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Production and Evaluation of Biomass Briquettes from Rice Husk using Different Binders

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Abstract: *The objective of this study was to provide an alternative energy source from biomass that could ordinarily be environmental hazard through direct combustion as well as evaluate the quality of the produced energy. Briquettes was produced from rice husk using locust bean powder, paper and cassava starch as biding agents. Mechanical and physical properties of the briquettes were tested to determine their qualities in terms of compressive strength, burning rate, shattering index, compressed density, relax density, and relaxation ratio. Results obtained shows that the compressive strength of the briquettes using locust bean, paper and cassava starch as binding agents were 9.475 Mpa, 7.585 Mpa and 6.715 Mpa, respectively; indicating that briquettes produced with locust bean binder having more compressive strength than the other binding agents. The results also indicate that briquettes produced with locust bean powder binding agent has the least burning rate of 2.2 kg/min while briquettes produced with paper as binding agent has the highest burning rate of 2.8kg/min signifying those briquettes produced with locust bean powder as binding agent has the slowest burning rate when compared to other briquettes (cassava starch binder has 2.4kg/min). It was observed that briquettes with locust bean powder have an average of 1.1433%wt having the lowest shattering index therefore produce stronger briquette than the other biding materials used. This was followed by briquettes with plain paper as biding agent (1.299%wt) and cassava starch binding agent (1.4047%wt). The study established that rice husk could be used for briquette production for sustainable energy generation in that it is environmentally friendly, cost effective and affordable compared to fossil fuel.*

Keywords: *Concrete, Glascrete, Density, Compressive strength, Workability, Water-cement ratio*

INTRODUCTION

Nigeria as the most populous country in the African continent produces a large quantity of agricultural waste every day. Waste generation rate in Nigeria is estimated at 0.65-0.95 kg/capita/day which gives an average of 42 million tons of wastes generated annually (MacMillan *et al.* 2017) This is more than half of 62 million tons of waste generated in sub-Sahara Africa (Ike and Chinedu, 2018). In addition, the continuous increase in global human population has brought about enormous increase in waste generation. A study shows that in 2016, the worlds' cities generated 2.01 billion tons of solid waste. With the rapid population growth and urbanization, annual waste generation is expected to increase by 70% from 2016 levels to 3.40 billion tons in 2050 (The Word Bank, 2019). These wastes are either dumped off to litter the street or burned inefficiently, causing extensive pollution to the environment.

However, if such wastes are processed and put to more productive purpose, there is the tendency of producing low thermal efficiency and less pollution to the environment. To overcome these problems, the concept of "Biomass Briquettes" is adopted. Biomass briquettes are made from agricultural waste and are a replacement for fossil fuels such as oil or coal. Briquetting of residues takes place with the application of pressure, heat and binding agents on the loose materials to produce the briquettes. The briquettes can be used for domestic purposes (cooking, heating, barbequing) and industrial purposes (agro industries, food processing) in both rural and urban areas (Abedeen, 2012).

The advancement in technology has made life better, secure, safe and efficient. However, this advancement comes with a huge price to be paid. Almost all industry in one way or another is dependent in the oil to provide a source of power. The oil industry holds a major potential of hazards for the environment, and may impact it at different levels: air, water, soil, and consequently all living beings on our planet. There is, therefore, the need to device an alternative source of energy that will replace firewood and oil. This alternative source should be economical and affordable and easily made with simple tools by the rural dwellers. Faced with the challenges of poverty, unemployment and access to cooking fuel, many poor households will find briquette as a goldmine, because the prevalent source of energy for household consumption in Nigeria i.e., petrol, gas, kerosene are not affordable for an average household. One of the ways of obtaining biofuel is by biomass briquetting. Biomass is a very abundant, renewable raw material that is environmentally friendly. Also, due to the level of consumption and rice growing areas, rice husk has become one the most disturbing agro waste material, Brand (2017). In many areas, the common method of disposing rice husk is by burning and after that there is a disposal problem because of great amount of silica present in the rice husk. Rice husk contains an approximately of 20-25% Silica which is present in hydrated amorphous form and causes multiple disease including silicosis, incurable lung diseases, chronic obstructive pulmonary disease (CDOP) etc. (Tandukar and Heijndermans, 2014). This hydrated silica can be retrieved as amorphous silica under controlled thermal conditions by converting them into briquettes mixed with other materials. Uncontrolled burning of rice husk releases a large quantity of carbon dioxide (CO_2). Solid wastes are detrimental to the environment if they are not properly managed (Alves and Gonçalves,2010). There is, thus, the need for proper management of the waste into ways that are not only free from harm, but of benefits to the environment, hence, the focus of this study.

MATERIALS AND METHODS

Materials that would be used for this study include: locust bean powder, rice husk, water, plain paper, mortar and pestle, sieve ASTM (0.5mm diameter), hydraulic press briquetting machine, pair of scissors, cassava starch, 500 ml water jar, 1000 ml measuring cylinder, stopwatch, 100 kg capacity weighing balance (WT1000KF, 0.001 Accuracy), universal materials testing machine (CAT.NR.261 model), desiccator (NOVUS NS24/29) and oven (Heraeus/Hanau). The briquetting machine used for the study is capable of producing four (4) units of briquettes of 8.5cm diameter each at a time.

Collection and Preparation of Materials

Rice husk was obtained from 'Yan Goro market, Sabon-Gari Local Government Area, Zaria – Kaduna State, while the locust bean powder and cassava starch, where obtained from Samaru market, also in Sabon-Gari Local Government. Locust bean powder and cassava starch obtained were ovum dried at 60°C for 12 h to a constant weight and their respective moisture contents were determined. The size of the materials (locust bean powder, rice husk and cassava starch) was reduced with the use of mortar and sieved with a 0.5 mm diameter to get fine particles.

Waste paper collected within the university environment was cut into pieces and soaked in water for 5 days shown in Fig. 1.

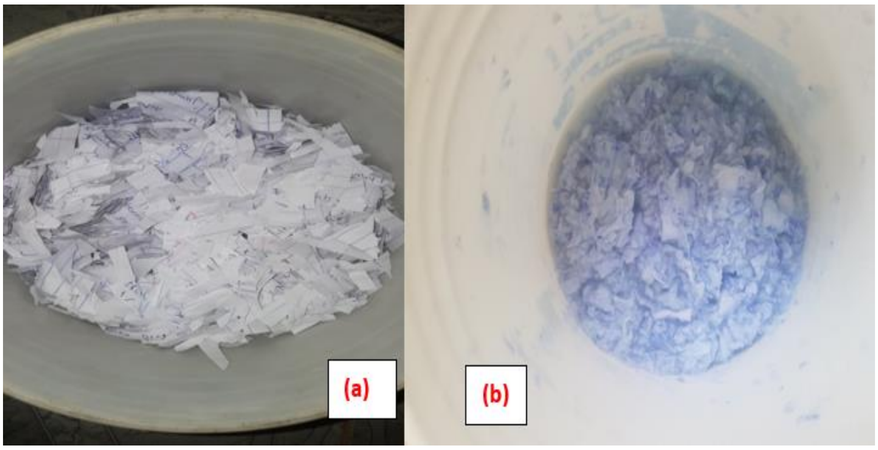

Fig. 1 (a) Shredded paper (b) Soaked paper

Experimental Procedures

The rice husk was divided into 4 portions/samples of 295 g into three groups (i.e., 295 × 4 × 3). Binding materials (shredded paper, locust bean powder and the cassava starch) at a ratio of 40% by weight of each material would be mixed with a portion of the rice husk to form a homogeneous mix. This study was conducted in the Processing Laboratory of the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University (A.B.U) Zaria.

Using Plain Paper as Binding Material

Three samples of 295 g of rice husk were each mixed with 40% (118 g) of soaked paper and mix thoroughly to achieve homogeneous mix. This was kept for three hours (3hrs) for the soaked paper and rice husk to have a strong bond before being transferred into the briquetting machine. The mixture was then compressed to form the briquettes using a hydraulic press briquetting machine. The produced briquette was later removed and allowed to dry.

Using Cassava Starch as Binding Material

Cassava starch was sieved into the finest particle using 0.5mm sieve, a small quantity of water was added to form a paste. Later boiled (100°C) water was poured to make in liquid form at the same time stirring it gently till it cools down to room temperature. At this stage, it becomes viscous and sticky. Samples of rice husk were then added to the starch and mixed thoroughly until homogeneous mixture was obtained. The mixture was then compressed to form the briquettes using a hydraulic press briquetting machine. The produced briquette was later removed and allowed to dry.

Using Locust Bean as Binding Material

Locust bean powder was sieved by a 0.5mm diameter sieve. Small quantity of water is added while stirring it gently and thoroughly to prevent it from coagulating. Samples of rice husk were then added and mixed thoroughly until homogeneous mixture was obtained. The mixture was then compressed to form the briquettes using a hydraulic press briquetting machine. The produced briquette was later removed and allowed to dry.

Procedure for Determination of Mechanical Properties of the Produced Briquettes

Mechanical properties determined include: compressive strength, and burning rate.

Compressive Test

The ability of the briquette to withstand loads tending to compression (compressive strength) was determined using the Universal Materials Testing Machine (CAT.NR.261) in the Department of Mechanical Engineering of the University. Two samples each of briquettes produced from the three binding materials were test for the compressive strength. The testing machine has the capacity of releasing a load of 100KN on the sample. This load was gradually released on the briquettes until failure stage was reached.

Burning Rate Test

The burning rate test was carried out on the produced briquettes to determine the rate at which a mass of the briquette is combusted in air. The weights of the briquettes were measured before combustion (W_i) and then ignited with fire to allow it to burn. The time taken to combust was noted with a stopwatch to determine the time it take for a specific briquette to burn completely. The final weight after combustion (W_f) was also noted. The burning rate of the briquette was calculated using equation (1) as suggested by Islam (2013):

$$B_r = \frac{Wi - Wf}{T} \quad (1)$$

Where B_r= Burning rate (g/min)
W_i = Initial weight briquette before combustion
W_f = Final weight of briquette after combustion
T= Total burning time

Procedure for Determination of Physical Properties of the Produced Briquettes

Physical properties of the produced briquettes determined include: shape, volume diameter height, moisture content, shattering index, compressed density, relax density, and relaxation ratio.

Moisture Content

Moisture content of milled biomass samples is determined using the oven-drying method in compliance with the procedure described in ASAE (2003) and Baumler *et al*. (2006):

$$Mc_{(wb)} = \frac{Wi - Wf}{Wi} x100 \quad (2)$$

where,
Mc= Moisture content
W_i= Mass of wet sample (kg)
M_f= Mass of dried sample (kg)

Shattering Index

Shattering index (or durability index) indicates the durability of briquettes during storage, handling and transportation. Briquettes shattering index was measured according to (ASTM 2001).

$$S_i = \frac{W_i}{W_f} \tag{3}$$

Where;

S_i = Shattering index

Compressed Density

The compressed density of the briquettes was determined immediately after ejection from the machine. It is the ratio of measured mass over calculated volume. The volume of briquette was determined using the fundamental formula of cylinder while subtracting off the volume of the hole within the briquette (Kataki and Pant, 2015).

$$\rho_{mc} = \frac{Me}{Ve} \tag{4}$$

$$V_e = \frac{\pi}{4} H\,(D^2 - d^2) \tag{5}$$

where,

ρ_{mc}= compressed density (kg/m^3)

M_e = mass of wet sample (kg)

H= height of sample (m)

V_e = volume of wet briquette sample (m^3)

D = Outer diameter of the sample (m)

d= inner diameter of the sample (m)

Relax Density

Relaxed density of a dried briquette sample was determined by measuring the mass of a dried sample (ASAE, 1998). Weight was measured using electric weighing balance after 15 days of production of the briquette while the volume was calculated using cylinder basic dimension. Relax density of a randomly selected samples were given as:

$$\rho_r = \frac{Md}{Vd} \tag{6}$$

where,

ρ_r=relaxed density(kg/m^3)

M_d= mass of dried sample (kg)

Relaxation ratio - Relaxation ratio describes the stability of the briquettes after ejection from the mould, which is the ratio of compressed density to relaxed density of briquettes, Vukelic and Krizan (2009).

$$R_r = \frac{\rho mc}{\rho r} \tag{7}$$

where,

R_r = Relaxation ratio

RESULT AND DISCUSSION

Briquettes were produced using rice husk as the main materials whiles shredded paper, locust bean powder and the cassava starch were used as binding agents (Fig. 2).

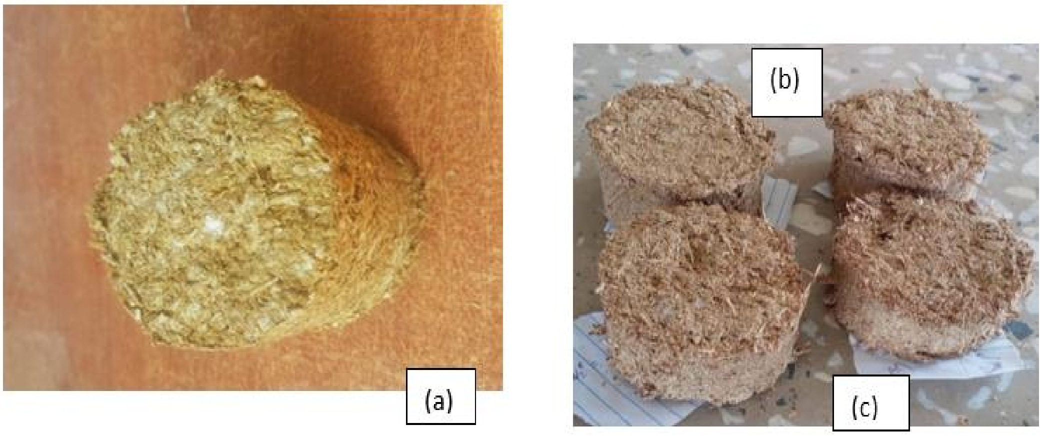

Fig. 2 Briquette Produced using (a) Paper (b) Cassava starch and (c) Locust bean binders

The mechanical properties of the produced briquettes were also determined. These properties were the compressive strength and the thermal properties. The results of the study (Fig. 3) shows that the compressive strength of rice husk using locust bean, paper and cassava starch as binding agents were determined as 9.475 Mpa, 7.585 Mpa and 6.715 Mpa, respectively. It could be deduced from the results that briquettes produced with locust bean as binding agent has more the compressive strength than those produced using plain paper and cassava starch as binding agents. It is, therefore, capable of withstanding more compressive load before reaching its rapture stage when compared with the briquettes produced using cassava starch and paper as binding agents.

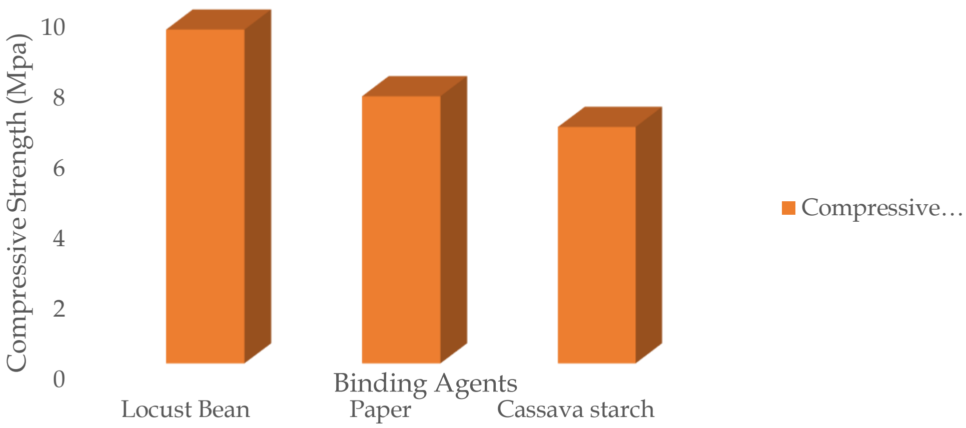

Fig. 3 Compressive Strength of the Produced Briquettes

The Fig. 4 shows the burning rate of the produced briquettes. The results indicated that briquettes produced with locust bean powder as binding agent has the least burning rate of 2.2 kg/min while briquettes produced with plain paper as binding agent has the highest burning rate of 2.8kg/min.

The implication of this results was that briquettes produced with locust bean powder as binding agent has the slowest burning rate when compared to other briquettes, and thus more economical to use since it takes longer periods to be completely burnt. The burning rate in locust bean briquette is the slowest could be attributed to its higher compressive strength earlier determined (9.475 Mpa). This was due to the higher compaction rate resulting from its ability to bond well with the rice husk living very little pore space. Its higher relaxation ratio was also noted to be an added advantage.

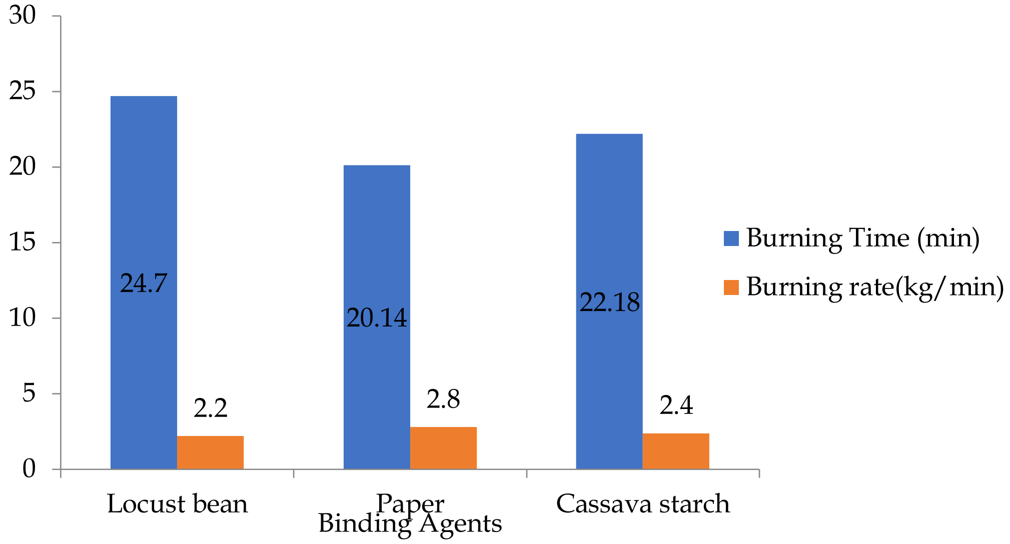

Fig. 4 Burning rate

The physical properties which include; shape, volume diameter height, shattering index, compressed density, relax density, relaxation ratio and moisture content were also determined. The Fig. 5 shows the shattering index of the produced briquettes using rice husk and the tree biding agents. Random samples of the briquettes were selected and dropped 3 times from a height of 2 meters onto a concrete floor. It was observed that briquettes with locust bean powder as biding agent has an average of 1.1433%wt. This was followed by briquettes with plain paper as biding agent (1.299%wt) and cassava starch binding agent (1.4047%wt). These figures shows that locust bean as biding agent has the lowest shattering index than plain paper and cassava starch. Cassava starch as biding agent was, therefore, observed to produce stronger briquette than the other binding materials used. The implication of this means briquettes produced with cassava starch as biding agent may likely last longer while burning. It would also withstand the rigours of loading, unloading, transportation, falling or breakdown due to impact loading that the other binders used. Briquettes produced with locust bean powder were the weakest in terms of strength.

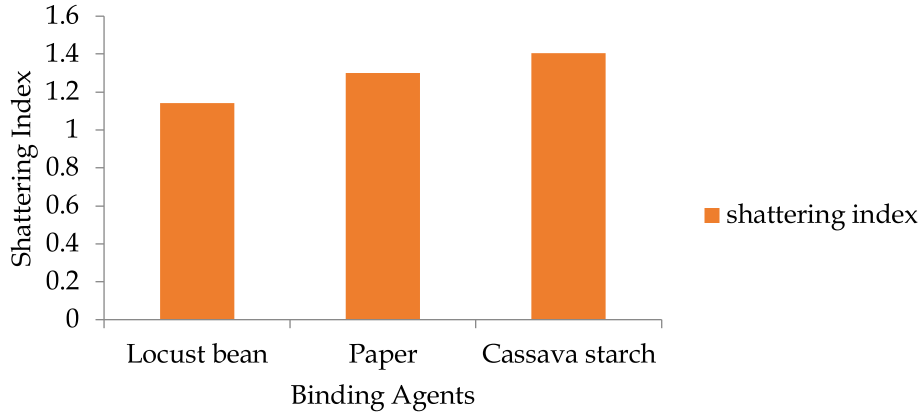

Fig. 5 Shattering index

The results of the study (Fig. 6) show the relationship between compressed density and relax density of rice husk briquettes using the three biding agents (shredded paper, locust bean powder and the cassava starch). Results obtained shows that the compressed density ranges from 852.75Kg/m³ to 770Kg/m³. This indicates that the initial density of the briquette samples immediately ejection was higher when plain paper was used as biding agent when compared to locust bean and cassava starch briquettes. Similarly, the relaxed density of the produced briquettes ranges from 367.5Kg/m³ to 317Kg/m³, indicating the density of the briquette after being dried is higher using plain paper at 367.5Kg/m³. This shows that the compressed and relax density were higher for briquettes produced from rice husk with plain paper as binding agent, while briquettes produce with cassava starch as biding agent has the lowest compressed density of 770Kg/m³. However, the relax density of briquettes produces with cassava starch as biding agent (315.05Kg/m³) was observed to be higher than that of locust bean briquette as biding agent (359.25Kg/m³). The variations in compressed and relax densities might be attributed to certain factors such as their shape and diameter of the briquettes, some environmental factors such as humidity, moisture content as well as the characteristics of the binding agents.

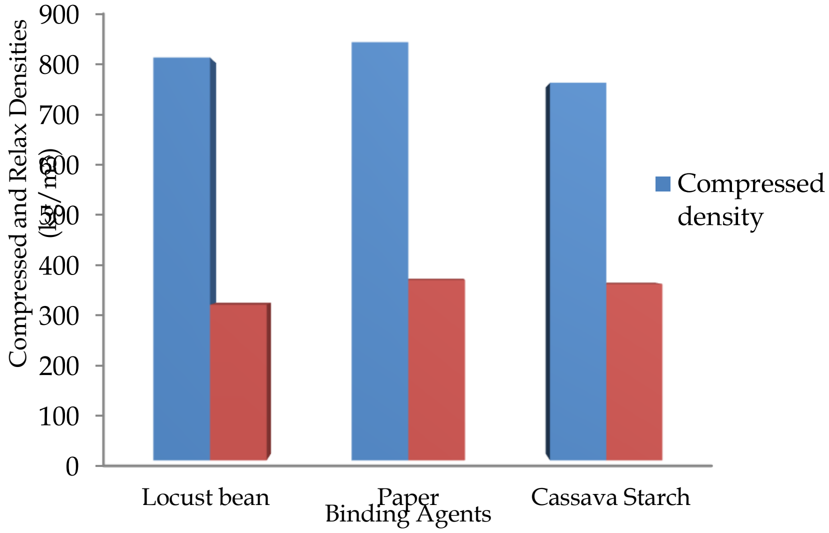

Fig. 6 Compressed and Relax Densities

Results obtained from the study (Fig. 7) shows that the relaxation ratios of the produced briquettes using locust bean, plain paper, and cassava starch as binding agents were 2.69, 2.2625 and 2.16, respectively.

The implication of these results is that briquettes produced with locust bean as binding agent were more stable than using plain paper and cassava starch as binding agents. This might be attributed to the stronger cohesive binding characteristics of locust bean powder in both wet and dried conditions.

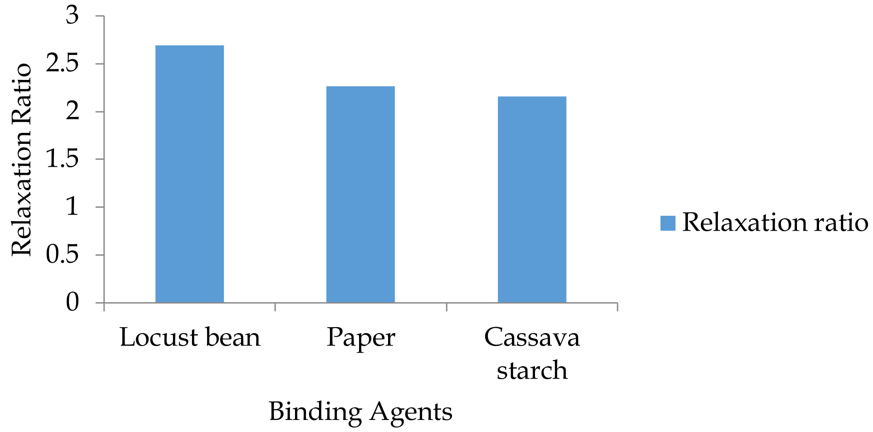

Fig. 7 Relaxation Ratio

Fig. 8 shows the mean moisture content of the rice husk briquettes produced using different binding agents. The moisture contents of the briquettes were taken before and immediately they were produced. Results obtained shows that the moisture content of briquettes produced shows that briquettes produced with locust bean as binding agent having a mean moisture content of 63%, while those produced with plain paper and cassava starch as binding agents having moisture contents of 58 and 54%, respectively. The difference in moisture content was possibly due to the varying characteristics of the binding agents, especially their water absorption abilities and the rate of their water retaining capacities. The briquettes were later dried in ovum before put to use.

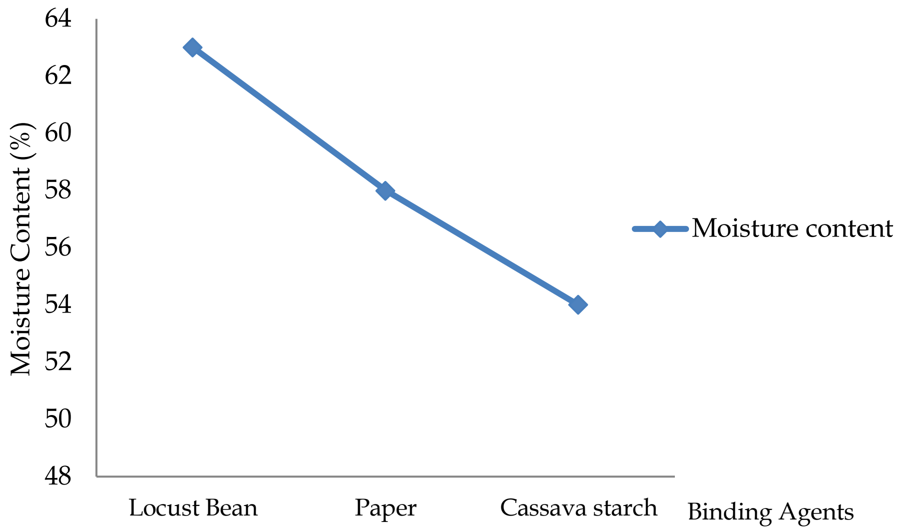

Fig. 8 Moisture Content

CONTRIBUTION TO KNOWLEDGE

This study has established that rice husk that has become a nuisance and threat to environmental conditions of most cities in Nigeria could be converted into useful energy through briquette production. It's evident that hips of rice husks are eye saw due to massive rice production in the country. Similarly, materials such as waste papers could be put into use by making them as binding agents in briquette production. This study has, therefore, introduced energy production and minimum cost. The study has also introduced a system of improving environmental condition rather than allowing hips of rice husks to pollute the environment through direct combustion.

CONCLUSION

Biomass briquettes from rice husk using three different binding agents (locust bean powder, plain paper and cassava starch) have been produced and evaluated. The properties tested (mechanical and physical) tested were the compressive strength, moisture content, relax density, compressed density, shattering index and relaxation ratio. Results obtained from the study shows that the relaxation ratios of the produced briquettes using locust bean, plain paper, and cassava starch as binding agents were 2.69, 2.2625 and 2.16, respectively; indicating that briquettes produced with locust bean as binding agent were more stable than the other binding agents. The study concludes that briquettes produced with locust bean as binding agent has more the compressive strength than those produced using plain paper and cassava starch as binding agents. It is, therefore, capable of withstanding more compressive load before reaching its rapture stage when compared with the briquettes produced using cassava starch and paper as binding agents.

DECLARATION OF CONFLIT OF INTERST

The authors declare no competing interest

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