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Development of a Light Weight Briquetting Machine for Small and Medium Scale Enterprise

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Abstract

One of the greatest challenges being faced in Nigeria is the issue of waste generation, utilization and control. With the constant fluctuation in the prices of charcoal and petroleum products in Nigeria, the need to utilize other sources of fuel majorly in the rural and urban area became necessary. Unfortunately, because of ignorance, a good number of rural and urban dwellers dispose waste carelessly. This has contributed to air, land and water pollution. The purpose of this study is to convert generated waste materials into wealth by developing a simple, movable, light weighted briquetting machine for production of solid bio-briquettes. The biomass waste materials used in this research are: water hyacinth plant (WHP) and saw dust (SD). The saw dust are readily available at sawmills while the hyacinth plants are found growing on the surface of water. Quality samples of fuel briquettes were produced from a blend of water hyacinth plant and sawdust, using cassava starch as binder in the ratio 100:0, 70:30, 60:40, 50:50, 40:60, 30:70, 0:100. The briquettes were made and oven dried using a locally made oven at a temperature of about 105°c. The moisture content of each produced briquette samples were calculated and recorded. The developed traditional briquetting machine has been designed to eliminate the deficiencies of the adapted machine in terms of cost effectiveness, ease of operation, portability and flexibility of assemblage. Conclusively, the briquettes produced from the traditional briquetting machine are capable of producing cheap briquettes in large quantities to support cooking in rural and urban province. It is a good source of income to local farmers and rural dwellers and would greatly provide employment opportunities for youths and raise the standard of living of poor masses. Initial start-up is at low or no cost since it is a blend of SD and recycled WHP cleared from sea. The solid briquettes produced are useful for cooking in homes, hotels and industrial settings.

Keywords: Bio-briquettes, Seaweed, SD, WHP.

1.0 Background of the study

Agro waste is the most promising energy resource for a developing country like Nigeria. The decreasing availability of fuel woods has brought about the need to make maximum utilization of agricultural wastes. These waste have acquired considerable importance as fuels for many purposes, such as domestic cooking and industrial heating. Some agricultural wastes materials can be used directly as fuels for example coconut shell, wood pulp and wood waste. Research has shown that agricultural residues and other decomposable waste can be converted into a cleaner, affordable solid, liquid or gaseous fuel source which can serve as a substitute to fuel wood. Millions of tons of agricultural wastes are generated in Nigeria on a daily basis. For instance: Papers used in offices are disposed carelessly on a daily basis after work; grasses cleared in homes, offices and factories are gathered and burnt; water hyacinth plants cleared from the surface of the sea are constantly discharged by the sea side. It is unfortunate that local farmers still practice "clear-and-burn" agriculture. The agricultural wastes they gather together during or after clearing of land are usually burnt off. By this practice, the waste materials are rendered useless causing environmental pollution, this goes a long way to also affect soil fertility. In line with this point of view Patomsok (2008) suggested that biomass in the form of agricultural superfluous and other form of bio-degradable wastes noted as promising energy resources in developing and developed nation should be converted into wealth rather than burning them. The benefits of these waste agricultural materials cannot be overemphasized.

Environmentally, the use of biomass briquettes produces much fewer greenhouse gases, specifically, 13.8% to 41.7% CO2 and NOX. The use of bio-briquettes have increased recently with reduction in falling down of trees, Honaker (2010) and Onuegbu (2010) reported that large portion of rural settlement and a small part of urban dwellers depend on fuel wood (charcoal, firewood and sawdust) as their major energy sources for past decades. However, amongst the available energy resources in Nigeria, coal and coal derivatives such as smokeless coal briquettes, bio-coal briquettes, and biomass briquettes have been shown to have the highest potential for use as suitable alternative to coal/fuel wood in industrial systems for thermal application and domestic purposes. Global warming caused by greenhouse gasses of which carbon dioxide is one of the major contributor has become a major concern in the world at large. Research has shown that increased emissions of CO_2 is as a result of deforestation. The trees cut down on a daily basis is higher than the trees planted (Onuegbu, 2010).

Nigeria is blessed with abundant agricultural and wood residues which can efficiently be used for resolving energy problems to a significant extent by adopting proper measures. The Niger Delta region of Nigeria is also surrounded by rivers and ocean. The sea weed popularly known as Water Hyacinth (WH) Plant is a threat to biodiversity. They prevent free movement of vessels on high sea. Oil and Gas companies

spend huge sum clearing these weed from the sea. Research has shown that these waste materials are good source of fuel (briquettes). Apart from water hyacinth plant, other forms of waste found in abundance which can serve as solid fuel include: melon shell, rice husk, palm kernel shell, coconut shell, orange peels and so on. Olorunnisola (2007) is of the opinion that, considering all the various types of biomass processing technologies, there are currently potentially viable local markets for biomass which requires low capital investment for initial startup. Also, Russell (1997) stated that briquetting is often seen as a relatively high-cost high-pressure technology, and that it is possible to use a low-cost low-pressure technique to produce acceptable briquettes. There is therefore no doubt that briquette will perfectly serve as an alternative fuel to replace firewood can also improve the living conditions of urban and rural dwellers who spend most of their time collecting firewood instead of engaging in other income generating activities or attending school.

This research is aimed at the design and construction of a classical moveable briquetting machine for production of briquettes using different waste materials.

2.0 Review of Literature

2.1 Briquetting Technology

Bapat et al. (1997) is of the opinion that apart from coal and crude oil, biomass remains the third prevalent energy resource in the world. In terms of energy consumption, biomass dominated global energy consumption until the mid-19th century. Also, Purohit et al. (2006) and Shriamm (2010) conducted research further on energy and biomass. In their research, they noted that biomass still provides above one billion tons of energy representing roughly 14 to 15% of worlds energy consumption thereby competing with oil notwithstanding the fact that constant use of fossil fuel has led to decrease in consumption of energy for years now. Likewise, Duku (2011), Li and Hu (2003) in a brief and well-meaning research came to a conclusion that biomass is becoming more and more significant and also gaining global relevance as a reliable and clean energy resource gradually replacing fossil fuel.

So far, the least expensive and simplest form of energy is the energy obtained from waste materials especially waste materials from agricultural products. It is unfortunate that the supply of these waste materials is limited. To overcome this constraint, there is a global research on development of technologies for efficient and effective use of biomass for energy purpose. In the United States of America and most of Europe, biomass has already penetrated the energy market. Hall et al. (1992) confirmed that in the United State of America and most of Europe, biomass has already penetrated the market with 4% to 13% of their energy from biomass. Also, Sweden and Germany are coming up with to plans to increase the use of biomass energy, reduce the use of fossil fuel and end the use of nuclear plants (Björheden, 2006).

In African countries, production of heat and light source using fuel wood is prevalent especially in rural areas of Nigeria. The advantages of biomass as a source of fuel cannot be overemphasized. The most significant advantage of biomass is that of sustainability and renewability of the energy feedstock. A good example is the sea weed or hyacinth plant which can be used to produce briquettes for heating in homes. The char effluence materials after heating can be used to wash or remove stains from pots. They are also good source of fertilizers (Okwu and Emovon, 2018**).** Moreover, it has the capacity to reduce carbon emissions unlike fossil fuels, meaning that sustainable and renewable fuel is regarded as a clean progressive mechanism for plummeting greenhouse gas emissions (Li and Hu, 2003).

During production of briquettes from waste materials, it is important to note the type of materials, the pressure applied and the binder used, different binding methods are used to achieve the expected compact. Physical properties of biomass like: thermal, moisture content and bulk density are very significant in the process of binding the biomass materials into solid fuel briquettes. Compacting biomass under high pressure results to formation of solid briquettes as a result of mechanical interlocking of mixtures, usually mixture of waste materials and binder. A good binder require high level of viscous bonding material such as tar. Other molecular weight organic liquid can form good bonds. Binding require good adhesive forces at the solid or liquid boundary and cohesion forces at the interface. Binding of biomass material can also be supported using lignin process under high temperature and pressure. They also support the formation of bonds between the individual particles. It is very necessary to be consistent in briquette technology to enable production of finely bonded briquettes. Inconsistency can lead to production of weak briquettes with scratches and cracks which is not suitable. It is important to note that briquettes with higher density have a longer burning time.

2.1.1 Types of Briquettes

Different kind of materials are availale for briquette production. Some good examples are: Corn cob, coffee husk, jute stick, cotton shell, sawdust (mixed), tannin waste, pine needle, almond shell, soya bean stalk, areca nut shell, bagasse, castor stick, water hyacinth plant coffee spent, groundnut shell, coconut shell, coir pith, sunflower stalk, bagasse pith, jowar straw, bean straw, olive pits, barley straw, arhar stalk, paddy straw, grass, tobacco dust, plantain leaves, jute dust, tea waste, rice husk, tamarind husk and so on. The most popular ones are:

Sawdust Briquettes- These are high quality briquettes commonly found in sawmills or lumber companies. These briquettes are the most common for heating in rural and urban settings. If properly carbonized, the briquettes formed from sawdust burn without smoke. The briquettes produced from sawdust are used to provide heat to industrial boilers which in turn produces electricity from steam. They are also used

for cooking in guest in, hotels, factories and home environment.

Agro Waste Briquettes- These briquettes are made from agricultural waste materials. They are ecofriendly since they are made from renewable source of energy and do not emit gases that contain sulfur content which can pollute the environment. When compared with loose biomass they have higher density. They are easy to light, simple, cheap, durable and portable.

Wood Briquettes- One of the characteristics of these briquettes is that it has good burning efficiency. It can be as substitute in place of coal and fire wood it is a very important source of energy. These briquettes when carbonized are smoke free with excellent burning efficiency.

Paper Briquettes- Paper briquettes are made of recycled shredded paper material which is compressed into a small cylindrical form. Since paper briquettes reduces the amount of paper waste, it is said to be ecofriendly.

Peat Briquettes- Peat briquettes are made from raw peat, a type of decayed organic matter found in bogs and mires. Since peat are found in large quantities in Ireland, thus peat briquettes are commonly used in this country. These briquettes burn slowly, smokeless and can be easily stored and transported.

2.2 Review of Previous Research Work on Briquette making and Raw Materials

The study conducted by Kishan et al. (2016) focused on the design and fabrication of low cost portable briquetting machine and the production of biomass briquettes using raw materials mainly sawdust and dry leaves with binding agents like coffee husk and wheat flour. This was projected based on their affirmation that the excess use of fossil fuels which appears to be the major source for energy generation would lead to serious environmental issues like global warming and air pollution. With the frequent use of fossil fuels making its early depletion visible and the need for the global market to start making use of biomass wastes such as sawdust, coir pitch, coffee husk, rice husk etc., to useful biomass briquettes which will be the substitute for some of the fossil fuels.

Also, Akinbami (2001) found that the use of wood account for about 51% of the total annual energy consumption in Nigeria and traditionally, wood in form of fuel wood, twigs and charcoal has been the major source of renewable energy in Nigeria. The other sources of energy include natural gas (5.2%), hydroelectricity (3.1%), and petroleum products (41.3%). Okwu and Emovon (2018) researched on characteristics of bio-briquette produced from blend of water hyacinth and clay soil using waste oil as a binder. Olawale et al. (2014) investigated the effect of starch and gum arabic as binders in the combustion characteristics of briquette prepared from sawdust of different ratios. Briquettes of sawdust were produced by mixing with different binders and agglomerate using starch paste and gum arabic. They reported that when the calorific value, the volatile

matter and flame temperature were determined the results showed that the briquette formed using starch as a binder performed better in all aspect than the gum Arabic when the mixture was compressed at 110kN using manually operated hydraulic briquette machine and sun dried. Study conducted by Adegoke (2001) showed that mixture of sawdust and biomass materials when compressed using a specially developed briquetting machine and the briquettes dried either directly in the sun or in an oven. When burned in internally lined stoves, the heat loss to the environment is much reduced and a lot of cooking energy is obtained from a relatively small amount of the sawdust briquettes. The result of this study conducted in the Mechanical Engineering Department of the Federal University of Technology, Akure, have further shown that sawdust mixed with certain biomass materials of appropriate grain sizes and in certain proportions have improved calorific values. Olorunnisola (2007) found that when briquettes were manufactured using a manually-operated closed – end die piston press at an average pressure of 1.2 x 10 3 N/m2 using four coconut husk: waste paper mixing ratios (by weight), i.e., 0:100; 5: 95; 15: 85; and 25: 75. Briquettes produced using 100% waste paper and 5:95 waste paper-coconut husk ratios 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. The mean durability rating of all the briquettes exceeded 95%. It was concluded that stable briquettes could be formed from waste paper mixed with coconut husk particles.

Amanor (2014) designed and constructed an appropriate, cost effective biomass briquetting machine suitable for use in rural communities that are easy to operate manually and this was tested using jatropha curcas husk at different particle sizes. Xie (2012) in investigating the use of the harvested weed as a source of energy in the form of briquettes stated that water hyacinth (Eichhornia crassipes), known to be native to South America, has now become an environmental and social challenge throughout most water sources in Zimbabwe. Okwu et al. (2016) developed a hyacinth briquetting machine. The machine developed uses a hopper solution technique and quite difficult for a layman to operate. This necessitated the need for production of a light weight, easy to use machine.

3.0 Materials and Method

3.1 Briquetting Machine Design and Fabrication

The selection of a suitable material for engineering purposes is one of the most difficult problems engineers often encounter. The best material is one which serves the desired objective at an affordable rate. The following factors are considered in the selection of materials for the design of the light weighed briquetting machine: Availability of the material, ease of fabrication, serviceability and cost of the material.

The Parts that makes up the full classical briquetting machines produced are: main frame, compaction chamber, base plate, piston and compression plate.

3.1.1 The Main Frame: The main frame was made from mild steel, angular iron bars and sprocket. **:** The main frame houses and support the other parts of the machine

Figure1. Frame of the briquetting machine

3.1.2 Compression Chamber: Compression Chamber was manufactured from a cylindrical pipe 8cm internal diameter, 9cm external diameter and a height of 30cm. the compression of the briquettes takes place in this chamber.

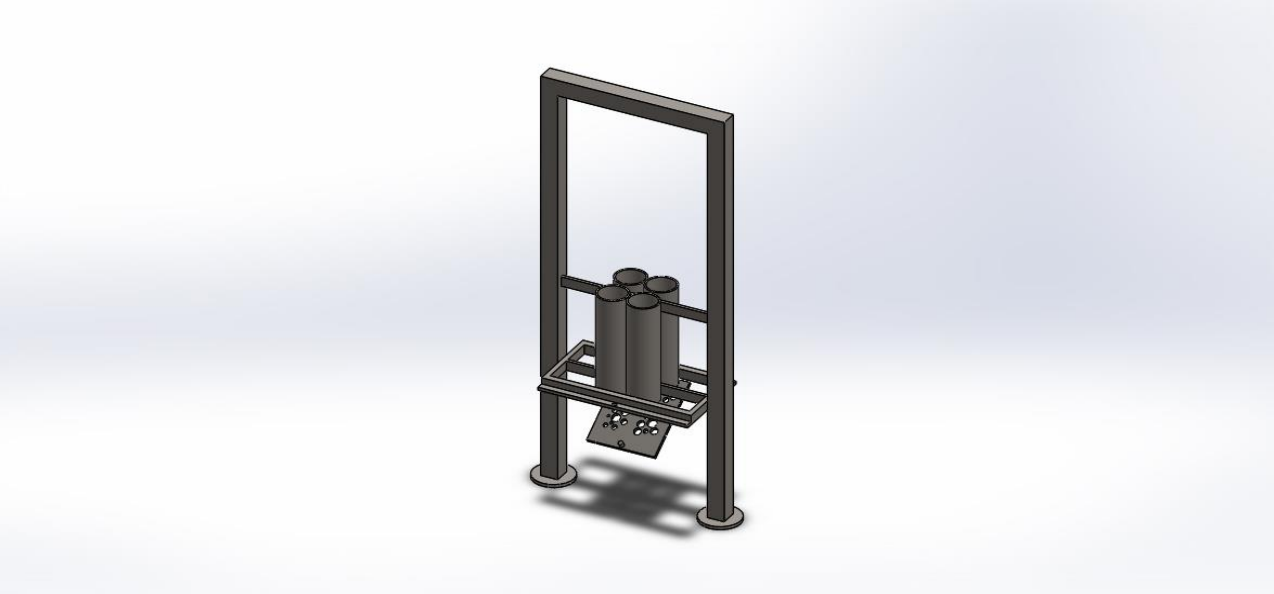

Figure 2. Compression chamber and base plate of the briquetting machine

3.1.3 Base Plate: The Base plate of the machine is made from mild steel and is housed within the frame of the machine just beneath the compaction chamber. It is machined with holes so that water and starch (binder) can be removed from the briquettes during compression.

3.1.4 Piston: Four pressure transmitting mild steel rods are welded to the compression plate of the machine. The piston is 30cm high. The four pressure transmitting mild steel rods are welded to a flat plate at the top. The flat plate hydraulic jack during compression and ejection of the briquettes.

Figure 3. Piston and compression plate of the briquetting machine.

3.1.5 The Compression Plate: The Compression plate is a 3mm thick mild steel was machined into a circular shape of diameter 7.8cm for easy passage into the circular chamber during briquette compaction. The four compression plate are welded to each piston rod. It is the compression plate that compresses the briquettes against the base plate so that a solid cylindrical shaped briquettes can be attain.

3.1.6 Maintenance: The maintenance of this simple briquetting machine includes regular cleaning after use, tightening of nuts and bolts and replacement of worn out parts.

3.1.7 Testing: The design uses hydraulic jack for the compression and also to eject the compacted briquettes. Thus it makes ejection process slower and fragile in order not to damage the compressed lump. The time taken for production of a briquette is 5 minutes.

3.6 Exploded View of the Briquetting Machine

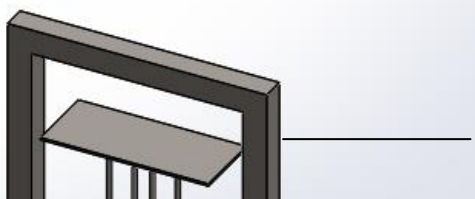

Figure 4. Exploded view of the briquetting machine: (1). Frame (2). Piston (3).Compression Plate (4). Compression Chamber (5). Base plate (6).Sprocket

3.2 Materials and Equipment

Sawdust (SD), water hyacinth plant (WHP) and starch were obtained from Osubi sawmill, Ogbijor river and Ugbomro market, Uvwie Local Government Area, Delta state, Nigeria. Oven for drying water hyacinth plant, electronic weighing balance was used to measure the weight of the produced briquettes before and after drying.

3.2.1 Development of Briquette

The briquetting process involves sourcing for the water hyacinth plants and sawdust. The water hyacinth plant is dried with an oven and grinded. The raw materials were binded with starch in ratio of hyacinth to sawdust in proportions of 100:0, 0:100, 70:30, 30:70, 60:40, 40:60, and 50:50. A piston-press briquetting machine was used to conduct production of fuel briquettes.

3.2.2 Physical Property of Briquette

The physical properties determined from the produced briquettes was moisture content of each samples of briquettes produced.

Determination of Moisture Content:

The briquettes samples were weighed immediately after production and oven drying process. Both initial weight and final weight of the briquette samples were recorded.

The moisture content and other properties are calculated using the equation:

$$Moisture\ content, MC(\%) = \frac{initial\ weight - final\ weight}{initial\ weight} \times 100 \quad (1)$$

$$Ash\ content, AC(\%) = \frac{oven\ dry\ weight\ after\ heating}{initial\ weight} \times 100 \quad 2$$

$$\mathrm{VM}(\%) = \frac{\text{final weight} - \text{oven dry weight after heating}}{\text{final weight}} \times 100 \quad 3$$

$$\text{Fixed Carbon Content FC } (\%) = 100 - (\%\mathrm{MC} + \mathrm{VM} + \mathrm{AC}) \quad 4$$

3.3 Preparation of Fuel Briquettes

The designed manual piston press briquetting machine was employed to develop the briquette. The process of production of briquettes from waste material is itemized:

3.3.1 Material Preparation:

Two sacks of water hyacinth plant (WHP) were collected from Ogbijor River and a sack of sawdust was obtained from Osubi saw mill. Water hyacinth plant (WHP) and sawdust served as the materials for briquetting. The water hyacinth plants were oven dried and grinded into particles while the saw dust was collected dry. Cassava starch is the recommended binder because it is available in local markets. The cassava starch was obtained from Ugbomro market

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Mixing:

This is the process of mixing the water hyacinth plant and saw dust at given proportions with a film of binder (starch). It enhances adhesion and produces uniform good quality briquettes. Proper proportions of water hyacinth plant, saw dust and starch were poured into the mixing container. The ground materials and the binder were manually mixed thoroughly. Little quantity of water was added to the mixture to aid mixing.

Briquetting:

The mixture was converted into finished products using the newly designed machine. Briquetting machine is a simple energy and money saving device made out of locally — available materials used for converting biomass into briquettes. This was done by pouring the mixture directly into the cylindrical compression chamber which produced it into uniformed shape and sized briquettes. The briquettes were produced at the compression chamber with the aid of a hydraulic jack. The produced briquettes were oven dried in the laboratory at 105 degree Celsius for 2 hours.

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4.0 Physical Properties of Developed Bio-briquettes

Figure 5 represent the physical properties of bio-briquettes produced from blend of water hyacinth plant (WHP) and saw dust (SD). The two materials were blended together at different ratio or proportion and starch binder was used for effective bonding. Briquettes were produced using the developed machine and the initial and final weights (Wi and Wf) of different sample briquettes were recorded and moisture content for all the samples were calculated.

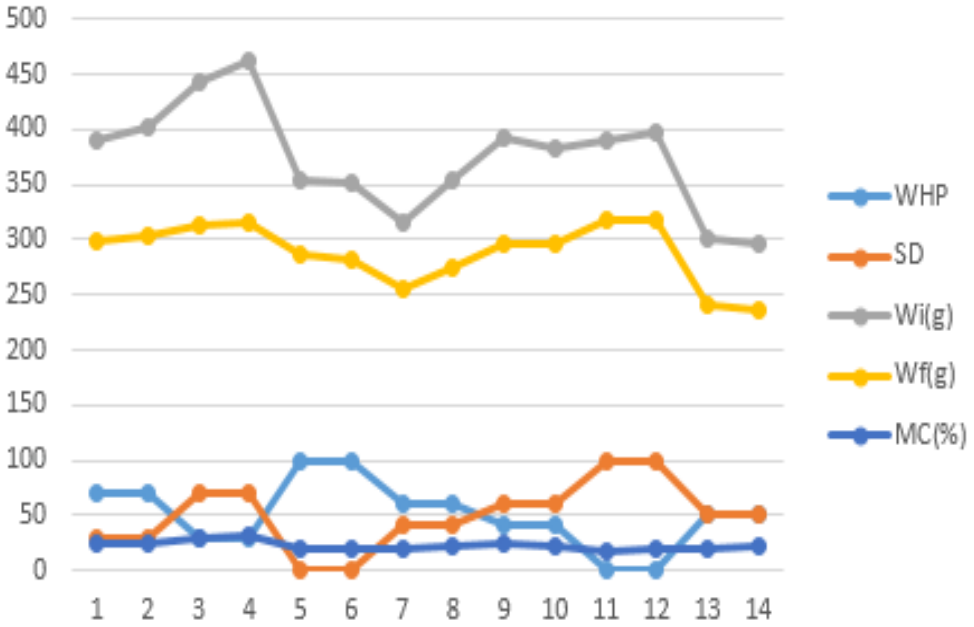

Figure 5: Physical properties of briquettes (moisture content)

4.1 Bill of Engineering Measurement and Evaluation (BEME)

Table 3: The BEME table for the manual briquette machine

S/N	PART	QUANTITY	UNIT (Naira)	PRICE	TOTAL PRICE (Naira)
1	2 Inch Square Pipe	2	3,500		7,000

2	Cylindrical pipe(full length)	1	8,000	8,000
3	12mm lifting bar	2	3,500	7,000
4	Angle bar	1	2,500	2,500
5	3 inch mild steel plate	1	3,000	3,000
6	5mm mild steel plate	1	7,000	7,000
7	Sprocket	2	2,000	4,000
8	Electrode	2 packets	1,500	3,000
9	Total			40,000

Conclusion

A simple, portable and easily maintained briquetting machine has been found to be successfully developed in Mechanical Engineering Workshop at the Federal University of Petroleum Resources Effurun. The developed briquetting machine is capable of producing briquettes from any form of biomass waste. The research focus is centered on the production of briquettes from a blend of two waste materials (water hyacinth and sawdust). The time taken to mix the raw materials with the right quantity of binder was five (5) minutes; it took another five minutes for effective compression process of the blended waste material into useful briquettes. Summarily, the total time recorded to produce twenty samples of briquettes after mixing was twenty five minutes. The light weight traditional briquetting machine has been designed to eliminate the deficiencies of the adapted machine in terms of cost effectiveness, ease of operation, portability and flexibility of assemblage. In conclusion, the briquettes produced from the traditional briquetting machine would serve as a good source of income to local farmers and rural dwellers. It would totally prevents black soot and also prevent massive use of fuel wood and deforestation. Bio-briquettes are relatively cheaper than any other source of energy since they are produced from waste. It would greatly replace the use of cooking gas and kerosene stove which are quite expensive. It is also a good source of income would greatly reduce unemployment rate in Nigeria.

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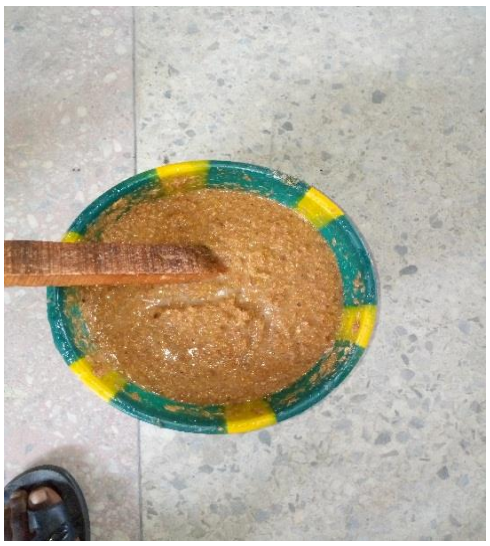
APPENDIX

1: Water hyacinth plant

2: Dried and grinded

3: Saw dust sample 1

4: Sawdust sample 2



5: Mixture of materials

6: Mixture set for compacting

7: Briquetting process

8: Samples of briquettes produced