COMPARATIVE STUDY OF ENERGY VALUES OF BRIQUETTES FROM SELECTED AGRICULTURAL BY-PRODUCTS

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DECLARATION

I hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree, diploma or certificate at any university or institution. Information derived from personal communication, published and unpublished works were duly referenced in the text.

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CERTIFICATION

This project titled "Comparative Study of Energy Values of Briquettes from Selected Agricultural By-Products" by MOPAH, Esuga Job meets the regulations governing the Award of Post graduate Diploma Degree (PGD) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This project is dedicated to the Almighty God and all those who love God.

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ABSTRACT

The effect on environment by agricultural and other industrial wastes is on the increase and is causing a lot of problem. Adequate means of disposing of these wastes are lacking. Hence, converting them to other useful product such as briquette is desirable. In this work, the energy values of briquettes made from some of these agricultural by-products were determined. Wastes from rice husk, maize cob, groundnut shell and sugarcane baggasse were briquetted using two different types of agricultural by-product binders (banana peel and cassava peel gel). The briquettes were subjected to energy evaluation test using the Fulton XRY-1B Oxygen Bomb Calorimeter. The results obtained showed that the average energy values of the briquettes were 26.612kJ/kg, 29.980kJ/kg, 28.255kJ/kg, 28.981kJ/kg, 33.703kJ/kg, 32.432kJ/g, 32.762kJ/kg, 31.508kJ/kg for rice husk, maize cob, groundnut shell and sugarcane baggasse respectively; alternating cassava peel gel and banana peel as binder for each of the by-products. The result show that groundnut shell briquette has the greatest energy value suitable for starting and maintaining effective fire required for agricultural processing such as heating, cooking, boiling, drying, frying e.t.c. From the Statistical Analysis of data drawn from Table 4.2, test of treatment (briquettes) H0: $t_1 = t_2 = t_3 = t_4$ Vs H_1: Not H_0. From table 4.3ai, Fcalculated =564.09 (MST/MSR) > P- value (0.001). We conclude that the average calorific value does not depend on the value of the briquettes produced from the selected agricultural by-product. This significant that each of the briquettes produced, varies on the amount of energy produced within a specific period of time. Also the test of individual energy value against the by-products produced indicated that Fcalculated = 2.082 (MST/MSR) > P- value (0.1729). There are significant variation among means between the data but the matching appearing within the blocks are not effective to measure the average energy

produced on each of the by-products. The effective utilization of these Agricultural by-products based on their energy value as high grade solid fuel would contribute in solving the problems of Agricultural by-product disposal, desertification, soil erosion and also help in alleviating the energy crisis in the use of non- renewable fuel (petroleum products as domestic fuel).

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CHAPTER ONE

1.0. INTRODUCTION

It is an acceptable environmental philosophy that some agricultural by-products sometimes referred to as waste, have value and should be utilized based on these four "R's" (Reduce, Reuse, Recover and Recycle). These enable by-products from Agricultural processing to be transformed into more useful products like briquette, which provide a potentially important alternative sources of energy for domestic use (cooking fuel). Agricultural by-products vary in energy value, which makes them more combustible than the other.

A briquette is a collection of combustible materials from Agricultural by-products and Industrial wastes compressed into solid fuel product of convenient shapes that can be burnt to start and maintain a fire. Thus, briquette is the physical transformation of loose raw materials to form a high bulk density, low moisture content, uniform size and shape, material through a compressed unit.

1.1. Statement of Problem

Agricultural waste (by-product) management during processing is one of the most serious rural-urban environmental problems in developing countries. This problem is attributed to inadequate resource mobilization, the use of inappropriate technology, lack of public awareness on waste management, absence of sufficient capacity for by-product processing/ recycling and non-implementation of environmental laws pertaining waste disposal.

The volume of Agricultural by-products generated in Nigeria is very high. For example, groundnut shell, sugar cane baggasse, rice husk, maize stalk, palm kernel shell e.t.c are found in large heaps which constitute environmental hazard and when burnt off, results in air pollution.

Furthermore, fallen woods used as fuel, can result in desertification and eventually lead to soil erosion, which are undesirable problem.

Currently there are dearth knowledge/information on the energy values of some of the briquettes produced from the so call waste.

The effective utilization of these Agricultural by-products based on their energy value as high grade solid fuel would contribute in solving the problems of Agricultural by-product disposal, desertification, soil erosion and also help in alleviating the energy crisis in the use of non- renewable fuel (petroleum products as domestic fuel).

1.2. Objectives of the Study

i. To identify the various types of combustible Agricultural by-products for briquetting.

ii. To test and evaluate the calorific value briquettes produced from selected combustible agricultural by-product

iii. To determine the most suitable by-product for briquetting from the selected by-products in terms of the energy value.

1.3. Significance of the Study

i. To reduce environmental hazard posed by large heap of Agricultural by-product/residue

ii. Utilization of by-products into useful product and a mean of employment generation.

iii. Alleviating the problems of energy crisis in use of non- renewable fuel (petroleum products as domestic fuel).

1.4. Scope of Study

This project is to cover the identification of selected combustible Agricultural by-product/residue such as rice husk, maize cob, groundnut shell and Sugarcane baggasse (with banana peel and cassava peel gel binder), test and determination of their energy value.

CHAPTER TWO

2.0. LITERATURE REVIEW

Renewable energy sources are been sought for domestic cooking in developing countries due to the fact that their non-renewable counterpart such as kerosene, LPG, etc., are not keeping up with peoples' demand. Also the high cost of non-renewable energy sources has made people to start deviating to the use of renewable energy sources for domestic cooking. The use of biomass fuel such as composite sawdust briquette has been proposed to be a good source of renewable energy for domestic cooking (Kuti *et al;* 2008). This is due to the fact that sawdust, i.e., the chief raw material in the production of composite sawdust briquette is readily available in large quantities as wastes in majority of the wood processing industries. It has been proposed that the conversion of sawdust wastes through briquetting process will go along way in reducing waste disposal problems in majority of the wood processing industries. Furthermore deforestation which promotes pollution will be drastically reduced if the use of sawdust waste is enhanced.

Before promoting the use of any new type of fuel, it is expedient to have good understanding of its performance. The performance of any solid biomass fuel such as sawdust briquette can be evaluated effectively when it is combusted in a specially made biomass stove. Cooking stoves which are internally lined with local clay of low thermal conductivity have been found to be more effective and efficient to burn sawdust briquettes in order to evaluate their performances (Adegoke *et al;* 1999). (Adegoke *et al;* 2002). The reasons for carrying out performance tests are to determine the comparative performance of fuel to the stove, to determine the potential and expected fuel savings offered by a stove and to obtain the data necessary for optimization of fuel in relation to its stove.

(Stewart, 1987) highlighted the three main types of tests that can be carried out on solid fuel. These are field test, water boiling test (WBT) and controlled cooking test (CCT). These tests are meant to reveal quantitative and qualitative information about the fuel performance.

The WBT involves the simulation of standard cooking procedures that measures the fuel consumed and time required for simulated cooking. It is a well-developed test that measures the time taken by a given quantity of fuel to heat and boil a given weight or volume of water (Kuti, 2003). Scientists or field workers, at the initial assessment and development stage, usually carry out WBT in a laboratory or a field station. It can be used for assessment of stove design and optimizations of stoves when a solid fuel is made to combust. In some cases where cooking tests or kitchen field tests cannot be undertaken, water boiling test can be used to give a rough approximation of relative fuel savings.

The use of organic waste as cooking fuel in both rural and urban area is not new. In seventeenth century, the rural poor often burn dried cow dung because of the acute shortage of wood fuel to wide spread deforestation according to (Jacob, 2005) as in (Lardinois and Klundert,1993).

In the beginning of the nineteenth century, sawdust briquettes were made with binding material such as tar, resin and clay which bind the small particles together. None of these processes attained great importance because of their relatively high costs compared to wood and conventional charcoal fuel. (Jacob, 2005) as in (Lardinois and Klundert, 1993).

Fuel briquettes emerged as a significant business enterprise in the 20th Century. In the 1950's several economic methods were developed to make briquettes without a binder. A multitude of factories throughout the world produces literally ten million of tons of usable and economic material that met the household and industrial energy needs. During the two world wars, household in many European countries made their own briquette from soaked waste paper and other combustible domestic waste, using simple lever-operated press (Jacob, 2005) as in (Lardinois and Klundert, 1993).

Today's industrial briquetting machines, although much larger and more complex, operates on the same principles although the market briquettes are now sold at a premium for occasional backyard. For over 100 years, informal waste collectors in Cairo have separated and dried organic waste product for sale as fuel for domestic use. This process faded when fossil fuel source became available (Jacob, 2005).

According to (Jacob, 2005) the following three critical factors contributed to the resurgence of briquetting.

i. Change in the economics of using fuel briquette as an energy source necessitated by recent developments of briquette processing and binding.

ii. Shortage of fuel wood, which has become increasingly severe in most of the developing countries

iii. Steady increase by environmental concerns to address the problem of domestic and urban waste disposal, a problem that briquetting can remedy.

Despite the numerous sources of energy in Nigeria, the country is still experiencing an unprecedented energy crisis. The non-renewable energy sources such as Kerosene and gas are progressively getting outside the reach of the common man (Adegoke, 1999).

Electricity supply, another conventional energy source is epileptic where available or non-available at all in some parts of the country. This development call for search for alternative sources of energy for domestic and industrial use.

The conversion of Agricultural by-products, wood waste and coal dust to high energy value briquettes for cooking and drying have been investigated and found to be feasible (Adegoke, 1999).

In this research, composite sawdust briquette fuel were produced and utilized in order to simulate cooking. Within a time frame, a known amount of water was boiled to simulate cooking by burning composite sawdust briquettes in a biomass stove. The composite sawdust briquettes were produced using sawdust and charred palm kernel in percentage compositions of 50:50, 60:40, 70:30, 80:20 and 90:10, respectively. Starch gel was used as a binder. The boiling of water using the fuels was characterized into 3 namely, the intermediate phase (initial boiling), high power phase (15 minutes after the initial boiling) and the low power phases (30 minutes after the high power phase). From the experiment, in respective of the percentage composition of the composite sawdust briquettes, the Percentage Heat Utilized (PHU) was found to increase from the intermediate phase through the low power phase. For other parameters like the Specific Fuel Consumption (SFC), Power Output and Burning Rate respectively, there was a sharp decrease from the intermediate phase through the low power phase (Kuti, 2009).

Fuel briquette could be produced from Agricultural by-products such as sugar cane baggasse, rice husk, maize husk e.t.c. and other waste like coal dust and saw dust. Although the conversion of these wastes materials to high grade solid fuel is important and should be pursued. (Adegoke, 1999).

Result from recent studies at the Mechanical Engineering Department of Federal University of Technology Akure, have shown that Agricultural by-products mixed with biomass materials especially palm kernel shell of appropriate grain size in certain proportion have improved calorific value (Jacob, 2005).

This mixture of Agricultural by-product and biomass material is compressed using a specially developed briquette making machine and the briquette are dried either directly under the sun or in an oven. The addition of palm kernel shell to ordinary saw dust improves the calorific value of the formed briquette from 18 mJ/kg to about 23 mJ/kg (Adegoke, 1999; Adegoke, 2001; Adegoke and Mohammed, 2002). When burn in an internally lined stoves, heat losses to the environment are much reduced and lot of cooking energy is obtained from a relatively small amount of saw dust briquette and Agricultural by-product briquettes (Adegoke, 1999; Adegoke, 2001; Adegoke and Mohammed, 2002).

2.1. Production of Fuel Briquette

The raw material of briquette must bind during compression, otherwise when the briquettes are removed from the mould, they will crumble. Improved cohesion can be obtained with a binder but also without, since under high temperature and pressure some materials such as wood bind naturally (Olorunisola, 1999).

A binder must not cause sticker or gummy deposits, while the creation of excess dust must be avoided. Two different sorts of binders may be employed. Combustible binders are prepared from natural or synthetic resins, animal manure or treated, dewatered sewage sludge. Non-combustible binders include clay, cement and other adhesive minerals. Combustible binders are preferable (Olorunisola, 1999).

Non-combustible binders may be suitable if used in sufficiently low concentration, for example, if organic waste is mixed with too much clay, the briquettes will not easily ignite or burn uniformly.

Suitable binders include starch (5 to 10%) or molasses (15 to 25%) although their use can prove expensive (Hughart, 1979). It is important to identify additional inexpensive materials to serve as briquette binder in Nigeria and their optimum concentration. The exact method of preparation depends upon the material being briquetted.

The machine press for briquetting must be well designed, strongly built and capable of agglomerating the mixture of the waste and binder sufficiently for it to be handled through the curing or drying process. About 4 – 8% of starch made into paste with hot water is adequate (Johannes, 1984). First, the fines are dried and screened, undersized fines are rejected and oversized hammer milled. The powder is blended with starch paste and fed to the briquetting press. The briquettes are dried in a continuous oven at about 80^0c. The starch set through loss of water, binding the material into a briquette.

2.2. Advantages of Briquetting Agricultural By-Products

The effective use of Agricultural by-products results in the following advantages according to (Bourgeois and Doat, 1985).

i. Easy to handle and store

ii. Fire risk is minimized

iii. Easy to transport at lower cost

iv. It turns waste to wealth through the conversion of waste to high grade fuel that can be sold.

v. Simplicity of the technology involved in making the fuel briquettes and the stoves to burn them

vi. Briquettes can be mass-produced using briquette making machine that can turn out several briquette at the same time.

vii. Briquette are cheaper than coal, oil or lignite and once used can not be replaced.

viii. There is no sulfur in briquette

ix. Biomass briquette has a higher practical thermal value and much lower ash content (2 – 10%) as compared to 20 – 40% in coal.

x. Briquette has a consistent quality, have burning efficiency, and is ideally sized for complete combustion

xi. Combustion is more uniform compared to coal and boiler response to change in steam requirement is faster due to high quality volatile matter in briquette

xii. Loading, unloading and transport cost are much less and storage requirement is drastically reduced.

xiii. Briquettes are clean to handle and can be packed in bags for ease of handling and storage.

2.3. Agricultural By-Product Briquettes

Rice Husk Briquetting

Rice husk has been extensively used throughout Africa as the main feed stock for briquette; this study investigates the usefulness of rice husk as an alternative fuel for household energy in rice production zones. (Olorunisola, 1999).

According to (Adegoke, 2001) the use of Agricultural by-product as fuel is limited and insufficient. In 1999, a study was implemented to identify those

Agricultural by-products with most useful energy potential. Rice husk, coffee husk and cotton stalk were found to be best. This conclusion was reached through a study of the fraction of the waste produce and where they had been produced in the previous year.

Fuel Briquette from Sugar Cane Baggasse

Surplus baggasse present a disposal problem for many sugar cane factories. The average tonnage of excess baggasse produced per year is over 24,000 tons (Keya *et al;* 2000). Using a baggasse to briquette. Sugar factories could produce 4855 tons of baggasse briquette (Keya *et al*; 2000). The pilot briquette technology remains simple, applicable and of benefit to the surrounding communities as a low cost product that compete with wood charcoal.

The production of carbonized baggasse briquette by char dust Ltd based at Chanehl Sugar factory involves the following stages:

1. Size reduction: chop, rolling or hammer fresh sugar cane baggasse
2. Drying: Remove moisture in the baggasse by open air drying or by using forced, heated air in a large rotating drum
3. Carbonization: Combust the dried baggasse under limited oxygen condition in a buried pit or trench until it carbonizes into charcoal.
4. Preparation of feed stock: Mix carbonized baggasse with binder (e.g. clay or molasses) to form the briquette feed stock
5. Compaction and extrusion: Pass the material through the machine or manually operated intruder to form "rolls" of charcoal.
6. Dry and rolls: Air dry the roll for 1 to 3 days causing them to break into chunks.

2.4. Briquetting Technology

The processes involved in briquetting are drying, crushing, grinding and sieving, (Adegoke, 2001).

The briquettable material is obtained and sun dried to remove some moisture. The material is crushed after drying and then sieved to obtain the material for briquetting production. The material is channeled to compressing equipment known as screw extruder (briquettor) or forming machine while it is still in a hot/warm state. (Adegoke, 2001).

The pressure and thermal energy forced the resin to bind the waste material under high pressure to form briquette with density much higher than ordinary waste. (Adegoke, 2001).

The briquette has characteristic hole through the centre from central screw drive and have hexagonal cross section.

The briquetting technology varies according to the presses being used. Basically, Celina Industries Limited use screw press method where the waste must be dried with 40 – 46% moisture content (dry basis) (Adegoke, 2001).

The material is poured into the feeder and passes through a duct by the aid of the blower. The air-lock further releases the dry waste (raw material). As the dry waste come into the briquettor, the screw forces the material into a die which is heated to a required temperature of $300^{o}c$ – $350^{o}c$ (Adegoke, 2001). The brown briquettes are extruded out of the box where machines are fixed to cut them into set diameter of 7cm and length of 20cm.

2.5. The Screw Press and Piston Technology

High compaction technology or binder less technology consists of the piston press (Adegoke, 2001). Most of the unit currently installed is reciprocating type where the material is pressed in a die by a reciprocating ram at a very high pressure (Adegoke, 2001). In a screw extruder press, the material extruded continuously by a screw through taper die, while in a piston press, the ram and die is less compared to the screw and die in a screw extruder press.

(Adegoke, 2001) also reported that the power consumption in the former is less than that of the latter but in terms of briquette quality and procedure, screw press is definitely superior to piston press technology.

The central hole incorporated into the briquette produced by the screw extruder help to achieve uniform and efficient combustion and these briquette can be carbonized (Adegoke, 2001)

2.6. Evaluating Energy Value of Briquettes

Calorimeter is a standard device to determine the calorific (heat energy) value of a given material in Joules per gram (KJ/kg). The briquette is to be placed inside sealed container surrounded by water and burning is activated by an electric heating coil. The heat produced is found from the temperature rise and heat capacity of the surrounding water and it vessel, the calorific value, or heat per unit mass, of the briquette can be determined using an Oxygen Bomb Calorimeter. (Nelkon, 1981)

The heating value or calorific value of a substance, usually a fuel or food, is the amount of heat released during the combustion of a specified amount of it. The calorific value is a characteristic for each substance. It is measured in units of energy per unit of the substance, usually mass, such as: kcal/kg, kJ/kg, J/mol, Btu/m^3. Heating value is commonly determined by use of a bomb calorimeter.

The heat of combustion for fuels is expressed as the HHV, LHV, or GHV:

The quantity known as higher heating value (HHV) (or gross calorific value or gross energy or upper heating value) is determined by bringing all the products of combustion back to the original pre-combustion temperature, and in particular condensing any vapor produced. This is the same as the thermodynamic heat of combustion since the enthalpy change for the reaction assumes a common temperature of the compounds before and after combustion, in which case the water produced by combustion is liquid.

The quantity known as lower heating value (LHV) (or net calorific value) is determined by subtracting the heat of vaporization of the water vapor from the higher heating value. This treats any H_2O formed as a vapor. The energy required to vaporize the water therefore is not realized as heat.

Gross heating value accounts for water in the exhaust leaving as vapor, and includes liquid water in the fuel prior to combustion. This value is important for fuels like wood or coal, which will usually contain some amount of water prior to burning.

A common method of relating HHV to LHV is:

$$HHV = LHV + hv \times (nH_2O,out/nfuel,in)$$

where hv is the heat of vaporization of water, nH_2O,out is the moles of water vaporized and nfuel,in is the number of moles of fuel combusted.

Most applications which burn fuel produce water vapor which is not used and thus wasting its heat content. In such applications, the lower heating value is the applicable measure. This is particularly relevant for natural gas, whose high hydrogen content produces much water. The gross calorific value is relevant for gas burnt in condensing boilers and power plants with flue gas condensation which condense the water vapor produced by combustion, recovering heat which would otherwise be wasted.

Both HHV and LHV can be expressed in terms of AR (all moisture counted), MF and MAF (only water from combustion of hydrogen). AR, MF, and MAF are commonly used for indicating the heating values of coal:

AR (As Received) indicates that the fuel heating value has been measured with all moisture and ash forming minerals present.

MF (Moisture Free) or Dry indicates that the fuel heating value has been measured after the fuel has been dried of all inherent moisture but still retaining its ash forming minerals.

MAF (Moisture and Ash Free) or DAF (Dry and Ash Free) indicates that the fuel heating value has been measured in the absence of inherent moisture and ash forming minerals. (www. wikipedia)

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Identification and Selection of Agricultural By-Products for Briquette and Binders

The best material for briquetting is one which served the desired objective at minimum cost. The following factors were considered in selecting the by-product suitable for briquette.

i. Availability of the by-product.

ii. Cost of the by-products.

iii. The weight, volume and the bulk density of the by-products before and after briquetting.

iv. Combustibility of the material.

v. The binding properties of the by-products (cohesion).

3.2. Selected Agricultural By-Product for Briquetting

The following combustible Agricultural by-products from different waste dump site at a cost free price were considered for this project:

i. Rice husk

ii. Groundnut shell

iii. Sugarcane baggasse

iv. Maize cob

3.3. Selected Agricultural By-Products Binders for Briquetting

Binders are substance capable of holding materials together by surface attachment base on their cohesive and adhesive properties. A combustible binder collected at a cost free price from different dump sites includes:

i. Cassava gel   ii. Banana peel

3.4. Determination of weight of the Briquette Materials

The weights of the materials were determined by using a Mettler PM 200 electrical digital weighing balance in gram (g) of sensitivity 0.01

But weight of the material, w = g

Volume of the product, v = cm^3

3.5. Selected Briquette Machine

A manually operated hydraulic briquetting machine designed and fabricated in Mechanical Engineering Department of Federal University of Technology Minna, (Plate 3.1) was used for the compression of each mashed selected Agricultural by-product and binder which was fed as a feed stock into the model and compressed at a maximum pressure of $60KN/m^2$ to enhance perfect compaction. The mould was placed over an appropriate opening and the formed cylindrical briquettes were extracted by gradual application of pressure at the hydraulic jack. The same procedure was carried out for each of the selected Agricultural by-product under consideration. (by compression producing sixteen (16) cylindrical briquette of size 40mm diameter and length 80mm at a time) was used.

3.6. Method of Briquette Production

As the briquetting material was fed into the machine, the machine cover was firmly closed while the hydraulic jack was being jacked up to move the piston upward. The upward movement of the piston exerted pressure and compressed the material together to form a cylindrical shaped briquette.

The machine produces sixteen (16) briquettes at a stroke.

Rice husk was collected from the dump site and weighed. Weighed gel made from cassava peel was mashed in a certain proportion (1:1) with rice husk to form the mould was fed into hydraulic briquetting machine while the hydraulic press is jacked-up to extrude rice husk briquette made from cassava peel gel as binder. The same process was repeated with rice husk mashed with Banana peel and cassava peel gel i.e. two (2) set of briquette from rice husk with two (2) different binders are produced. The above process was repeated for maize cob, sugar cane baggasse and groundnut shell using the same cassava peel gel and banana peel as binders.

3.7. Types of Briquettes Produced

i. Rice husk and gel from cassava peel briquette (Plate 3.2)

ii. Rice husk and banana peel briquette (Plate 3.3)

iii. Maize cob and gel from cassava peel briquette (Plate 3.4)

iv. Maize cob and banana peel briquette (Plate 3.5)

v. Groundnut shell and gel from cassava peel briquette (Plate 3.6)

vi. Groundnut shell and banana peel briquette (Plate 3.7)

vii. Sugarcane baggasse and gel from cassava peel briquette (Plate 3.8)

viii. Sugarcane baggasse and banana peel briquette (Plate 3.9)

3.8. Drying of Briquettes

The extracted briquettes were allowed to dry in sun for seven days. After sun drying, they were packed and conveyed for the comparative testing in the laboratory to determine the heat values one after the other with the aid of a Calorimeter.

3.9. The Calorimeter

This is a standard device to determine the calorific (heat energy) value of a given material in Joules per gram (kJ/kg). The briquette was placed inside sealed container surrounded by water and burning was activated by an electric heating coil. The heat produced was found from the temperature rise and heat capacity of the surrounding water and its vessel, the calorific value, or heat per unit mass, of the briquette was determined using an Oxygen Bomb Calorimeter (Plate 3.10).

The Oxygen Bomb Calorimeter (OBC) was made up of the following components:

(a) **Calorimeter mainframe:** This is the main component of the calorimeter used to form a constant temperature system and to ensure the sample in the condition, during the procedure of "fir" and "stir". It displays the rising temperature and thus calculates the calorific value of the given sample (briquette)

(b) **Mould:** This is a frame of screw mould used to convert the sample (briquette) to a desired mould of 1g for the calorimeter

(c) **Bomb bracket, oxygen inflator and deflation valve:** This is a complete system for installing electrothermal tinsel, auxiliary inflate oxygen before and deflate oxygen after determination

(d) **Microcomputer:** This is one of the most important part of the OBC which automatically control the determination procedure, record and save the test information.

(e) **LCD:** This unit displays the processed information (screen)

3.10. Determination of the Calorific Value of Briquettes using the Oxygen Bomb Calorimeter

(a) 1g Rice husk with cassava peel gel briquette was measured using the electrical digital weighing balance

(b) The screw mould bracket was used to re-mould the 1g briquette into the calorimeter bomb accepted sized bucket.

(c) The electrothermal tinsel was installed by placing the bomb lid on the bomb bracket.

(d) An electrothermal tinsel of 9cm was measured and cut using a rule and a scissors.

(e) Pour 10ml distillated water into the bomb. Then join the inflator with an industrial oxygen cylinder to the bomb and then open the valves to fill the bomb slowly with a pressure limited between 2.5 – 3.0Mpa for 1minute.

(f) Put the bomb on the inside canister bracket containing the distilled water (to about 2/3 of the inflator screw). The inside canister was put inside the outside canister insulating bracket

(g) The bomb lid was covered.

(i) Turn on the red switch on at the back of the Oxygen Bomb Calorimeter.

Microcomputer Controlling:

The moment the calorimeter was switched on, the controlling software was started in English interface, operated conveniently and understands easily.

(a) "R-P Calibrate" was chosen and the mass of the briquette sample were inputted

(b) Choose "Start determination" and press the "Enter" key then the instrument begins to auto calibrate or measure with the values displayed on it screen for reading, recording and saving.

(c) Turn-off the power switch when the process is completed as indicated on the screen. Though the instrument is switched off but the data is still intact even when the system is restarted until the next determination.

(d) Open the entire instrument to remove the residue from the bomb after burning.

(e) Measure the weight of the residue (ash content) after burning using the electric digital weighing device and compare with the 1g briquettes burned.

NOTE: The same process is repeated for each of the briquette selected for comparison.

3.11 STATISTICAL ANALYSIS

The One-Sample Statistical analysis is adopted for T-test. In this analysis, all the subjects, i.e. energy value, temperature and time are put into consideration for the analysis. Statistical software (SPSS 7.0) is employed for these analysis and results are shown in Table 4.3 to 4.8. The One-Sample analysis is based on the informations available on Table 4.2 below.

CHAPTER FOUR

4.0. RESULTS

4.1. Physical Parameter of Briquettes

Volume and bulk density of the briquettes before and after briquetting and drying were determined and shown on table 4.1.

Table 4.1: Physical Parameter of Briquettes

SAMPLE	Briquette	Volume Before Briquetting (cm^3)	Bulk Density Before Briquetting (g/cm^3)	Volume After Briquetting (cm^3)	Bulk Density After Briquetting (g/cm^3)
A1.	Rice husk & cassava peel gel	100.53	1.67	67.86	0.72
A2.	Rice husk/banana peel	100.53	1.67	72.89	0.78
B1.	Maize cob/cassava peel gel	100.53	1.67	60.32	0.68
B2.	Maize cob/banana peel	100.53	1.67	65.35	0.69
C1.	Groundnut shell/cassava peel gel	100.53	1.67	76.66	0.81
C2.	Groundnut shell/banana peel	100.53	1.67	80.42	0.80
D1.	Sugarcane baggasse/cassava peel gel	100.53	1.67	56.55	0.66
D2.	Sugarcane baggasse/banana peel	100.53	1.67	62.83	0.63

4.2. Calorific Values of Briquettes

Table 4.2 show the average calorific (energy) value of briquettes produced from the selected Agricultural by-products as displayed on the Oxygen Bomb Calorimeter

Table 4.2: Calorific Value of Briquettes

SAMPLE	Briquette	Heat value (kJ/kg)	Tempt. (^{0}c)	Time taken (mins)	Ash content (g)
A1.	Rice Husk & cassava peel gel	26.612	30.396	35	0.18
A2.	Rice Husk & banana peel	29.980	30.642	39	0.16
B1.	Maize cob & cassava peel gel	28.255	30.454	36	0.06
B2.	Maize cob & banana peel	28.981	30.565	35	0.03
C1.	Ground nut shell & cassava peel gel	33.703	30.671	40	0.04
C2.	Ground nut shell & banana peel	32.432	30.660	40	0.08
D1.	Sugar cane baggasse & cassava peel	32.762	30.670	34	0.02
D2.	Sugar cane baggasse & banana peel	31.508	30.655	38	0.04

4.3 STATISTICAL ANALYSIS

Statistical software (SPSS 7.0) is employed for these analysis and the summary of the ANOVA is shown in Table 4.3. Analysis is based on Table 4.2 above and those in Appendix II, with reference to the energy value, temperature, time taken and the final residue.

Table 4.3ai: Summary of Analysis of Variance

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	$F_{calculated}$ Value	P- Value
Energy Values	3317.3	3	1105.8	564.09	0.0001
Briquettes	12.244	3	4.081	2.082	0.1729
Random Residue (Error)	17.642	9	1.960		
Total		15	3347.2		

F = 564.09 = MS Energy Values/MS Error

Assumption test: Was the matching effective?

This test uses a second value of F and a different P value.

F = 2.082 = (MS Briquettes/MS Error)

P value is 0.1729, considered not significant.

Effective matching or interaction (blocking) results in significant variation among means. With these data, the matching appears not to be effective.

CHAPTER FIVE

5.0. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. DISCUSSION

The result in Table 4.1 has shown that the volume and bulk density of Agricultural by-products were reduced by thirty percent (30%) after conversion to a more useful product like briquette.

Much research work has been carried out on sawdust briquette and some agricultural by-products briquette in respect to their energy value, these values ranges between 18mJ/kg – 23mJ/kg (1800kJ/kg – 2300kJ/kg) which is extremely low compared to the least energy value (26.612kJ/kg) shown in Table 4.2 using the oxygen bomb calorimeter.

The large variation in energy value as compared to past research work could be attributed to the choice of the binders used for briquetting. Cement, clay, animal dung, bitumen, gum Arabic was often used in the past as binder for briquetting. These binders are not agricultural by-products; their combustibility is low. Their low combustibility also results in their low energy value. These binders are not economically viable for briquetting as compared to banana peel and cassava peel gel binders used for this work

From the result in Table 4.2, ground nut shell with cassava peel gel as binder has proved to have the highest energy value of 33.703kJ/kg among the selected common Agricultural by-products. Next to it was sugar cane baggasse briquette with cassava peel gel binder which has an energy value of 32.762kJ/kg and the least ash content (residue) of 0.02g compared to others.

Ground nut shell briquette and banana peel as binder is the next in energy value (32.432kJ/kg) also with low ash content of 0.08g, followed by sugar cane baggasse briquette with banana peel binder having the energy value of 31.508kJ/kg and the same ash content of 0.04g as that of ground nut shell and cassava peel briquette.

Further more, rice husk/banana peel, maize cob/banana peel, maize cob/cassava peel gel and rice husk/cassava peel gel briquette possessed the following energy value: 29.980kJ/kg, 28.981kJ/kg, 28.255kJ/kg, 26.612kJ/kg and ash content: 0.16, 0.03, 0.06, 0.18 respectively.

Rice husk briquette with cassava peel gel binder has the least energy value and the highest ash content of 0.18g as compared to others from the selected Agricultural by-product briquettes considered for the comparative study.

The results in Table 4.2 have proved that briquettes made from groundnut shell using an Agricultural by-product as binder, has a higher energy value amongst the agricultural by-products selected for comparison. Also, briquettes made with agricultural by-product binder have higher energy value compared to those made from non-agricultural by-product binder.

The One-Sample Statistical analysis as in Appendix II (Tables 4.3a and 3b) shows that the mean of the heat values is 30.5291kJ/kg while it standard deviation is 2.47421. Also the mean of temperature is 30.5891^{0}c and it standard deviation is 0.10793. Using comparative analysis, the average temperature is higher than that of the heat value. This shows that the energy value depend on the temperature produced within a given time.

The 95% Confidence interval as in Appendix II (Table 3.3b) of the mean difference between energy value and temperature is (28.4606kJ/kg, 32.5976kJ/kg) and (30.4989^{0}c, 30.6794^{0}c) respectively. This implies that there is higher level of significance between the energy value and the temperature.

From the ANOVA Model (Table 4.5c). Sum of Square Regression, is 35.940 while residual is 6.912.

We seek to reject H_0 if $F_{1\ tabulated}$ 0.005 is less than $F_{calculated}$. Since $F_{1\ tabulated}$ 0.005 (5.99) is less than F (31.198) hence, accept H_0 that energy and temperature are same.

H_0: $\mu_1 = \mu_2$ Vs $H_1 : \mu_1 \neq \mu_2$ or H_0: $\mu_1 = \mu_2$ Vs H_1 : Not H_0

The correlation coefficient as in Appendix II (Table 4.6) between the time and the ash content of 2-tailed significance level of sample size (8) has a coefficient 0.898. This mean that the coefficient lies between $-1 \leq P \leq 1$. There is positively high correlation between time taken and the ash content produced.

The regression analysis as in Appendix II (Table 4.7c) between Time and Ash Content, The ANOVA table shows that the calculated F is 0.018 with significance 0.898 which also mean that time taken to heat the briquettes and the ash content produced after heating are highly related.

From the Statistical Analysis of data drawn from Table 4.2, test of treatment (briquettes) H0: $t_1 = t_2 = t_3 = t_4$ Vs H_1: Not H_0

From table 4.3ai, Fcalculated =564.09 (MST/MSR) > P- value (0.001). We conclude that the average calorific value does not depend on the value of the briquettes produced from the selected agricultural by-product. This significant that each of the briquettes produced, varies on the amount of energy produced within a specific period of time. Also the test of individual energy value against the by-products produced indicated that Fcalculated = 2.082 (MST/MSR) > P- value (0.1729). There are significant variation among means between the data but the matching appearing within the blocks are not effective to measure the average energy produced on each of the by-products.

For comparison test, we use Tukey-Kramer Multiple Comparison Test to determine the variation between the briquettes produced and energy value with respect to their Agricultural by-products

In view of the above, agricultural by-products are suitable for briquetting because of their high energy value; availability and affordability to start and maintain a fire in this age of energy crisis in place of non-renewable fuel (petroleum products as domestic fuel).

5.2. CONCLUSION

The volume of Agricultural by-products generated in Nigeria resulting into environmental hazard has necessitated the effective utilization of a high grade biomass fuel (solid fuel) called briquette.

Briquettes are produced from different Agricultural by-products which vary in their combustibility base on their energy value (heating value). The best cooking fuel is that, which has a good and safe heating effect at low cost. In view of this, an agricultural by-product with a higher energy value must be researched and considered for briquetting rather than producing briquettes from other products that will not have a good heating effect and value.

The One-Sample Statistical analysis as in Appendix II (Tables 4.3a and 3b) shows that the mean of the heat values is 30.5291kJ/kg while it standard deviation is 2.47421. Also the mean of temperature is 30.5891^{0}c and it standard deviation is 0.10793. Using comparative analysis, the average temperature is higher than that of the heat value. This shows that the energy value depends on the temperature produced within a given time.

The 95% Confidence interval as in Appendix II (Table 4.3b) of the mean difference between energy value and temperature is (28.4606kJ/kg, 32.5976kJ/kg) and (30.4989^{0}c, 30.6794^{0}c) respectively. This implies that there is higher level of significance between the energy value and the temperature.

It was in view of the above, that a comparative study of selected Agricultural by-products was undertaken to determine the energy value of by-products commonly used for briquetting.

5.3. RECOMMENDATIONS

This work is based on some selected agricultural by-products that a commonly used for briquetting without a prior knowledge of their heating effect and value. It is in view of this fact; I am making the following recommendations:

1. Further research should be embarked upon for other agricultural by-products briquettes in other to concentrate on the production of briquette with higher heating value rather than just producing briquettes that will not have a good heating effect and value.
2. Further research work should be carried out on the chemistry of the smoke generated in burning the briquettes in case of any side effect on human health.
3. Further research work should be carried out to determine if the residue of the burnt briquette can be recycled and reused for other purposes.
4. The performance of any solid biomass fuel such as agricultural by-product briquettes can be evaluated effectively when it is combusted in a specially made biomass stove. In view of this, I recommend that, special stove should be developed for agricultural by-product briquettes at a low cost.

REFERENCES

Adegoke, C.O (1999): A Preliminary Investigation of Sawdust as High Grade Solid Fuel, Nigeria Journal of Renewal Energy (NJRE), 7 (1&2):102 – 107.

Adegoke, C.O. (2001): Waste to Wealth: Sawdust Briquette as a case study, Paper presented at the Mechanical Division of NSE conference, held at Lafia Hotel Ibadan 20 – 21 April.

Adegoke, C.O. and Mohammed, T.I (2002): Investigation of Briquette as High Grade Fuel, the West India Journal of Engineering. Faculty of Engineering, University of West India

Badejo, S.O.O. (1990): Residues Utilizaation, Invited paper, Natural Workshops on Forestry Management Strategies for Self Sufficiency in Good Production, FRIN, Ibadan: 12 – 15 June 1990.

Badejo, S.O.O and Odeyinde M.A (1988): commercial Utilization of Agricultural Residue in Nigeria. Invited Paper 1st National Congress of Science and Technology, University of Ibadan14 – 20 August 1988.

Bourgeous, J.P and Doat, J. (1985): Terrified Wood from Tropical Species Advantages and Prospects in Bioenergy 84, 3: 153 – 159.

http://www. wikipedia

Hughartd (1979): Prospect for Traditional and Non Congenital Energy Sources in Developing Countries. World Bank Staff Working Paper No 346 Published by World Bank, Washinton D.C

Jacob, K.K. Simon N.M; Jonathan M; Canon N.S and Wanjongo E. (2005): Recycling Waste into Fuel Briquettes, www.formatkenya.org/ormbook/chapters/chapter15 htm

Johannes H. (1984): Flowerpot and Brick pile Stoves Burning Rice Hulls Five Leaves and Coarse Biomas. Paper presentation at UNESCO Regional on Solar Drying Gadjagmada University Jogyankarta. Indonesia.

Keya, J.R. Kumar T.S and Vasudevan P. (2000): Pattern of Non-Commercial Energy Consumption in India Domestic Sector – A Case Study Published by IIED London.

Lindley, J.A and Vossoughi (1989): Physical Properties of Biomass Briquettes, American Society of Agricultural Engineers, Vol. 32(2) March – April 1989.

Nelkon, M. (1981): Principles of Physics, Pearson Education Limited Edinbrgh Gate Harlow Essex CM20 2JE, England

Olorunisola, A.O.(1999): The Development and Performance Evaluation of a Briquette Burning Stove: Nigeria Journal of Renewable Energy, Vol 7 No 1 and 2 pp 91 – 95.

Stewart, B. (1987), Improved wood waste and charcoal Burning Stoves (Practioner's Manual) Published in Kenya.

SPSS Statistic Software Version 7.0

APPENDIX I

Calculations

Volume Of By-Products Before Briquetting And Drying, Vb.

V = Volume of cylinder (Mould), cm^3

But $V = \pi r^2 h$

Where:

$\pi = 3.14$

r = radius of cylinder, cm

h = height of cylinder, cm

r = ½ D

D = 4cm ∴ r = 2cm

h = 8cm

$Vb = 3.14 \times 2^2 \times 8cm$

$= 100.53cm^3$

Bulk Density Of By-Products Before Briquetting And Drying, ρb

But ρ = Mass /Volume

Mass = 166.67g

Volume = $100.53cm^3$

∴ $\rho b = 166.67g/100.53cm^3$

$= 1.67g/cm^3$

VOLUME OF BRIQUETTE AFTER COMPRESSION AND DRYING, Va

(i) RICE HUSK & CASSAVA PEEL GEL BRIQUETTE

r = 2cm

h = 5.4cm

∴ $Va = 3.14 \times (2cm)^2 \times 5.4cm$

$= 67.86cm^3$

(ii) RICE HUSK & BANANA PEEL BRIQUETTE

r = 2cm

h = 5.8cm

∴ $Va = 3.14 \times (2cm)^2 \times 5.8cm$

$= 72.89cm^3$

(iii) MAIZE COB & CASSAVA PEEL GEL BRIQUETTE

$r = 2cm$

$h = 4.8cm$

$\therefore\ Va = 3.14 \times (2cm)^2 \times 4.8cm$

$= 60.32cm^3$

(iv) MAIZE COB & BANANA PEEL BRIQUETTE

$r = 2cm$

$h = 5.2cm$

$\therefore\ Va = 3.14 \times (2cm)^2 \times 5.2cm$

$= 65.35cm^3$

(v) GROUNDNUT SHELL & CASSAVA PEEL GEL BRIQUETTE

$r = 2cm$

$h = 6.1cm$

$\therefore\ Va = 3.14 \times (2cm)^2 \times 6.1cm$

$=76.66cm^3$

(vi) GROUNDNUT SHELL & BANANA PEEL BRIQUETTE

$r = 2cm$

$h = 6.4cm$

$\therefore\ Va = 3.14 \times (2cm)^2 \times 6.4cm$

$= 80.42cm^3$

(vii) SUGAR CANE BAGGASSE & CASSAVA PEEL GEL BRIQUETTE

$r = 2cm$

$h = 4.5cm$

$\therefore\ V a= 3.14 \times (2cm)^2 \times 4.5cm$

$= 56.55cm^3$

(viii) SUGAR CANE BAGGASSE & BANANA PEEL BRIQUETTE

$r = 2cm$

$h = 5cm$

$\therefore\ Va = 3.14 \times (2cm)^2 \times 5cm$

$= 62.83cm^3$

BULK DENSITY OF BRIQUETTE AFTER COMPRESSION AND DRYING, ρa

But $\rho a = \dfrac{\text{Mass of Briquette After compression drying, g}}{\text{Volume after compression and drying, cm}^3}$

(i) BULK DENSITY OF RICE HUSK & CASSAVA PEEL GEL BRIQUETTE

Mass = 48. 98g

Volume = $67.86cm^3$

$\rho a = 48.98g/67.86cm^3$

$= 0.72g/cm^3$

(ii) BULK DENSITY OF RICE HUSK & BANANA PEEL BRIQUETTE

Mass = 56.64g

Volume = $72.89cm^3$

$\rho a = 56.64g/72.89cm^3$

$= 0.78g/cm^3$

(iii) BULK DENSITY OF MAIZE COB & CASSAVA PEEL GEL BRIQUETTE

Mass = 41.48g

Volume = $60.32cm^3$

$\rho a = 41.48g/60.32cm^3$

$= 0.68g/cm^3$

(iv) BULK DENSITY OF MAIZE COB & BANANA PEEL BRIQUETTE

Mass = 45. 24g

Volume = $65.35cm^3$

$\rho a = 45.24g/65.35cm^3$

$= 0.69g/cm^3$

(v) BULK DENSITY OF GROUND NUT SHELL & CASSAVA PEEL GEL BRIQUETTE

Mass = 61.74g

Volume = $76.66cm^3$

$\rho a = 61.74g/76.66cm^3$

$= 0.81g/cm^3$

(vi) BULK DENSITY OF GROUND NUT SHELL & BANANA PEEL BRIQUETTE

Mass = 64.34g

Volume = $80.42cm^3$

$\rho a = 64.34g/80.42cm^3$

$= 0.80g/cm^3$

(vii) BULK DENSITY OF SUGAR CANE BAGGASSE & CASSAVA PEEL GEL BRIQUETTE

Mass = 37.08g

Volume = $56.55cm^3$

$\rho a = 37.08/56.55cm^3$

$= 0.66g/cm^3$

(viii) BULK DENSITY OF SUGAR CANE BAGGASSE & BANANA PEEL BRIQUETTE

Mass = 40.20g

Volume = $62.83cm^3$

$\rho a = 40.20/62.83cm^3$

$= 0.63g/cm^3$

APPENDIX II

ONE-SAMPLE STATISTICAL ANALYSIS

Statistical software (SPSS 7.0) is employed for these analysis and results are shown in Table 4.3 to 4.8. The One-Sample analysis is based on Table 4.2 above with reference to the energy value, temperature, time taken and the final residue.

T-Test

[DataSet0]

Table 4.3a: One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
HEAT	8	30.5291	2.47421	.87477
TEMPT	8	30.5891	.10793	.03816

Table 4.3b: One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
HEAT	34.900	7	.000	30.52913	28.4606	32.5976
TEMPT	801.629	7	.000	30.58913	30.4989	30.6794

Univariate Analysis of Variance

[DataSet0]

Table 4.4a:
Between-Subjects Factors

		N
TEMPT	30.40	1
	30.45	1
	30.57	1
	30.64	1
	30.66	1
	30.66	1
	30.67	1
	30.67	1

Table 4.4b: Tests of Between-Subjects Effects

Dependent Variable:HEAT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	42.852[a]	7	6.122	.	.
Intercept	7456.220	1	7456.220	.	.
TEMPT	42.852	7	6.122	.	.
Error	.000	0	.		
Total	7499.072	8			
Corrected Total	42.852	7			

a. R Squared = 1.000 (Adjusted R Squared = .)

Regression

[DataSet0]

Table 4.5a: **Variables Entered/Removed[b]**

Model	Variables Entered	Variables Removed	Method
1	TEMPT[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: HEAT

Table 4.5b: **Model Summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.916[a]	.839	.812	1.07332

a. Predictors: (Constant), TEMPT

Table 4.5c: **ANOVA[b]**

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	35.940	1	35.940	31.198	.001[a]
	Residual	6.912	6	1.152		
	Total	42.852	7			

a. Predictors: (Constant), TEMPT

b. Dependent Variable: HEAT

Correlations

[DataSet0]

Table 4.6: **Correlations**

		TIME	CONTENT
TIME	Pearson Correlation	1	-.055
	Sig. (2-tailed)		.898
	N	8	8
CONTENT	Pearson Correlation	-.055	1
	Sig. (2-tailed)	.898	
	N	8	8

Regression

[DataSet0]

Table 4.7a: **Variables Entered/Removed[b]**

Model	Variables Entered	Variables Removed	Method
1	TIME[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: CONTENT

Table 4.7b: **Model Summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.055[a]	.003	-.163	.06121

a. Predictors: (Constant), TIME

Table 4.7c: **ANOVA[b]**

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.018	.898[a]
	Residual	.022	6	.004		
	Total	.023	7			

a. Predictors: (Constant), TIME

b. Dependent Variable: CONTENT

Table 4.8a: **Coefficients[a]**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.130	.356		.366	.727
	TIME	-.001	.010	-.055	-.134	.898

a. Dependent Variable: CONTENT

```
CREATE
  /TIME_1=DIFF(TIME 1)/CONTENT_1=DIFF(CONTENT 1).
```

Create

```
[DataSet0]
```

Table 4.8b: **Created Series**

	Series Name	Case Number of Non-Missing Values		N of Valid Cases	Creating Function
		First	Last		
1	TIME_1	2	8	7	DIFF(TIME,1)
2	CONTENT_1	2	8	7	DIFF (CONTENT,1)

APPENDIX III

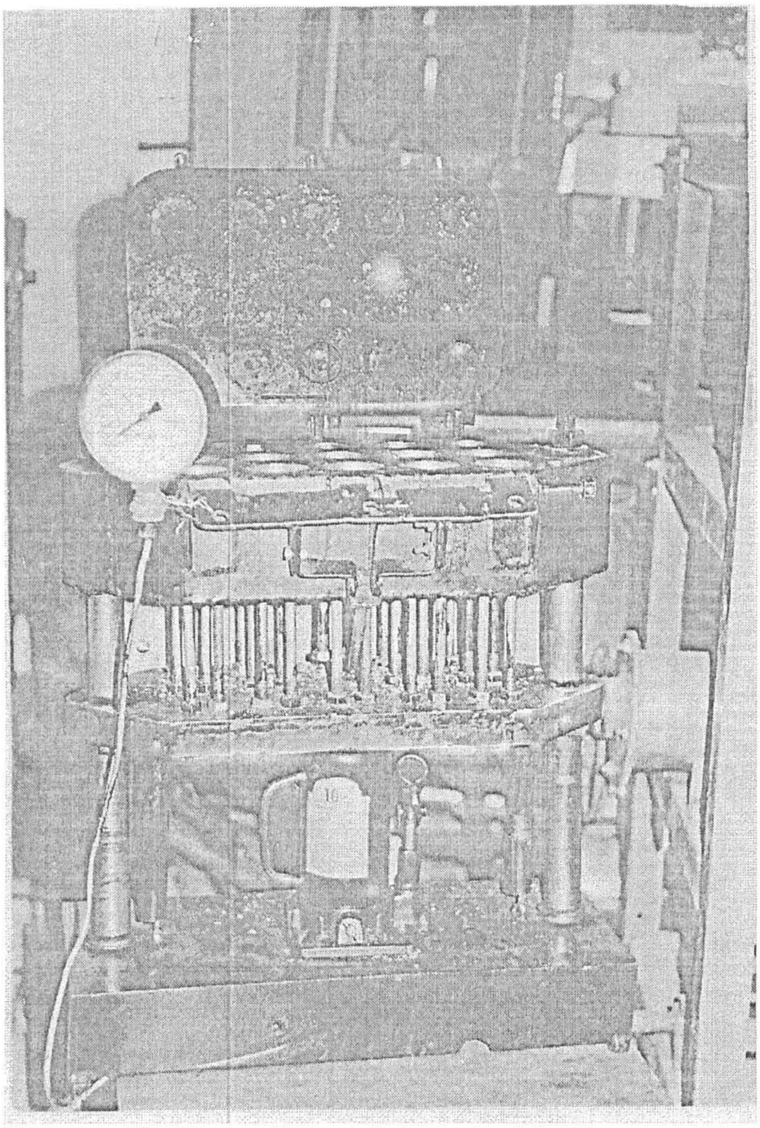

Plate 3.1: The Hydraulic Jack Briquetting Machine

APPENDIX IV

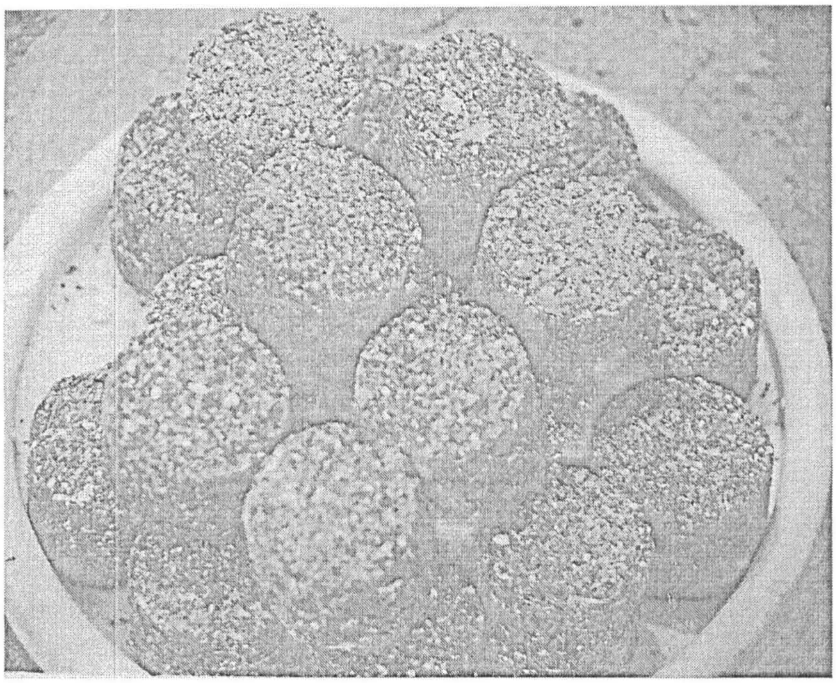

Plate3.2: Briquettes produced from rice husk and cassava peel gel binder

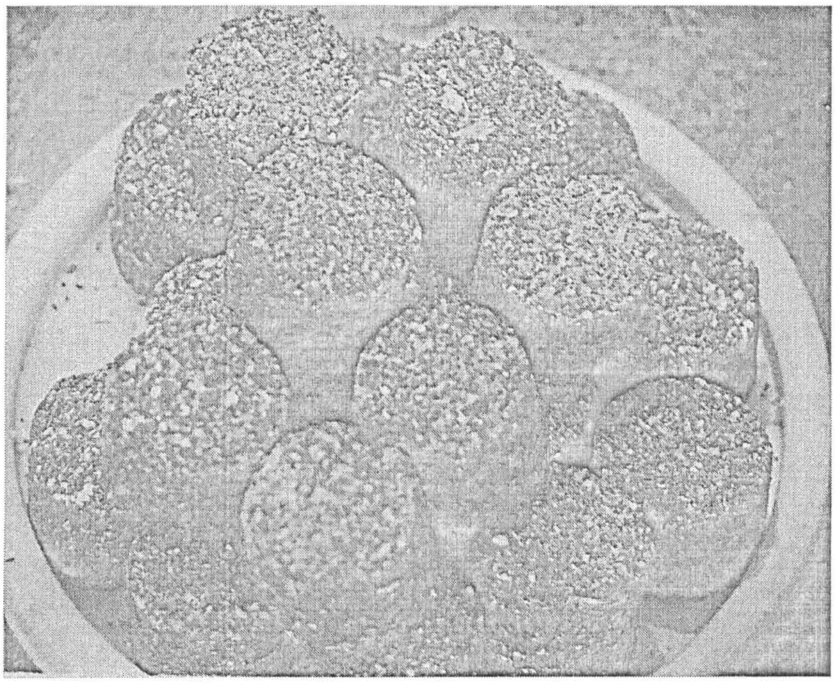

Plate3.3: Briquettes produced from rice husk and banana peel binder

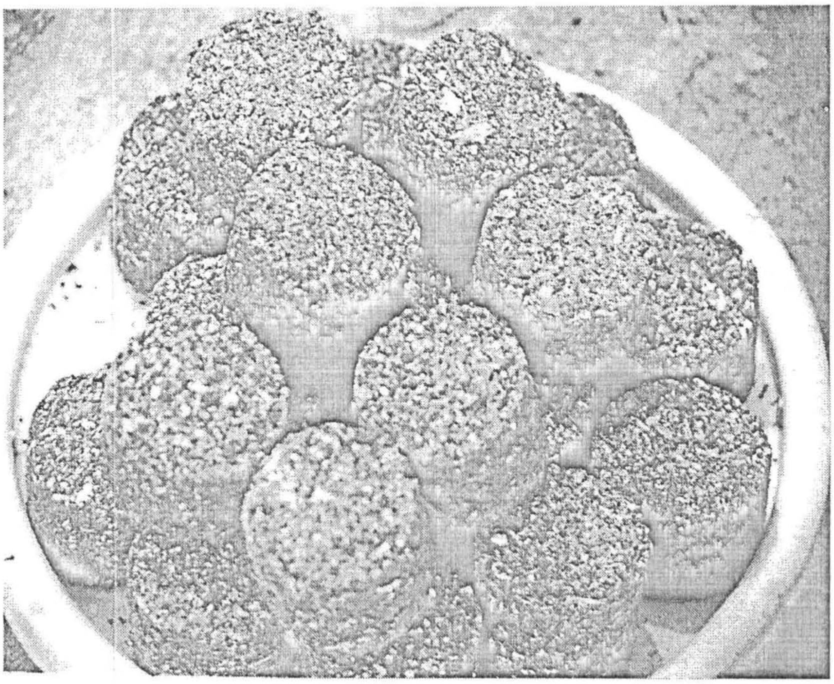

Plate3.4: Briquettes produced from maize cob and cassava peel gel binder

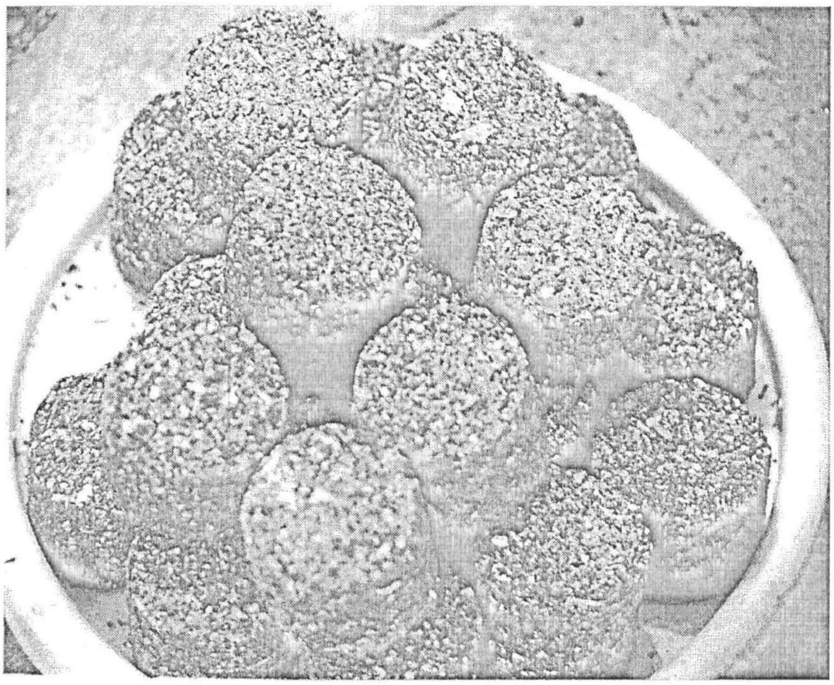

Plate3.5: Briquettes produced from maize cob and banana peel binder

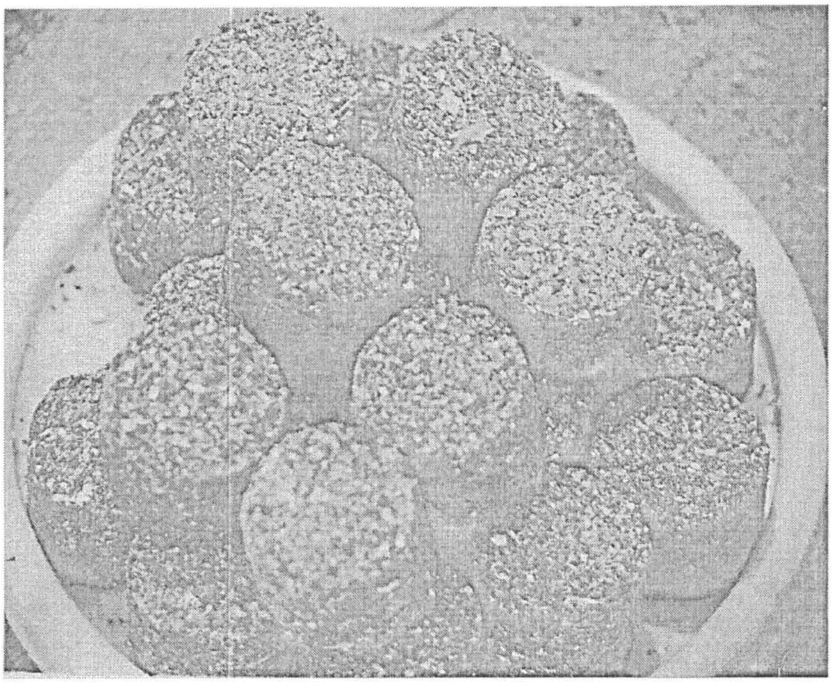

Plate3.6: Briquettes produced from sugarcane baggasse and cassava peel gel binder

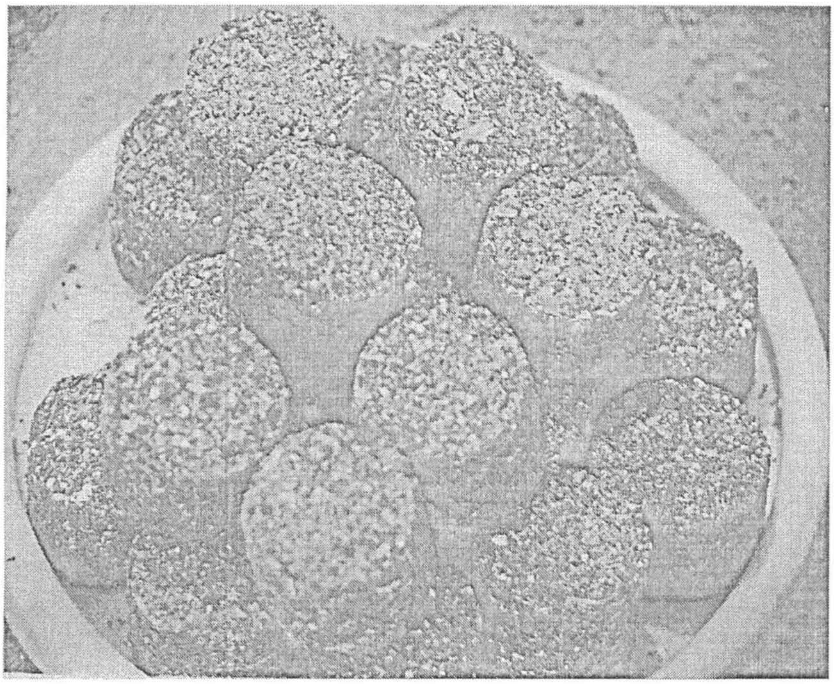

Plate3.7: Briquettes produced from sugarcane baggasse and banana peel binder

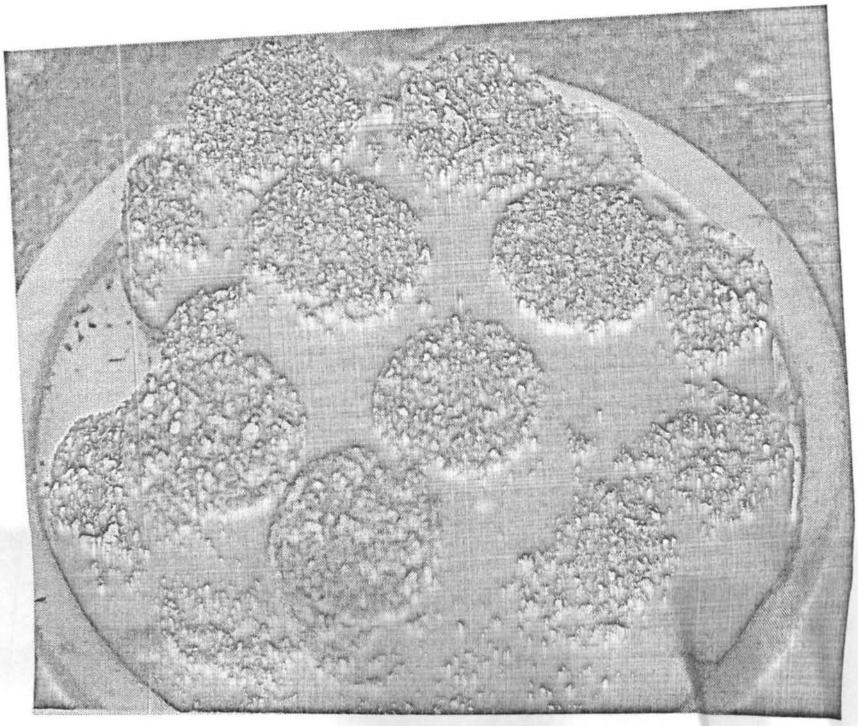

Plate3.8: Briquettes produced from groundnut shell and cassava peel gel binder

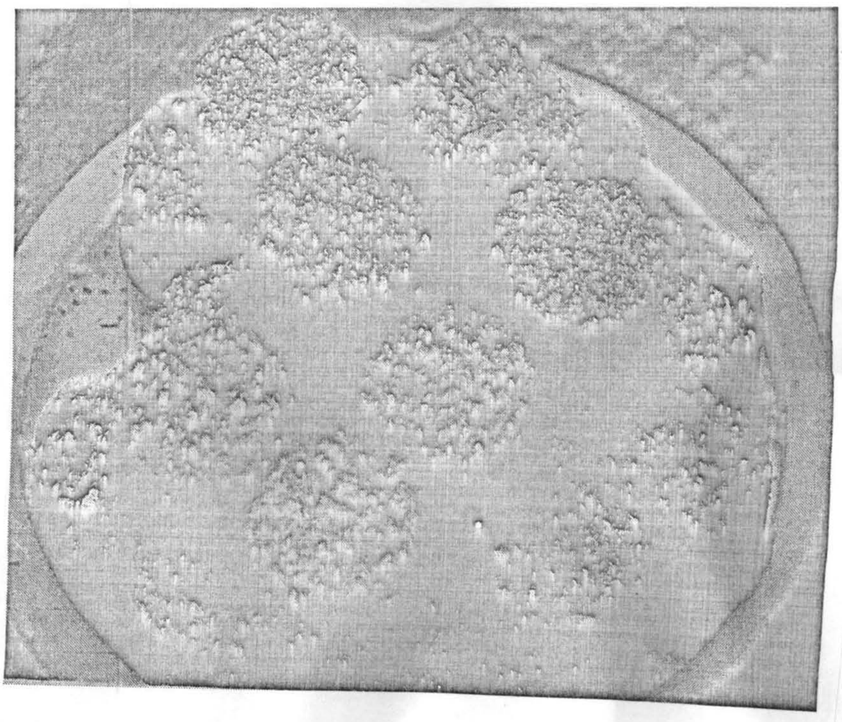

Plate3.9: Briquettes produced from groundnut shell and banana peel binder

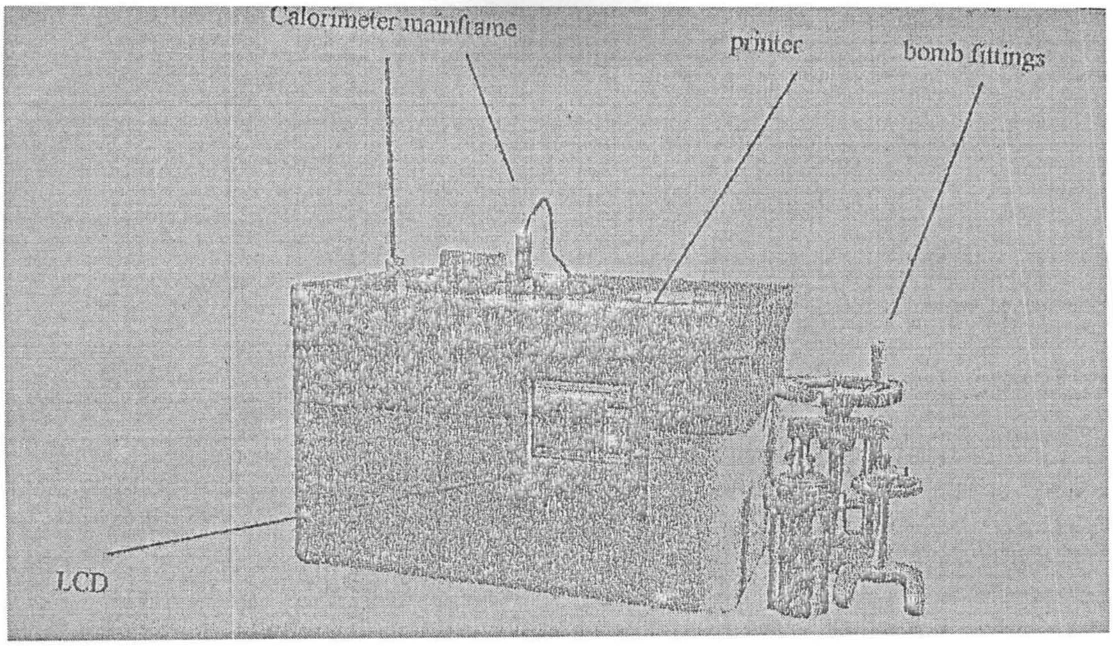

Plate3.10: The XRY – B1 Oxygen Bomb Calorimeter