DEVELOPMENT OF WATER HYACINTH BRIQUETTING MACHINE

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Abstract - Briquetting technology is one of the renewable sources of energy that was developed to address problems concerning global warming, energy catastrophe, as well as solid waste management. Nigeria has abundant supplies of biomass resources and unrestricted solid waste, whose potentials are yet to be fully tapped for energy generation. It is, therefore, necessary to convert these waste into a product that will provide alternative energy to the people rather than constituting environmental problems. The study was undertaken to develop of hyacinth briquette machine and examine the properties of fuel briquettes produced from a mixture of waste paper (WP) and water hyacinth plant (WHP) using corn and cassava starch as a binder. WP from the academic environment and WHP harvested from the surface of fresh waters were used. Briquette machine was designed using a screw type extruder to convert the processed WHP and WP into solid briquette for domestic consumption. Samples of WHP was harvested, ground, dried and mixed with WP. The mixture was poured into a hopper. The physical and combustion properties of the briquette were determined at varying WHP and WP-binder ratios of 100:10, 100:15, 100:25, 100:30 and 100:45, 100:55 using corn starch as the binding agent. It was discovered that the binder ratio 100:25 demonstrated the most affirmative value of biomass energy than others. It was also observed that the cooking time for the briquette produced using WHP and WP was 40min/kg with SFC of 0.4kg/kg. The designed machine has production efficiency of 84% and also produced smoke-free WH briquettes with high resistance to mechanical action, better handling and efficient fuel characteristics for household use.

Keywords: Briquette, water hyacinth, waste paper, heated die, binder

1.0. INTRODUCTION

Briquetting is the method of transforming a granular or powdery substance into a generously proportioned and more convenient sized element. The world population is growing speedily. Based on this fact, the energy requirement of the entire world is increasing, firewood and charcoal are the most important cooking fuel sources for the poor and middle-income households in Nigeria. (Maglaya and Biona 2010). A good number of rural dwellers rely on biomass for heating and cooking. This dependence on traditional charcoal and firewood is responsible for the prevailing deforestation and soil degradation which has impacted the environment adversely. The continuous use of solid fuels for cooking such as charcoal and wood fuel has been observed to be the major cause of respiratory infections given that they emit much smoke. It is therefore very necessary to encourage the use of briquette for domestic cooking especially in rural areas since it is smoke-free. Briquetting is a process of binding together pulverized carbonaceous matter, often with the aid of binder (Martin, *et al*., 2008).

Energy demand in the form of fuel keeps increasing on a daily basis, and the problem of non-renewable nature of the fossil fuel had been the major concern to most Nigerians. This apprehension has called for alternative ways of generating energy, one of which is the use of biomass (i.e.,.hyacinth plant). Water hyacinth is an aquatic plant found growing on the surface of the water, which is a threat to biodiversity. Efforts are underway all over Africa to remove water hyacinth from waterways by hand, machine, using chemical and biological control (PACE, 2011). It has been discovered in recent time that hyacinth plant seen as a waste has various uses such as for making bio-fertilizer, furniture, sewage and biological waste-water treatment, and biogas production (Rademaker, 2006). Other uses include feed for livestock, a substrate for mushrooms and as a vegetable for humans (Ambali, 2000). To further broaden its effectiveness as a renewable source of energy, the plant can be processed into biomass briquettes for heating purposes. It is very necessary to understand the specific characteristics of briquettes biomass before embarking on its production (Moraj, et al., 2015)

Satisfactory briquette can be produced from waste materials. There are so many waste biomass materials available in our environment that can be used to make the fuel briquette. Good examples include Charcoal dust; Waste paper and cardboard; Waste from plants; Waste from bio-product industries like sawmills, plywood industries, furniture factories. Rajkumar and Venkatachalam (2013), conducted research on briquette production using the agro residues produced from cotton/ soybean and pigeon pea stalks. The quality of the briquettes they produced was a function of the type and level of raw materials used. Oladeji (2013) produced briquette from four different waste materials namely: Rice husk, cassava peel, melon shell and sawdust. In research conducted by Daiwey et al. (2010), a briquette machine was supplied in the Aurora province for their usage. This machine transforms coconut husks into charcoal briquettes and uses cassava as the binder. Also, another study carried out by Martin et al. (2008), a briquette machine was designed which can mould 12 cylinder-shaped briquettes in every extrusion period. Olorunnisola (2007) investigated the properties of fuel briquettes produced from a mixture of a municipal solid waste and an agricultural residue, i.e., shredded waste paper and hammermilled coconut husk particles. He manufactured a manually-operated machine with closed end die piston press used to produce briquette at an average pressure of 1.2 x 103 N/m2 using four coconut husk: waste paper mixing ratios (by weight), i.e., 0:100; 5: 95; 15: 85; and 25: 75. Results obtained showed that briquettes produced using 100% waste paper and 5:95 waste paper-coconut husk ratios respectively exhibited the largest linear expansion on drying. Arinola and Justina (2013) produced briquette machine with a single extrusion die screw press which consists mainly of driving motor, screw, die, belts and the housing with a hopper. The belt transmits power from the motor to the screw through the pulley. The machine has a production capacity of about 95kg/hr and it is driven by a 3 kW, 1440 rpm electric motor driving the screw shaft at 480 revolutions per minute (rpm). This research will focus on the design of hyacinth briquette machine capable of converting waste (WHP and WP) to a useful material (briquette). Osarenmwinda and Ihenyen (2012) designed and fabricated a manually operated briquette machine using the locally available material, they did not test to ascertain the utility of the material regarding briquette production but predicted that it could produce up to twenty briquettes at a time.

The main objective of this study was to develop a hyacinth briquette machine for the production of dense briquettes as fuel for domestic use. The specific aims of the study were: To design and construct a WH briquette machine; To undertake the performance of the briquette machine using WHP and WP at varying binder levels; To determine the physical and the combustion properties of the WH briquette produced. This study is noteworthy, due to the increasing demand for energy and regular importation of fuel from other countries, the need to optimize the use of local energy sources should be given much attention. Production and operation of alternative energies such as briquettes can be of help to address the rising energy needs of the country.

2.0. MATERIALS AND METHODS

For the purpose of the study, WHP and WP was used for the performance evaluation of the machine. The water hyacinth sourced from Otamiri in Owerri Imo State. Waste papers (mixed paper material: Grade 1) were gathered from two higher institutions in Owerri namely: Federal Universit of Technology and Federal Polytechnic Nekede Owerri, Imo State. Cassava starch and Maize Starch were used as binding agent mainly to surmount the biggest problem of material squashing. Little quantity was made available because a large amount of it can reduce the effectiveness of the briquette for domestic use.

2.1. Design Concept

The WH briquette machine was designed and constructed putting into certain consideration factor. The major factors considered in the design of the WH briquette include Portability of the equipment (the equipment for the design must be exceedingly portable); Production cost of the equipment (production cost must be affordable). Maintenance cost of the equipment (maintenance cost must be as low as possible); Design concept of the equipment (materials must be of simple design); Possibility of coupling/attaching and detaching of parts (parts that make up the machine are temporarily attached) for easy movement. Moreover, the choice of materials for construction met the following criteria: Surface property e.g. corrosion resistance; Ability to be fabricated; Bulk property e.g. strength; Appeal to potential buyers and customers; Economic competition with other alternative equipment.

2.2. Fabrication and Assembling of Parts

Materials used for the manufacture of the WH briquette machine are steeled mild cut into sizes welded and assembled. The various elements that make up the briquette complete machine are: The hopper and connector; Cylindrical barrel; Die; Screw, Shaft; Die heating stove and Electric motor

2.2.1. The Hopper and Connector

A mild steel sheet was used to design the hopper and connector of the briquette machine. The hopper was designed enough allowance to accommodate the adequate amount of mixed WHP and WP. The connector is essential because it serves as the link between the hopper and the barrel. A mild steel sheet of size 750mm x 250mm was marked out from a lengthy expanse. The marked out parts were cut and welded together to give the required shape of the hopper (Figure 1 and 2)

2.2.2. The Cylinder Barrel

The barrel is a cylinder of diameter 50mm, with a thickness of 2.5mm. The position of the hopper, the cylinder was clamped into a convenient position. The square hole was cut out after which the hopper with connector was positioned for welding and the hope was welded to the barrel. (Figure 3 and 4).

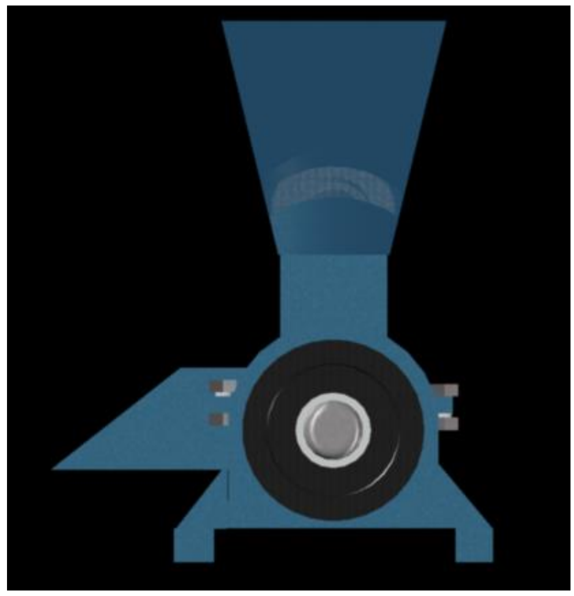

Fig. 1 Side View of the Hopper and Connector

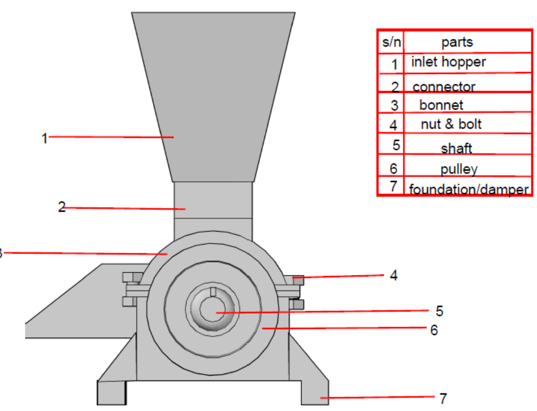

Fig. 2. Hopper and Connector With Parts Labelled

2.2.3. The Screw and Washer

The screw is made up of mild steel material, with an outer diameter of 70mm and washer thickness of 3.5mm and a shaft diameter of 32mm. The screw shaft was mounted on a lathe machine and turned into the desired shape. Washers were produced to be used as the screw thread with a thickness of 3.5mm which was inserted over the screw shaft one after another. The inserted washers were welded to the shaft to produce a complete screw ready for installation. (Figure 3 and 4)

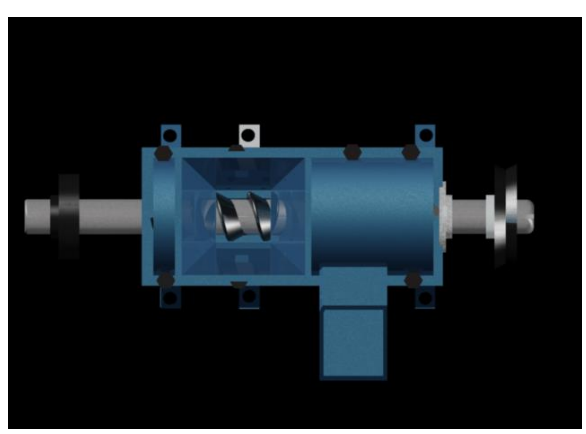

Fig. 3. Screw Fixed Inside The Barrel Ready For Coupling

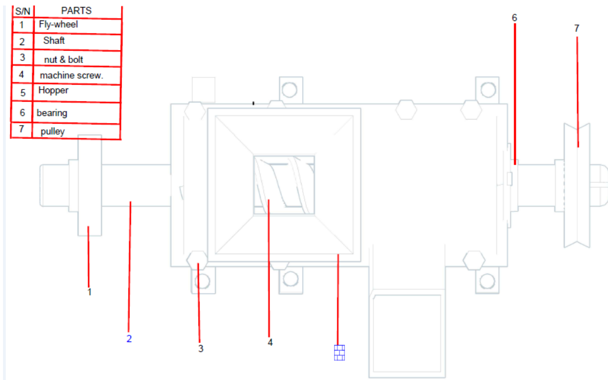

Fig. 4. Screw Fixed Inside The Barrel With Parts Fully Labelled

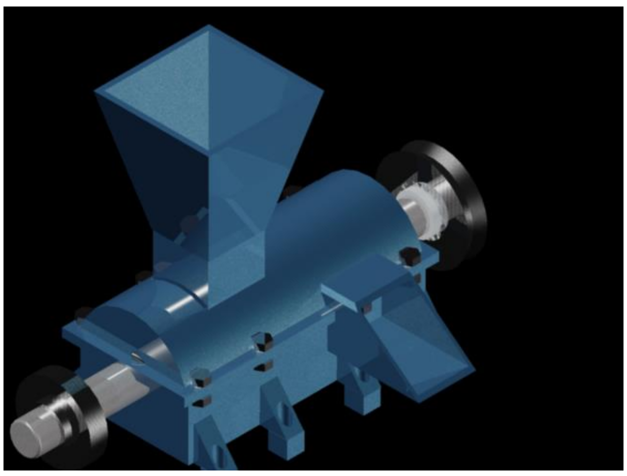

Fig. 5. Briquette Machine

3.0. TESTING AND EVALUATION

The machine developed was tested to ascertain its performance using WHP and WP with corn and cassava starch as a binder.

3.1. MATERIAL PREPARATION

Waste Paper:

The papers gathered from the university premises (the Federal University of Technology Owerri and Federal Polytechnic Nekede Owerri) were soaked and blended using a local pulping process. The pulp was dried and comminuted into smaller particle surfaces form so that the larger surface area of interaction was obtained.

Water Hyacinth:

The water hyacinth sourced from the surface of streams and Otamiri River in Owerri Imo State were collected wet, and the stem cut into smaller pieces for easy handling.

Binder:

It was found that the binding agent was most effective when applied in liquid. In Nigeria, cassava or maize starch can be used as a binder because of their relative abundance. In this research cassava and corn starch were sourced for because they are abundant and relatively cheap. Little quantity was made available because too much of it can reduce the effectiveness of the briquette for domestic use.

Drying: The cut pieces of hyacinth were open air dried for few days.

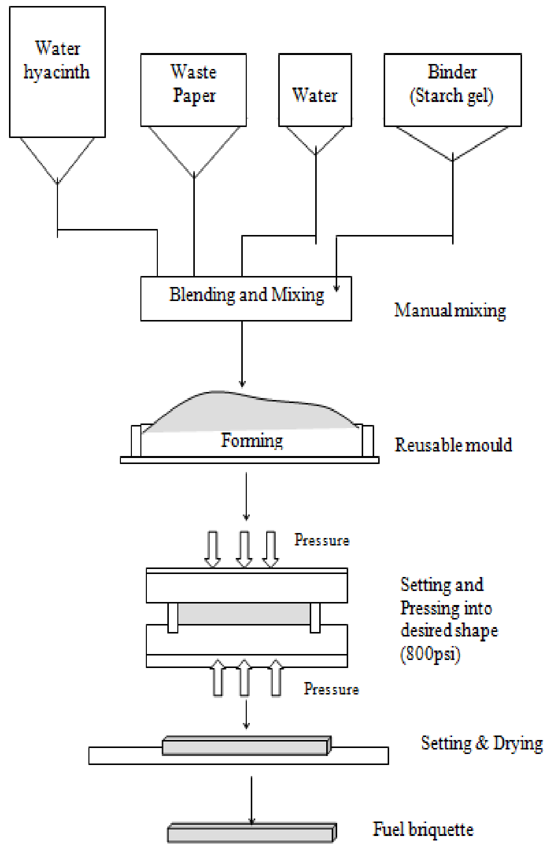

Fig. 6. The procedure of fuel briquette produced from hyacinth plant

3.2. Processing WH and WP Briquette

Proportions of the binder processed WHP and WP were weighed using the weighing balance and mixed with an adequate quantity of water and emptied into the hopper. When the loading of the mixture of WHP and WP has been completed, the machine was turned on to kickstart the briquette operation. From the mixing chamber, the WHP was conveyed to the barrel through the connector. While the WHP accumulates and settles inside the mold, it is instantaneously being heated by the heating system of the machine (die heating stove) at a temperature of 230^{0}C to 290^{0}C. A good quality WH briquette is obtained at a temperature as low as 230^{0}C. As soon as the mold was ready for compaction, it was moved directly below the hydraulic press which marks the start of the compression proper of the operation. An initial test run was conducted before having the machine totally engage into full operation which involves varying of both pressure and temperature.This test run will involve testing of whether the WHP became a briquette after going through the machine operating at maximum available pressure and temperature. If the WHP does not form into preferred shape and standard of briquettes, then amendments are to be made such as increase the amount of binding agent and vary the pressure and heating time until the desired briquettes are obtained.

Table 1. Material Composition of WP and WHP Blend (Sample 1)

S/N	Code	Water Hyacinth	Waste Paper	Water (ml)
1	W	100	100	1000
2	W	100	100	1000
3	W	100	100	1000
4	W	100	100	1000
5	W	100	100	1000
6	W	100	100	1000
7	W	100	100	1000

Table 2. Material Composition of WP and WHP Blend (Sample 2)

S/NO	Code	Water Hyacinth	Waste Paper	Starch Gel	Water (ml)
1	X	100	100	55	1000
2	X	100	100	45	1000
3	X	100	100	30	1000
4	X	100	100	25	1000
5	X	100	100	15	1000
6	X	100	100	10	1000
7	X	100	100	-	1000

Table 3. Material Composition of WP and WHP Blend (Sample 3)

S/N	Code	Water Hyacinth	Water Paper	Starch Gel	Water (ml)
1	Y	100	100	-	1000
2	Y	100	100	10	1000
3	Y	100	100	15	1000
4	Y	100	100	25	1000
5	Y	100	100	30	1000
6	Y	100	100	45	1000
7	Y	100	100	55	1000

Table 4. Material Composition of WP and WHP Blend (Sample 4)

S/N	Code	Materials (mass (g), % by weight)				
		Water Hyacinth	Waste Paper	Starch (cassava)	Starch (maize)	Water (ml)
1	Z	100	100	25	25	1000
2	Z	100	100	25	25	1000
3	Z	100	100	25	25	1000
4	Z	100	100	25	25	1000
5	Z	100	100	25	25	1000
6	Z	100	150	25	25	1000
7	Z	100	100	25	25	1000

Fig. 7 Briquette Samples

4.0. RESULT AND DISCUSSION

A test was carried out using samples of hyacinth briquettes produced to ascertain the utility of the developed briquettes. The specific fuel consumption and cooking time were investigated. The experiment was carried out with an unripe plantain. The pot containing water and unripe plantain was placed on the glowing fuel and left to cook with the sample of briquette produced. When the cooking was properly done, the mass of the cooked unripe plantain and time to achieve cooking was recorded. Also, the mass of the fuel remaining after cooking was also measured and recorded. The essence of carrying out this test was to investigate the performance of the hyacinth briquette produced. The data collected were computed and analyzed as shown in Table 5.

Table 5. Data collected during consumption of Hyacinth briquette

Parameter	Briquette
Mass of empty Pot, Mp (kg)	0.612
Mass of empty pot with cooked unripe plantain Mpc (kg)	0.862
Moisture content value of fuel assumed to be zero i.e. 100% dryness (X)	0
Mass of charcoal left Mc, (kg)	Negligible (Mc = 0)
Initial Mass of fuel before burning M_{f0}, (kg)	0.318
Final mass of fuel burnt M_{f1}, (kg)	0.218
Initial time before cooking t_0, (Min)	18
Final time after cooking t1, (min)	8

According to Danshehu (1996), the specific fuel consumption, S.F.C for a controlled cooking test was computed from the data using the equation below:

$$S.F.C = \frac{\text{Mass of Consumed Fuel}}{\text{Total mass of cooked food}}$$

$$S.F.C = \frac{(M_{fo} - M_{f1})(1-x) - 1.5mc}{M_{pc} - M_p}$$

Also according to Danshehu (1996), the time spent in cooking per kg; T for a controlled cooking Test was computed from the data using the equation below:

$$t = \frac{\text{Total time spent in cooking}}{\text{Total mass of cooked food}}$$

$$t = \frac{t_0 - t_1}{M_{pc} - M_p}$$

For briquette produced, the specific fuel consumptions are calculated thus:

$$S.F.C_{(B)} = \frac{(M_{f0} - M_{f1})(1-x) - 1.5M_c}{M_{pc} - M_p}$$

$$S.F.C_{(B)} = \frac{(0.318 - 0.218)(1-0) - 1.5(0)}{0.862 - 0.612}$$

$$S.F.C_{(B)} = \frac{(0.1)(1) - 0}{0.250}$$

$$S.F.C_{(B)} = \frac{0.1}{0.250}$$

$S.F.C_{(B)} = 0.4kg/kg$

Using briquette for cooking,

$$t_{(B)} = \frac{t_1 - t_0}{m_{pc} - m_p}$$

$$t_{(B)} = \frac{18-8}{0.862-0.612}$$

$$t_{(B)} = 40\min/kg$$

5.0. CONCLUSION

Hyacinth briquette machine was developed and tested. The performance of hyacinth briquette was studied. The mixture was poured into a hopper. The physical and combustion properties of the briquettes were determined at varying WHP and WP-binder ratios of 100:10, 100:15, 100:25, 100:30 and 100:45, 100:55 using corn starch as the binding agent. It was discovered that the binder ratio 100:25 demonstrated the most affirmative value of biomass energy than others (Table 4). It has been established in this research that hyacinth briquette, when used to cook, has a specific fuel consumption *0.4kg/kg at time 40mg/kg*. This implies that the hyacinth briquette can be used to achieve the cooking task. The hyacinth briquette produced for cooking at home is smoke-free, cost effective, available and economical. Considering the long term negative impact conventional fuels have on the environment, the use of hyacinth briquette could be one of the better options for reducing global warming effects. Establishing a small scale water hyacinth briquette firm in urban and remote areas could help create employment. It is also a better way of reducing deforestation and threat to biodiversity.

REFERENCES

Ambali, J.D. (2000). "Biology of water hyacinth." Proceedings of water hyacinth workshop for Mthunziwa Malawi. Chancellor College Zomba, 11-12 may 2000.[available online]: http://pdf.usaid.gov/pdf_docs/PNADB200.pdf.

Arinola B. A., Justina I. O. (2013) "Design of Sawdust Briquette Machine". Innovative Systems Design and Engineering. Vol.4, No.10.

Daiwey, A. S., Rotaquio, E. Jr. L., Angara, E. V. (2010). Charcoal Briquetting Technology in the Province of Aurora, Philippines. ASCOT International Journal, 3. Retrieved from http://ascot.edu.ph/research/2010/12/charcoal-briquetting-technology-in-the-province-ofaurora-philippines-2/

Danshehu, B.G.,A.T. Atiku and A.D Tambuwal, (1996). "Effect of glazing on the performance of improved wood-burning stoves" . Nigerian Journal of Renewable Energy. Vol.5, No. 1, pp. 15-18.

Martin, J.F.; J.M. Pineda,and A. Ocreto, (2008) "Design and development of charcoal briquetting machine," USM R & D, vol. 16(2), pp85-90,.

Maglaya, A.B. & Biona, J.B.M. (2010). "Combustion Properties, Performance And Net Energy Benefits Of Jatropha Bio-Coals Briquettes".

Manoj K. S., Gohil P., Nikita S. (2015) Biomass Briquette Production: A Propagation of Non-Convention Technology and Future of Pollution Free Thermal Energy Sources. American Journal of Engineering Research (AJER) . Vol. 4(2), 44-50

Oladeji, J.T. (2013). Investigation into Viability of Briquettes from different Agricultural Residues as Alternatives to Wood and Kerosene Fuels New York Science Journal; Vol.6 (8) 78-83 .

Olorunnisola A. (2007) "Production of Fuel Briquettes from Waste Paper and Coconut Husk Admixtures". Agricultural Engineering International: the CIGR Ejournal. Manuscript EE 06 006. Vol. 9.

Osarenmwinda J.O. Ihenyen O. I. (2012) "The Preliminary Design and Fabrication of a Manually Operated Briquetting Machine"; Journal of Applied Science and Environtal Management . Vol. 16 (2) 209 - 211

PACE (2011). "Water hyacinth. [available online]: www.paceproject.net:, March 2011.

Rademaker, L. (2006). "Turning pest into profit: bioenergy from water hyacinth". biopact, june 2006. [availableonline]:http://news.mongabay.com/bioener gy/2006/06/turning-pest-into-profit-bioenergy.html

Rajkumar D. and Venkatachalam P. (2013) "Physical properties of agro residual briquettes produced from Cotton, Soybean and Pigeon pea stalks. International Journal on Power Engineering and Energy (IJPEE) Vol. (4) 414-417