Global Journal of Engineering Science and Research Management

ASSESSMENT OF THE PERFORMANCE OF A DISC ACTUATED BRIQUETTE PRODUCTION MACHINE DEVELOPED AT THE NATIONAL CEREALS RESEARCH INSTITUTE, BADEGGI

Agidi Gbabo[*1] A. N. Efomah[2] S. A. Alake[3]
[*1]Engineering Department, National Cereals Research Institute Badeggi PMB 8, Bida, Niger State, Nigeria.
[2]DESFABENG Company Ltd, km 1 off St. Louis Primary School, Zungeru Road, Bida, Niger State, Nigeria.
[3]DESFABENG Company Ltd, km 1 off St. Louis Primary School, Zungeru Road, Bida, Niger State, Nigeria.

KEYWORDS: Design, fabrication, sugarcane bagasse, briquette, combustion.

ABSTRACT
A briquetting machine to utilize agricultural waste products as raw material was designed, fabricated and tested. The machine was developed in order to be utilized by cottage factories to produce briquettes for both domestic and industrial use as source of heat energy. The machine mainly comprised of a hopper, compaction chamber, compression lever mechanism and the main frame. The machine was tested by using it to produce briquettes from sugarcane bagasse produced directly from a cane juice expeller, rice husk and sawdust under the same conditions of binder concentrations at different levels. The samples were analyzed for combustion properties (volatile matter, ash content, fixed carbon and heating value), Bulk density and compressive strengths. Result showed that Sugarcane bagasse and rice husks had higher volatile matter and lower fixed carbon compared to sawdust. The volatile matter and fixed carbon were 80% and 12% for sugarcane bagasse briquette and 79.8% volatile matter and 11.2% fixed carbon for rice husk at 10% binder concentration. The bulk density, 2.1kg/m3 of the bagasse briquettes was less than that of the rice husk and sawdust briquettes which were 3.6kg/m3 and 3.2kg/m3 respectively at 10% binder concentration. The compressive strength of all the briquettes were almost the same with the highest values ranging from 0.9KN/m2 (for sugarcane bagasse briquette) to 1.2KN/m2 for rice husk briquette at 40% binder concentration. The machine was found suitable to be used in producing briquettes from sugarcane bagasse since it had higher volatile matter and lower fixed carbon which are good quality characteristics required from combustible materials meant for the production of heat energy for both domestic and industrial uses.

INTRODUCTION
Agricultural wastes are waste from farming, forestry, horticulture and other farm operations. There is a rapid increase in the volume and types of agricultural wastes due to intensive agriculture in the wake of population growth and improved living standards, which are now becoming a major problem as rotten waste biomass emits methane and leach-ate. Open burning of these wastes by farmers usually generates carbon dioxide (CO2) and other local pollutants (UNDP, 1982). Most agricultural solid wastes are generated by the rearing of animals, and harvesting and processing of crops. These wastes take the form of residual stalks, straw, leaves, roots, husk, nut or seed shells, waste wood and animal husbandry waste.

These wastes are managed through the processes of collection, storage and disposal in form of biomass. If not managed properly, agricultural waste from farm operations can pollute the environment and even degrade both surface and underground water as they contain a lot of nitrates which can reduce the ability of these resources to support aquatic life and serve for human and animal consumption (www.HaweeRiver Water Coalition.com, 2010).

In order to manage these waste agricultural biomass by converting them into useful material resource, considerable efforts have been made by many Governments and private entities but there are still major gaps to be filled (UNDP 1982). Also, there is a lack of awareness and capacity to divert most of the waste for useful materials, energy recovery and wealth. This could reduce the costs for waste disposal and would generate the revenue from the sale of the recovered materials and energy.

As part of efforts to convert agricultural waste into useful products in Nigeria, ECN and UNDP (2005) stated that several machines have been developed for briquettes production (ECN and UNDP, 2005). One of such equipment

ISSN 2349-4506
Impact Factor: 2.265
Global Journal of Engineering Science and Research Management

is a single cylinder extrusion machine that can process millet, rice husk and sawdust to briquettes at 13kg of briquettes/hour. There are, however, only two small scale companies in Nigeria situated in Ogun and Kaduna states which produce and market sawdust briquettes. The locally produced briquette has 6 to 7 times more energy content per kg than un-briquetted biomass. Today, most work on biomass briquetting is confined to University Research and Development centers. Russell (1977) carried out a study of a simple briquette making technique which was developed in Sri Lanka to produce corrugated briquette sheets made from coir and observed that the resulting briquettes can be cut easily or broken along the corrugation to produce small logs. Vogler (1986) technically assessed some simple sawdust briquetting techniques and concluded that when animal dungs are sun dried for use as fuel, dung cake burns longer if wood ash is added. Lardinois and Klundert (1993) stated that the use of organic waste as cooking fuel in both rural and urban areas is not new as the rural poor in England often burned dried cow dung in the seventeenth century because of acute shortage of wood fuel due to widespread deforestation. Kartha and Leach (2001) carried out a study using modern bioenergy to reduce rural poverty. Good results were obtained by adapting presses for bricks or earth blocks in briquetting wood and agricultural wastes. Adegoke (2002) pointed out, that the results of a recent study in the Mechanical Engineering Department of the Federal University of Technology, Akure, also showed that briquettes made from sawdust mixed with certain biomass materials of appropriate grain sizes in certain proportions had improved calorific values. Fernando, (2002), developed a technology for small scale briquetting, oriented at briquetting agricultural waste and basically all kinds of burnable wastes. A very interesting and exciting result was achieved in his aim to find an alternative to the costly extruder machine. Following the very principle of the world wide known CINVA RAM machine for producing compressed earth blocks, the machine was designed and operated with a pressure of around 3 – 7 MPa using a lever to apply a compressive force.

Olorunnisola (2004) carried out a study involving experimental production of briquettes from chopped rattan strands mixed with cassava starch paste and found out that the minimum proportion by weight of cassava starch required for briquette formation was 200%. Bello (2005) carried out a research project in processing of agricultural residues into briquettes using gum Arabic as binder and evaluated their performance characteristics based on fuel efficiency, cooking efficiency, boiling time and fuel consumption rate respectively. for cooking purposes in the department of agricultural engineering, Ahmadu Bello University, Zaria in which she produced briquettes from agricultural residues using gum Arabic as her binder and evaluated their performance characteristics based on fuel efficiency, cooking efficiency, boiling time and fuel consumption rate respectively.. Also, a hand operated biomass briquetting mould, have been fabricated with locally available materials to prepare the charcoal briquettes for its ultimate analysis. Olorunnisola (2004) undertook a study to investigate the properties of fuel briquettes produced from a mixture of a municipal solid waste and an agricultural residue and observed that briquettes produced using the following 100 % waste paper and 5 : 95 waste paper - coconut husk ratio respectively exhibited the largest (though minimal) linear expansion on drying. While the equilibrium moisture content of the briquettes ranged between 5.4 % and 13.3 %, there was no clearly discernible pattern in equilibrium moisture content variation with increase in coconut husk content. A reciprocal relationship was observed between compressed/relaxed density and relaxation ratio of the briquettes, while the mean durability rating of all the briquettes exceeds 95 %. It was however concluded that stable briquettes could be formed from waste paper mixed with coconut husk particles.

MACHINE DESCRIPTION

The briquetting machine is composed of the following components as described below:

Hopper:

The hopper, made from 1.5mm mild steel sheet is constructed in form of frustum and used to temporarily hold the prepared bagasse before they are fed into the compaction chamber. It measures 400 x 250mm at the top, 250 x 80mm at the bottom with a total slant height of 350mm (Plate 1).

 ISSN 2349-4506
Impact Factor: 2.265

Global Journal of Engineering Science and Research Management

Plate 1: Hopper

The Compaction Chamber:

This is where the briquettes are formed during compression when power is transmitted through the piston. It measures 100mm length x 130mm width x 90mm height. This chamber is made of three compartments as shown in Plate 2. An adjustable 20mm thick cover plate is used to cover this chamber in order to ensure proper compression of the bagasse. The upward movement of the pistons against the thick cover plate facilitates the formation of the briquettes.

Plate 2: Compaction chamber

The Lever Mechanism:

This consists of curved welded pipes connected to a crank mechanism. Curved pipes were welded together to form the lever arm. The forward and backward movement of the lever arm creates a reciprocating motion which aids in the compaction of the briquette. The crank mechanism consists of two semi-circular 8mm thick mild steel as shown in (Plate 3).

Plate 3: Lever mechanism

ISSN 2349-4506
Impact Factor: 2.265
Global Journal of Engineering Science and Research Management

The Main Frame:
This houses and supports the other parts of the machine. The main frame was made with U- channel angular mild steel iron (Plate 4).

Plate 4: Frame

Assembled Machine:
The component parts described earlier were assembled to form the briquette production machine as shown in plate 5. The samples of briquettes from the machine are also presented in plate 6.

Plate 5: Complete disc operated machine

Plate 6: Samples of briquettes produced from the machine

MATERIALS AND METHODS
Material Preparation
10 kg each of clean sugarcane bagasse, rice husk and sawdust were obtained from various factories producing these wastes in Bida town, Niger state, Nigeria. Four (4) starch solutions were prepared as binder by mixing boiled water with starch to form gels at different concentration levels of 10%, 20%, 30% and 40%. Each of these specimens was replicated three times. The starch specimens were then mixed with 5kg each of bagasse, husk and sawdust in separate plastic buckets. Each of the mixed specimens was fed into the machine to produce the briquettes. The samples were sundried to 5% moisture content. The dried briquettes were analysed for the following quality parameters and presented in Tables 1 - 3:

Combustion Properties
Percentage volatile matter (PVM)
A unit of each briquette sample of sawdust, rice husk and bagasse was placed in a crucible of known weight and oven dried (E.L.E limited-serial number S80F185-Hemal Hempstead Hertfordshire S80F185 – Hemel Hempstead Hertfordshire, England) to a constant weight after which it was heated in the furnace (Isotemp Muffle Furnace Model 186A – Fisher Scientific) at a temperature of 550ºC for 15 minutes. The percentage volatile matter was then expressed as the percentage of loss in weight to the oven dried weight of the original sample.

ISSN 2349-4506
Impact Factor: 2.265
Global Journal of Engineering Science and Research Management

$$PVM = \frac{A-B}{A} \times 100 \quad (1)$$

Where A is the weight of the oven dried sample and B is the weight of the sample after 15min in the furnace at 550°C.

Ash content

5g of the briquette samples was weighed into a porcelain crucible (W_{c1}, W_{c2}, W_{c3}, and W_{c4}). This was transferred into the muffle furnace set at 550^{O}C and left for about 4 hours. About this time it had turned to white ash. The crucible and the content were cooled to about 100ºC in air, then to room temperature in a desiccator and weighed. This was done twice and replicated for the three samples of sawdust, rice husk and bagasse .The ash content was computed as:

$$\text{Ash content} = \frac{\text{Weight of ash} \times 100}{\text{Original weight of sample}}$$

$$\text{Ash content} = \frac{W_{a}-W_{c}}{W_{o}-W_{c}} \times 100 \quad (2)$$

Where

W_a = weight of ash + can

W_c =weight of empty can

W_o =original weight of sample + can

Percentage Fixed Carbon

The formula for fixed carbon is obtained following the procedure by Bailey and Blankenhovn (1982) and is given as:

Fixed Carbon =100 – (% volatile matter + % ash content) (3)

The Heat Value (Hv)

The heat Value is also obtained using the expression given by Bailey and Blankenhovn, (1982) as:

$$H_v = 2.326\ (147.6C + 144V) \quad (4)$$

Where C = % fixed Carbon

V = % Volatile matter

Bulk Density

The weights of briquettes were determined on the balance in the laboratory. Then, the volumes of briquettes were determined by a simple calculation based on the direct measurement of height, diameter, and thickness of the briquettes. The bulk densities of the samples were conventionally calculated as:

D = M/V (5)

Where,

D = Density in kg/m^3

M = Mass in kg

V = Volume in m^3

Compressive Test

This is used to determine the compressive strength of materials or the maximum force or load a material can withstand. This test was carried out using the fuel sample of the produced briquettes and a compressive test machine (model C90 and weight 126kg). The machine consists of a hydraulic jack, a load measuring gauge and a dial gauge.

The material was placed in-between two plates of the machine and pressure applied to the hydraulic jack lever which pushed one of the plate upward as it compresses the materials against the second plate until the material starts to fail. The readings on the pressure gauge and dialed gauge were recorded.

Global Journal of Engineering Science and Research Management

RESULTS AND DISCUSSION

Combustion Properties

The following combustion properties were analyzed and results given in appendix 1:

Volatile matter

The volatile matter for all the samples from sugarcane bagasse, rice husk and sawdust reduced with increasing binder concentration. However, sugarcane and rice husk bagasse had the highest volatile matter of 80.0% for sugarcane bagasse and 79.8% for rice husk briquettes as shown in Fig.1. The level of volatile matter in the briquettes directly affects their burning efficiency. The higher the volatile matter, the more the burning efficiency of the briquette. Since, the sugarcane bagasse and rice husk briquettes had the highest Volatile matters, they have higher tendency to burn more efficiently than the sawdust briquettes with 72.5% volatile matter.

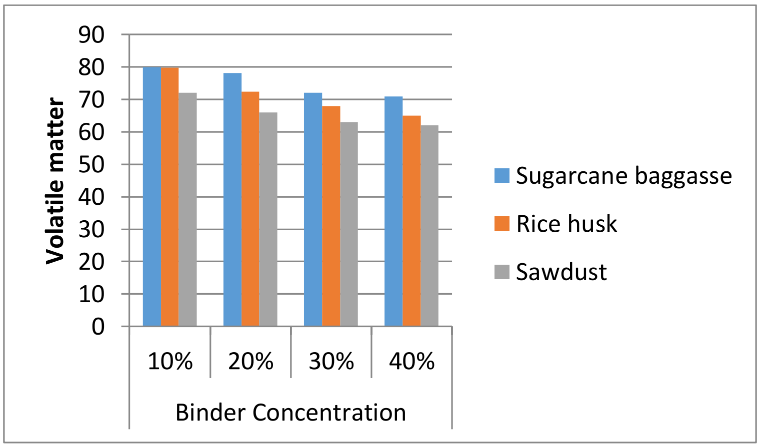

Fig. 1: Volatile matter vs binder concentration for briquettes from different materials

Fixed carbon

The fixed carbon value of the briquette generally increased with starch concentration. Comparatively, the sugarcane bagasse and rice husk had less fixed carbon ranging from 12.0% to 16.3% and 11.2% to 15% respectively at all levels of starch concentration (Fig.2). The highest values of 20.1% and 19.5% at different 40% and 30% binder concentrations respectively were recorded for sawdust briquettes. The level of fixed carbon in combustible materials is indicative of its burning efficiency. In contrast to volatile matter, the lower the fixed carbon, the higher the efficiency of burning. Therefore, sugarcane and rice husk briquettes with the lowest carbon values have the tendency to burn better than the sawdust briquette.

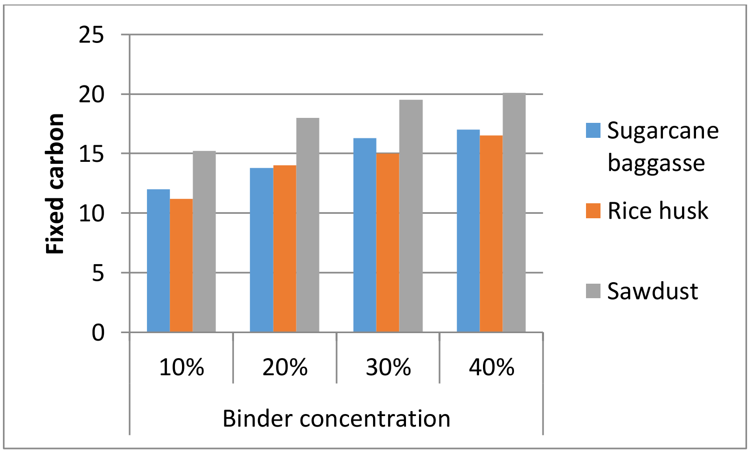

Fig. 2: Fixed carbon vs binder concentration for briquettes from different materials

ISSN 2349-4506
Impact Factor: 2.265

Global Journal of Engineering Science and Research Management

Ash Content

Sugarcane bagasse briquette and rice husk briquettes had the least ash contents of 8.1% and 8.8% respectively compared with the value of sawdust briquette with ash contents of 12.1% respectively at 10% binder concentration (Fig.3). The lowest ash content of sugarcane bagasse and rice briquettes indicates that they have higher burning degree.

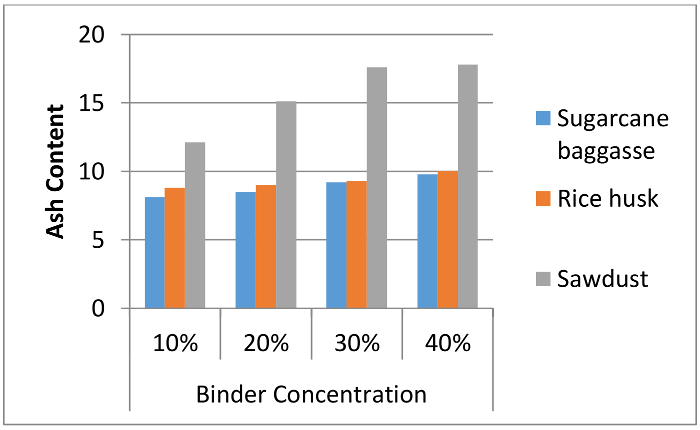

Fig. 3: Ash content vs binder concentration for briquettes from different materials

Heating value

The heating values of rice husk and sugarcane briquettes were almost the same at all levels of binder concentrations as shown in fig. 4. Although, sawdust briquette had the highest heating value of 39% at 40% binder concentration, those of sugarcane and rice husk ranged from 38-40.1% at 30% and 40% binder concentration. The value of 32.0% for saw dust was relatively lower. These results indicate that sugarcane bagasse and rice husk briquettes have tendency to have higher calorific values thereby releasing more heat energy when burnt.

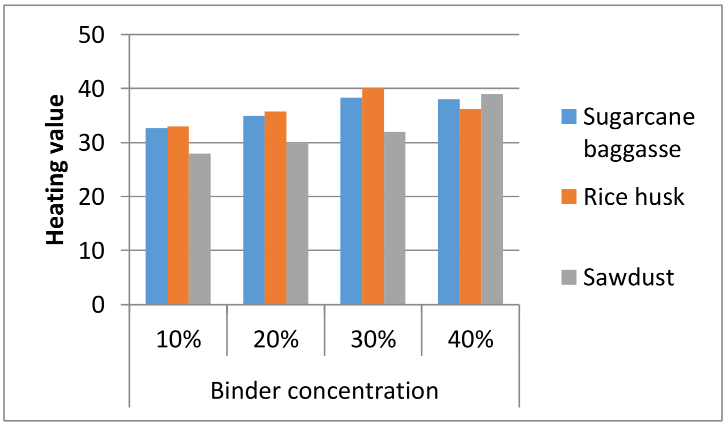

Fig. 4: Heating value vs binder concentration for briquettes from different materials

Bulk density

The bulk densities of all the briquettes increased as the quantity of the starch increased (Fig.5). This is due to the fact that the higher the binder concentration, the more the binding ability thereby reducing pore spaces in the briquettes. Sugarcane bagasse briquettes had the lowest bulk density of 2.10kg/m3 at 10% starch concentration and 2.7kg/m3 at 40% starch concentration. Rice husk briquettes were observed to have the highest value of 4.8kg/m3 at 40% concentration followed by sawdust with 4.1kg/m3 at 40% concentration. These results show that the rice husk and sawdust briquettes have higher storability and physical handling ability compared to sugarcane bagasse. However, it would cost less to transport bagasse briquette compared to those of rice husk and sawdust because the weight of the sugarcane bagasse briquettes is less.

 ISSN 2349-4506
Impact Factor: 2.265
Global Journal of Engineering Science and Research Management

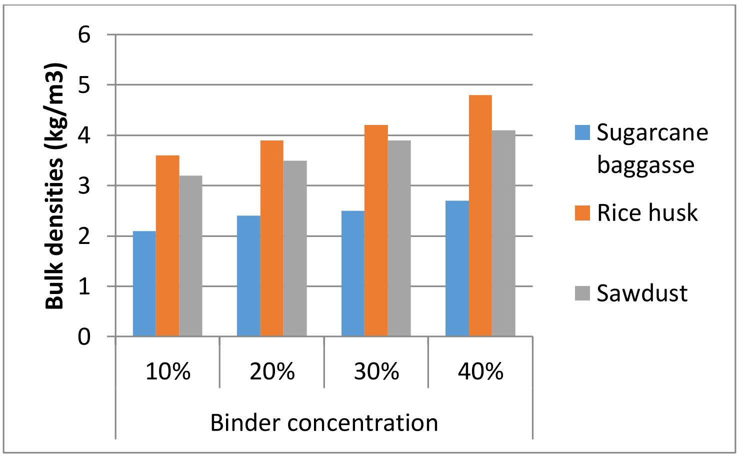

Fig. 5: Bulk density vs binder concentration for briquettes from different materials

Compressive strength

The compressive strength of all the briquettes is almost similar ranging from 0.2KN/m^2 at 10% binder concentration to 1.2KN/m at 40%. Although the compressive strength of all the samples is almost similar, the rice husk briquettes had slightly higher compressive strengths at all binder concentrations as presented in Fig.6.

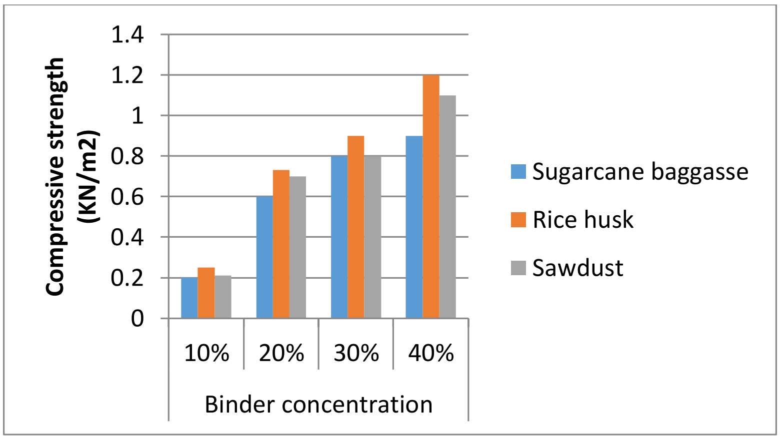

Fig.6: Compressive strength vs binder concentration for briquettes from different materials

CONCLUSION

The following conclusions are made with respect to the development of a briquetting machine for the production of briquettes from sugarcane bagasse:

i) The briquette making machine was found suitable to be used for sugarcane bagasse briquettes production. Results obtained from testing the equipment indicate that it is capable of solving environmental pollution effects in sugarcane growing communities. In addition to solving pollution problems, the equipment would be an income generating source in such communities.

ii) The test results on the performance of the equipment show that the sugarcane bagasse produced from the equipment has good combustion properties. Comparatively, the sugarcane bagasse had the highest volatile matter and lowest carbon value than the rice husk and sawdust briquettes .This shows that the sugarcane cane briquettes have higher tendency to burn better and generate higher calorific heat energy value. This is also indicative of the corresponding higher heating value for the sugarcane bagasse briquettes.

iii) The low bulk density of the bagasse briquette makes it more advantageous in terms of transport cost. Due to the fact that the bagasse briquette has lower bulk density, it also has a corresponding less weight which is more suitable for transportation.

iv) The equipment would still be used in testing sugarcane bagasse fragments of varying sizes to ascertain the optimum bagasse size to be recommended to users.

AUTHORS' CONTRIBUTIONS

Agidi Gbabo, designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. A. N. Efomah and S. A. Alake managed the analyses of the study. A. N. Efomah managed the literature searches. All authors read and approved the final manuscript.

REFERENCES

1. Adegoke, C. O. "Energy as Veritable Tool for Sustainable Environment". Inaugural Lecture Series 31. Delivered at the Federal University of Technology, Akure, Ondo State, Nigeria. (2002). Pp. 34 - 46.
2. Bello, A.W. "Processing of Agricultural Residues into Briquettes as Fuel for Cooking Purposes". BSc Project. Department of Agricultural Engineering Ahmadu Bello University. Zaria. (2005).
3. Energy Commission of Nigeria and United Nations Development Programme. Renewable Energy Master Plan. Final Draft Report, Energy Commission of Nigeria ECN & UNDP. November.(2005)
4. Fernando, M. "Binding Machines" (alternatives). Retrieved from www.crest.org/discussion stoves/200210/msg00082.html.(2002).
5. Kartha, S. and Leach, G. "Using Modern Bioenergy to Reduce Rural poverty". Stockholm Environment Institute. (2001).
6. Lardinois, I and Klundert, A. "Organic Waste Options for Small – Scale Resource Recovery". Waste Consultants. The Netherlands. (1993).
7. Olorunnisola, A.O. "Briquetting of rattan furniture waste". Journal of Bamboo and Rattans. (2004).3(2): 139-149.
8. Russell, A. "Using Biomass residue for Energy." Issue 39. Briquetting Agricultural Residues (knowledge Bank). Hedon Household Energy Network. (1997).
9. UNDP / World Bank Sri Lanka. Issues and Options in the Energy Sector Report No. 3794CE. (1982).
10. Vogler. J. "Understanding Wood Wastes as Fuel". Technical Paper No. 46. Published by Volunteer in Technical Assistance (VITA). ISBN: 0-86619-260-3. (1986)

APPENDIX 1

Table1: Combustion Properties of sugarcane bagasse briquette compared with rice husk and sawdust briquette

Briquettes	**Combustion Properties at various binder concentration (starch)**															
	10%				20%				30%				40%			
	Volatile matter	Ash content	Fixed carbon	Heating Value	Volatile matter	Ash content	Fixed carbon	Heating value	Volatile matter	Ash content	Fixed carbon	Heating Value	Volatile matter	Ash content	Fixed carbon	Heating value
Sugarcane Baggasse	80.0	8.1	12.0	32.7	78.2	8.5	13.8	35.0	72.0	9.2	16.3	38.3	71.0	9.8	17.0	38.0
Rice husk	79.8	8.8	11.2	33.0	72.4	9.0	14.0	35.8	68.0	9.3	15.0	40.1	65.0	10.0	16.5	36.2
Sawdust	72.0	12.1	15.2	28.0	66.0	15.1	18.0	30.0	63.0	17.6	19.5	32.0	62.0	17.8	20.1	39.0

ISSN 2349-4506
Impact Factor: 2.265
Global Journal of Engineering Science and Research Management

Table 2: Bulk Densities of sugarcane briquette compared with rice husk and sawdust briquettes

Briquettes	**Bulk Densities (kg/m^3)**			
	10% binder concentration	20% binder concentration	30% binder concentration	40% binder concentration
Sugarcane bagasse	2.1	2.4	2.5	2.7
Rice husk	3.6	3.9	4.2	4.8
Sawdust	3.2	3.5	3.9	4.1

Table 3: Compressive strength of sugarcane briquette compared with rice husk and sawdust briquettes

Briquettes	**Compressive strength (KN/m^2)**			
	10% binder concentration	20% binder concentration	30% binder concentration	40% binder concentration
Sugarcane bagasse	0.2	0.6	0.8	0.9
Rice husk	0.25	0.73	0.9	1.2
Sawdust	0.21	0.7	0.8	1.1