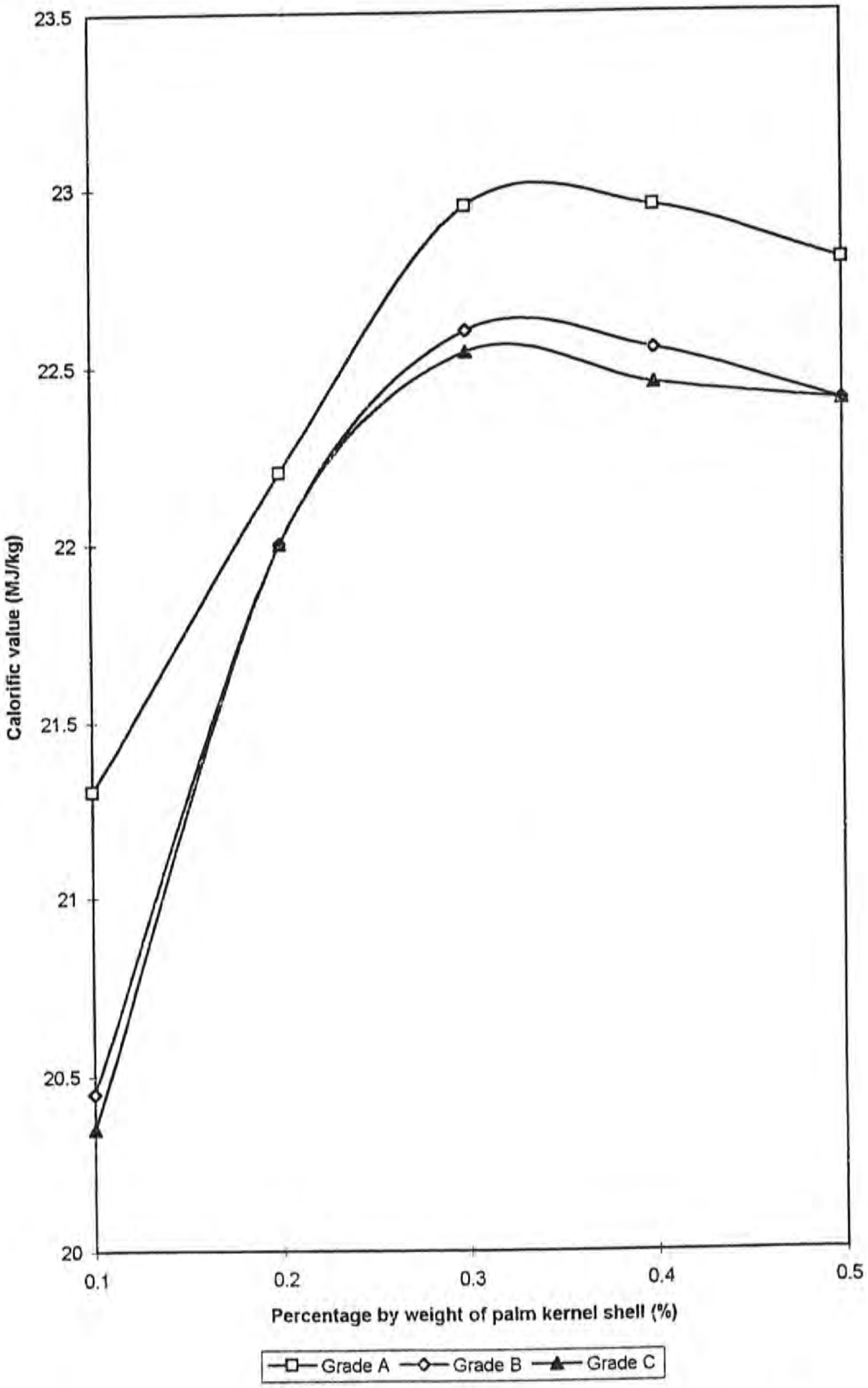

FIGURE 3: *Relationship between Calorific Value and Mass of Palm Kernel Shell for Various Grades of the Shell and Cassava Glue as the Bonding Agent*

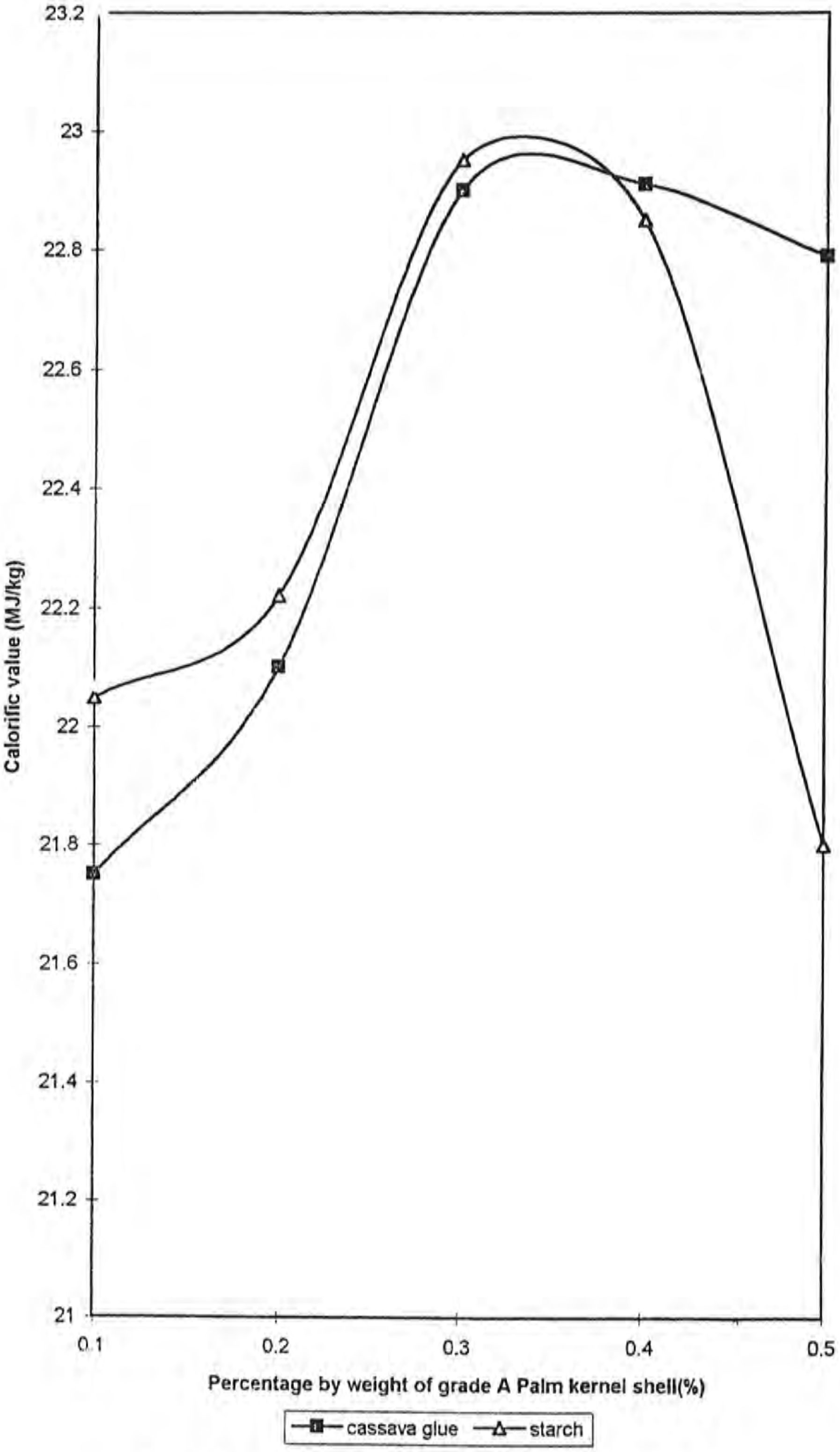

FIGURE 4: *Relationship between Calorific Value and Grade A Palm Kernel Shell as a Function of Bonding Agents*

Taking the finest grain size A (3mm) which displayed the highest calorific values, comparison was made as a function of the binding agent as shown in **Figure 4**. The point of highest calorific value is about the same for both (i.e., 33% by weight of palm kernel shell in sawdust). The starch binded briquettes, however, displayed higher calorific values than the cassava glue binder up to the point of interest which is about 33% by weight. The calorific value at this point is about 23.03 MJ/k.

4. Conclusion

This study has elucidated the improvement of calorific value of sawdust briqueters in terms of the grain size and amount of biomass additive - palm kernel shell. The grain size should not be more than 3mm while the amount should neither be higher than 33% nor lower than 30% by weight of palm kernel shell. Starch has also been found to be a better agent than cassava glue in the making of the briquettes.

Acknowledgement

The support of the Federal University of Technology, Akure in providing the facilities for this project is highly acknowledged. The efforts of Inegbedion, OF in data collection is also acknowledged.

References

[1] Schumacher, D. (1985). **Energy Crisis or Opportunity**. MacMillan, London.

[2] White, L.P. and Plaskett, L.G. (1981). **Biomass as Fuel**. Academy Press Inc., London.

[3] Hall, D.O., Bernard, G.W. and Moss, P.A. (1982). **Biomass for Energy in Developing Countries**. Peergamon Press, Oxford.

[4] Bansal, N.K., Kleemann, M. and Meliss, M. (1990). **Renewable Energy Sources and Conversion Technology**. Tata-McGraw-Hill, New Delhi.

[5] Mukunda, H.S. (1989). **Understanding Combustion.** McMillan Press, India.

[6] Kurstedt, H.A. (1981). **A Fuel Wood as a Source within Scenarios of Coordinated Energy Sources**. Alternative Energy Sources, Vol. 4, Hemisphere Corporation, Washington.

[7] Adegoke, C.O. (1999). **A Preliminary Investigation of Sawdust as High Grade Solid Fuel**. Nigerian Journal of Renewable Energy. 7(1&2): 102-107.