
COMPARATIVE ANALYSIS OF GUM ARABIC AND MOLASSES (BINDERS) IN BRIQUETTES PRODUCED FROM RICE HUSKS

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Abstract

The paper investigated the effects of binders (molasses and gum Arabic) on rice husk in briquette production. A fixed quantity of rice husk was combined with varying binder proportions (10%, 20%, and 30%) and compressed using a low-pressure fabricated briquetting machine. The briquettes were sun-dried to minimize moisture content before analysis. Proximate analysis revealed moisture content of 1.9–3.5%, ash content of 16.7–20.5%, volatile matter of 55.4–62.8%, and fixed carbon of 16.3–22.2%. Physical properties recorded values ranging from 0.71–0.77 g/cm³ (compressed density), 0.30–0.38 g/cm³ (relaxed density), 1.55–1.82 (compaction ratio), 1.85–2.36 (relaxation ratio), 15.0–38.5% (durability), and 10.5–36.0 sec (water resistance). An increase in binder percentage generally improved physical properties, except for compaction and relaxation ratios, which decreased. Fuel properties included ignition time (6.1–14.8 sec), afterglow (2.4–18.1 sec), water boiling time (6.02–8.20 min), and calorific value (25,770.59–27,014.91 KJ/kg). Higher binder content increased calorific value and ignition time but reduced water boiling and afterglow times. Overall, the findings indicate that rice husk briquettes bonded with gum Arabic demonstrated superior performance compared to molasses, making it a more effective binder for briquette production.

Keywords: Rice husk, Gum arabic, molasses

Introduction

Briquetting is the process of densification of biomass to produce homogeneous, uniformly sized solid pieces of high bulk density which can be conveniently used as a fuel (Ahmad, 2010). The intention for complete substitution of wood fuel by other sources will certainly take a few decades to materialize. In the interim, the development, production and active utilization of agro-residue briquettes will certainly be a step in the right direction. The briquetting of agro-residues

is one of the numbers of ways that has been developed to solve the problem of over dependence on wood as source of fuel. Briquetting thereby puts the huge volume of waste from agriculture and agro processing to some useful purposes (Ikelleet *al.*, 2017). The search for renewable and sustainable energy sources has intensified globally due to the rising cost of fossil fuels, energy insecurity, and environmental concerns. In many developing countries, including Nigeria, dependence on firewood and charcoal as primary household energy sources has resulted in deforestation, land degradation, and greenhouse gas emissions (Olorunnisola, 2007; Zubairu & Gana, 2014). Consequently, there is a growing interest in biomass energy, which utilizes agricultural residues and wastes as alternative energy resources.

Rice husk, an abundant agricultural by-product, constitutes about 20–25% of the total weight of harvested rice (Singh *et al.*, 2019). In Nigeria and other rice-producing countries, rice husks are often discarded or burnt in open fields, causing environmental pollution and health hazards (Onuegbu, 2010). Briquetting offers a sustainable solution by converting this low-density residue into compact, dense, and energy-efficient fuel suitable for domestic and industrial applications. Briquettes have advantages such as ease of transport, improved combustion efficiency, and reduced indoor air pollution compared to raw biomass (Emerhi, 2011). However, the quality and usability of biomass briquettes depend largely on the type of binder employed. Since rice husks contain low lignin, they lack the natural adhesiveness required for self-bonding during compaction (Obi *et al.*, 2013). Therefore, external binders are added to enhance durability, water resistance, and combustion efficiency. Molasses and gum Arabic are two commonly investigated natural binders with different physico-chemical properties that may influence the performance of briquettes.

Molasses, a viscous by-product of sugarcane processing, contains fermentable sugars and minerals, which enhance its adhesive properties. It has been widely used in briquette production due to its availability and relatively low cost (Grover & Mishra, 1996). Conversely, gum Arabic, a natural exudate obtained from *Acacia senegal* and *Acacia seyal* trees, is a complex polysaccharide known for its superior binding, emulsifying, and water-soluble characteristics (Ndong *et al.*, 2017). While gum Arabic is more expensive and limited in availability compared to molasses, it produces strong and durable briquettes with better resistance to mechanical stress (Adegoke *et al.*, 2014). Despite the documented advantages of both binders, there is a need for comparative analysis of their effectiveness in briquette production from rice husks. Such an evaluation is essential for identifying the most suitable binder in terms of physical strength, combustion efficiency, durability, and cost-effectiveness. The outcome of this study will not only promote the adoption of clean and renewable energy technologies but also enhance agricultural waste management and reduce dependence on unsustainable wood fuel in Nigeria.

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Materials and Methods

Preparation of the Briquettes

A cylindrical mould measuring 18.6 cm in height with an internal diameter of 8.5 cm, together with a metal piston of 8.5 cm in height and 8.4 cm diameter, was constructed and used for briquette production. Briquettes of different compositions were produced using rice husk as the biomass residue and gum arabic or molasses as binders. The rice husk and each binder were thoroughly mixed separately to obtain a uniform blend. For each mixture, a fixed weight of rice husk (350 g) was combined with 10%, 20%, and 30% molasses (35 g, 70 g, and 105 g, respectively). The same proportions were used for gum arabic. The prepared mixtures were hand-fed into the mould, compressed, and compacted with a dwell time of 5 minutes. Owing to the design of the mould, only one briquette was produced per batch. The pressure was gradually released to eject the compressed briquette, which was then sun-dried in open space to reduce moisture content to an acceptable level (Ayodele, 2014). Measurements were taken and later used for further analyses.

Proximate Analysis

The proximate analysis of the briquettes was carried out using standard methods of the American Society for Testing and Materials (ASTM), as reported by Ayodele (2014). The parameters determined included moisture content, ash content, volatile matter, and fixed carbon.

Calorific Value/Heating Value

The calorific values of the briquette samples were determined using an AC-350 calorimeter. One gram of briquette was placed in a crucible with a fuse wire and inserted into a bomb. Oxygen gas was introduced at a pressure of 450 psi, after which the bomb was placed in a combustion chamber containing 200 ml of distilled water. The stirrer ensured uniform temperature distribution, and the electronic thermometer recorded the change in water temperature during combustion. The calorific value was then displayed on the screen (Ryemshak et al., 2015).

Water Boiling Test (WBT)

This test was performed to evaluate the cooking efficiency of the briquettes by measuring the time required to boil an equal volume of water under similar conditions. In each case, 70 g of briquette was used to boil 200 ml of water in stainless cups placed on a domestic briquette stove (Ikelle et al., 2017).

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Ignition Time

Ignition time was measured in a wind-free environment. The briquette sample was clamped 5 cm above a burner, and the time between exposure to the heat source and the appearance of the first visible flame was recorded as the ignition time (Ayodele, 2014).

Afterglow Time

After ignition, the briquette was heated for 30 seconds, during which gas flow and glowing were observed. The briquette was then removed from the heat source, and the time between removal and the disappearance of the glow was recorded as the afterglow time (Ayodele, 2014).

Compaction Ratio

The compaction ratio was calculated as the ratio of the depth of the mould to the height of the briquette produced. Measurements were taken with a measuring tape (Sotande and Alandele, 2010).

Compressed Density

Compressed density was determined immediately after removing the briquette from the mould. It was calculated as the ratio of the measured mass (g) to the calculated volume (cm³). The mass was obtained using a weighing scale, while dimensions were measured with a vernier caliper. Volume was determined using the formula:

$$V = \pi r^2 h$$

where V is the volume, h is the height, r is the radius, and π is a constant (Olorunsola, 2007).

Relaxed Density

Relaxed density, also known as spring-back density, was determined using sun-dried briquette samples. It was calculated as the ratio of the briquette's weight (g) to its new volume (cm³) (Olorunsola, 2007).

Relaxation Ratio

The relaxation ratio was calculated as the ratio of compressed density to relaxed density, providing an indication of the briquette's stability after compression (Olorunsola, 2007).

Durability

Durability was assessed by drying the briquette to a constant weight and dropping it from a height of 1.5 meters onto a metal base. The percentage of unshattered material was recorded as the durability index. It was calculated using the formula (Suprin et al., 2008):

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$$\% \text{Durability} = M_a \text{ divided by } M_b \text{ multiplied by } 100\%$$

where M_a is the mass of the briquette after dropping, and M_b is the mass before dropping.

Water Resistance

Water resistance was evaluated by immersing the briquette in cold tap water and recording the time taken for the onset of dispersion. A higher water resistance value indicates greater stability against weathering (Richards, 1990).

Results and Discussions

Proximate Analysis of Briquettes Produced

Table 1: Moisture content, Ash content, volatile matter and fixed carbon of briquettes produced

Materials	Moisture content (%)	Ash content (%)	Volatile matter (%)	Fixed carbon(%)
RH 10% MO	2.8	10.0	67.5	19.7
RH 20 MO	2.7	9.0	69.4	19.0
RH 30%MO	3.0	8.6	61.9	26.5
RH 10% GA	2.1	11.4	71.8	14.7
RH 20% GA	2.6	7.8	76.6	13.0
RH 30% GA	3.0	8.3	67.4	21.3

RH: Rice husk, MO: Molasses, GA: Gum Arabic.

Moisture Content

The moisture content of the briquettes was below the required range of 5 and 10% for successful densification as recorded by Bianca *et al.*, (2014). The moisture content of all the briquettes produced was between the ranges of 2.1% - 3.0%. This may be as a result of the high level of heat experienced during sun drying.

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The moisture content is below the required range which has the effect of making the briquettes to be weak and fragile within a short period of time according to Nkemdirim, (2014), the briquettes still have the advantage of high combustibility and high flame temperature.

Volatile Matter

The volatile matter for briquettes made from rice husk and molasses, gum Arabic binders ranges from 61.9-69.4% and 67.4-76.6% respectively. Ikelle and Mbam, (2014), stated that when the particles of a combustible material are loose, the briquettes produced would have more volatile matter during pyrolysis.

The result indicates that the volatile matter increases as the percentage binder increases which shows that the binders had the influence of increasing the volatile matter.

Fixed Carbon

Fixed carbon is a measure of the solid combustible material in solid fuel after the expulsion of volatile matter Adekunle *et al.*, (2015). High fixed carbon implies high calorific value. The increase in fixed carbon when compared to the overall constituents is most likely due to the concentration of binder in the briquette preparation Onukaket *et al.*, (2017). From the results, the briquettes produced from rice husk to (molasses or gum arabic) binders has the percentage fixed carbon value of 19.0-26.5% and 13.0 – 21.3% respectively. From the result it can be deduced that rice husk with molasses had better fixed carbon, therefore may have higher calorific value. The result also indicates decreases in the percentage fixed carbon with increase in binder ratio.

Ash Content

Onukaket *et al.*, (2017) stated that high ash content decreases the burning rate and reduces the heating value of fuel. The briquettes with higher ash contents are due to the presence of more non-combustible compounds; as such they had lower calorific values Ikelle and Mbam, (2014). The lower the ash content the better the quality of fuel briquettes. High ash content results in high dust emissions which lead to air pollution and affects the combustion volume and efficiency. The general values of ash content may appear in a range of 5-20% (Igeet *et al.*, 2018). The ash content values obtained in this work were within the general value.

Physical Properties of Briquettes Produced

Table 2: **Compressed density, relaxed density, compaction ratio and relaxation ratio of briquettes produced**

Materials	Compressed Density(g/cm ³)	Relaxed Density (g/cm ³)	Compaction Ratio	Relaxation Ratio
RH 10% MO	0.52	0.19	1.71	2.69
RH 20% MO	0.58	0.24	1.80	2.37
RH 30% MO	0.56	0.24	1.69	2.31
RH 10% GA	0.56	0.18	1.79	3.14
RH 20% GA	0.60	0.20	1.71	3.01
RH 30% GA	0.60	0.20	1.72	2.93

Compressed Density

Compressed density of the briquettes is the density obtained immediately after compression Olorunnisola, (2007). The density of the compressed mixture increased with reduction in the particle size and increased with an increase in the binder ratio level. It was also observed that the higher the compaction pressure, the higher the density Oladeji and Enweremadu, (2012).

The results shows that increase in the binder ratio, the better the compressed density obtained. Both binders competed almost equally in this regard.

Relaxed Density

One of the parameters used to characterize briquettes is relaxed density, i.e. the density of briquette after removal from the press (Olorunnisola, 2007).

The increase in volume with fixed mass will ultimately result in reduction in the density. The briquette that expands more after extrusion will have the least relaxed density and vice versa Bamgboye and Bolufawi, (2008). High density is an indication of longer burning time Babajide *et al.*, (2018).

The result shows that the briquettes produced increase in relaxed density as the binder increases.

Compaction Ratio

Higher compaction ratio implied more void in the compressed materials. Higher value indicates more volume displacement, which is good for packaging, storage and transportation and above

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all, it is an indication of good quality briquettes. It was observed that the compaction ratio increased with increasing pressure and decreased with increasing binder ratio Oladeji, (2012). The result shows that the compaction ratio decreases with increase binder ratio. It also indicates that rice husk with gum arabic had higher value, therefore serves as a better combination in terms of compaction ratio.

Relaxation Ratio

The higher density and the lower relaxation ratio may perhaps be due to the plasticity and better bonding nature of binder enabling the briquetted materials to form stronger bond, consequently resulting in a denser and more stable product during compaction Frank and Akhiero, (2013). There is significant effect of particle size and of binder ratio on the relaxation ratio Joshua, (2017). According to the result, it is apparent that the more the binder the lower the relaxation ratio.

Fuel Properties of Briquettes Produced

The analyses conducted for the determination of fuel properties include: Ignition time, afterglow time and water boiling test.

Table 3: Ignition time, Afterglow time and water resistance and durability of briquettes produced.

Materials	Ignition time (sec)	Afterglow time (sec)	Water resistance (sec)	Durability
RH 10% MO	8.3	3.7	9.0	5.9
RH 20% MO	5.5	2.0	7.6	23.2
RH 30% MO	6.4	3.0	4.7	5.1
RH 10% GA	2.8	18.2	30.2	3.5
RH 20% GA	3.6	24.4	23.1	17.1
RH 30% GA	2.3	13.3	22.7	14.3

Durability

The result shows that the briquettes produced generally increase in durability as the binder ratio increases, which conform to the statement of Davies, and Davies, (2013) that the amounts of binder used have significant influence on the durability rating of the briquettes.

Water Resistance

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Hygroscopic property of briquettes at different binder proportions showed a decrease in water absorption capacity with increased quantity of utilized binder (Davies. and Davies, 2013). The result shows that the rice husk with the two binder types agrees with the statement above. That is to say increase in water resistance was observed as binder ratio increases and rice husk with gum arabic serves better in this regard.

Ignition Time

The obtained trend of the ignition time indicated that ignition time increased with increased binder proportion. The low ignition time could be attributed to high porosity exhibited between inter and intra – particles which enable easy percolation of oxygen and out flow of combustion briquettes due to low bonding force. Furthermore, briquettes compressed to a higher density will tend to have a lower porosity, and thus elongate the ignition time Davies and Abolude, (2013)

It can be observed from the result that ignition time increases with increase in the quantity of the binder. It can also be observed that the rice husk with gum arabic combination had lower values of ignition time, which could be due to low bonding force.

Afterglow Time

Pressure has minimal influence on the duration of lighting briquettes Onchieku, *et al.*, (2012). The afterglow time decreases with increase in binder except in the case of 20% gum arabic ratio. This could be due to irregular application of pressure during compression which is contrary to the statement of Onchieku, *et al.*, (2012).

Table 4. **Calorific value and water boiling test of briquettes produced**

Materials	Calorific value (KJ/kg)	Water boiling test (g/min)
RH 10% MO	29372.08	17.04
RH 20% MO	29372.15	16.10
RH 30% MO	29830.95	16.89
RH 10% GA	29095.75	16.97
RH 20% GA	30119.84	14.46
RH 30% GA	29887.89	19.13

Calorific Value

Heat value or calorific value determines the energy content of a fuel. It is the property of biomass fuel that depends on its chemical composition and moisture content. The most important fuel property is its calorific or heat value Ainaet *al.*, (2009). The higher the fuel's ash content, the

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lower the calorific value. The higher the number of carbon content of the briquettes the higher the calorific values, while the briquettes with low carbon content do have lower calorific values (Ikelle, *et al.*, 2017).

The result in table 4 shows that the briquettes produced increase in calorific value as the binder increases. Also the abnormal values obtain can be as a result of the irregular pressure applied during compression.

Water Boiling Test

The fuel briquette's density will affect its bulk thermal properties, the thermal conductivity will be reduced as the density is decreased (increased fuel porosity), but the lower the density, the less heat is required for a specific volume of fuel to reach the ignition temperature (Ikelle and Mbam 2014).

Okiaet *al.*, 2017 states that biomass having highest calorific value does not guarantee shortest water boiling time. The result in table 4 shows that the briquettes with gum arabic binder boil water faster than those with molasses binder. The binder ratio's influence could not be ascertained, which may be due to the irregular pressure during compaction.

Conclusion

Biomass briquettes are efficient and effective alternative source of fuel that will mitigate the felling of trees especially in rural areas. The challenges facing the environment can also be reduce through the use of briquettes. In this study, the briquettes produced shows that rice husk with molasses have better qualities and efficiency in adding to the physical strength while rice husk with gum arabic serves better with regards to proximate analysis and fuel property.

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