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Effects of Gum Arabic as Binder on The Physico-Mechanical Properties of Briquettes Made from Corn Cob

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Abstract

This study presents the effect of gum Arabic as a binder on the physical and mechanical properties of briquette made from corn cob. The corn cobs were charred and mixed with different concentrations (0%, 5%, 10%, and 20%) of gum Arabic to form a paste. The paste was compacted under 0.215 MPa for 5 minutes in a manual press to produce a briquette. The physical tests, which were comprised of density, shatter resistance, water resistance, and compressive tests, were carried out. The results demonstrated a significant increase in the density (0.63gm-3 compressed density, 0.42 gm-3), high shatter resistance index (99.87%), good water resistance index (85.52%) and good compressive strength (3.7 MPa) in comparison with the non-binder briquette. The study shows that the gum Arabic as a binder enhanced the qualities of the briquette in strength and durability.

Keywords: Binder, Briquette, Corn cobs, Gum Arabic, Strength.

1 | Introduction

The need to address the environmental degradation and its resultant global warming caused by indiscriminate dumping of agricultural wastes has led to using biomass as a sustainable substitute for fossil fuels. Agricultural wastes have enormous potential [1–3], which is heavily embedded in them and can be converted into solid fuels by briquetting technology [4–6].

Many feedstock types, such as rice husks [7, 8], coconut shells [9], coconut husks [10], groundnut shells [11], palm kernel shells [12], etc., have been used for briquette production. Due to its availability, low cost, and renewable nature, corn cobs have become a promising biomass feedstock for solid fuel conversion [13–16].

Corn cobs can be directly utilized as solid fuels. However, they are apparently unsuitable due to their massiveness, high moisture content, uneven nature, and low energy density [17, 18]. These inherent properties of corn cobs make them difficult to utilize in their raw form; hence, densification [19] into briquettes is needed for easy usage. Compressed biomass materials, briquettes, or solid biofuels have better handling, storage, and

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burning qualities than raw biomass. Some biomass naturally binds [20–22] during briquette processing when exposed to favorable temperatures and pressure conditions. But, if these conditions required for natural binding are not met, a binder is needed to gum the biomass particles together. Therefore, adding binders is frequently necessary in producing high-quality briquettes to increase their strength and resistance to disintegration. Different factors generally affect the overall quality of briquettes, such as the compaction pressure, effect of binder, curing temperature, mixing ratio, moisture content, and type of feedstock used. The effect of binder on briquette quality is very important and requires careful consideration. Recently, there has been interest in using gum Arabic, an exudate from the Acacia Senegal tree, as a binder for briquette production. Numerous researchers have explored the use of corn cobs for briquette production, but there is currently no available information on the effect of gum Arabic as a binder.

This study aims to investigate the impact of gum Arabic as a binder on the physical and mechanical properties of briquettes made from corn cobs. The use of gum Arabic has many benefits, including its availability, affordability, biodegradability, and non-toxic properties. Additionally, it has adhesive qualities that can increase the briquettes' structural stability and robustness, resulting in improved combustion efficiency. In the study, corn cob was charred and mixed with different ratios of gum Arabic to make a paste. The paste was densified. The effects of the different ratios of the binder on the strength and durability properties of the briquette were investigated.

2 | Materials and Methods

2.1 | Materials

Corn cobs were collected from an agricultural farm in Abuja-Nigeria, cleaned, and sun-dried to reduce moisture content. The dried corn cobs were carbonized in a kiln to produce char. The char was ground and sieved to a uniform particle size of less than 3mm. Gum Arabic was used as a binder and was sourced from a market in Abuja.

2.2 | Briquette Preparation

2g of gum Arabic(binder) was dissolved in 200 ml of water and was gelatinized in a heated water bath with continuous stirring until a smooth paste was formed. Different concentrations (5%, 10%, and 20%) of gum Arabic paste were added to the corn cob char granules of different weight percentages (95%, 90%, and 80%). The mixture was thoroughly mixed to obtain a paste. 10 g of wet paste was subjected to compaction at an applied pressure of 0.215 MPa for 5 minutes in a mold. The formed briquette was placed in a solar dryer, and its corresponding daily weight decrease was recorded until a constant weight was achieved. The dried briquette was stored in a nylon bag for further analysis.

2.3 | Physical and Mechanical Testing

2.3.1 | Density

The density of the briquette was determined immediately after briquette production (compressed density) and 7 days later for relaxed density after maintaining a constant weight at a constant drying temperature. The briquette density was calculated using the measured weight and dimensions (height and diameter). The compaction ratio was evaluated using *Eq. (1)*.

$$\text{Compaction ratio } = \frac{(\text{compressed density of briquette})}{(\text{relaxed density of briquette})}. \tag{1}$$

2.3.2 | Shatter resistance

The briquette shattering resistance test was determined by dropping the briquette sample repeatedly from a height of 1.6 m onto a solid base until it broke. The sample's weight change before and after the drop test was measured, and the weight loss percentage was evaluated using *Eq. (2)*. The shatter resistance index of the briquette was estimated using *Eq. (3)*.

$$\text{Weight loss (\%)} = \frac{\text{briquette weight before shatter} - \text{briquette weight after shatter}}{\text{briquette weight before shatter}}, \quad (2)$$

$$\text{Shatter resistance Index} = 100\ \%\ \text{weight loss}. \quad (3)$$

2.3.3 | Water resistance

Briquette was immersed in a cylindrical glass filled with 200 ml of tap water at room temperature for 30 minutes. The briquette was removed and cleaned with a paper towel to remove water on the surface of the briquette sample and re-weighed. The sample's weight change was measured, and the percentage of water absorbed was evaluated using *Eq. (4)*. The water resistance capacity of the briquette was calculated using *Eq. (5)*.

$$\text{Water absorbed by briquette (\%)} \frac{w_2 - w_1}{w_1} \times 100, \quad (4)$$

$$\text{Water Resistance Capacity (\%)} = 100 - \%\text{water absorbed}. \quad (5)$$

Where;

$w_1 =$ weight of briquette before dropping in the water,

$w_2 =$ weight of briquette after removal from water.

2.3.4 | Mechanical strength

A sample of briquette sample was placed in a compression testing machine (manual press machine), as seen in *Fig. 1*, and subjected to a gradual load increase. The load was increased until the briquette sample failed. The compressive strength of the material was estimated using *Eq. (6)*.

$$\text{Compressive Strenght} = \frac{\text{maximum load applied}}{\text{cross} - \text{sectional area of briquette}}. \quad (6)$$

Fig. 1. Manual press machine used for compressive strength.

3 | Results and Discussion

3.1 | Density

One of the key determinants of briquette quality is density. Briquette density plays a vital role in reducing the impact of handling, transportation, and storage costs and enhancing combustion properties. *Table 1* shows an increase in compressed density with a corresponding increase in binder concentration. A similar trend was observed in the relaxed density with its corresponding binder concentration. This shows that the densification of the briquette increased with the binder concentration and that gum Arabic filled more void spaces in the briquette compared to the non-binder briquette, which invariably improved the densification of the briquette. It was observed that further drying of the briquette for some days significantly affected its density.

Further drying lowered the density of the briquette, as evidently seen in the relaxed density compared with the compressed density. This is attributable to weight loss during the drying under the solar dryer. The weight loss could be bound and unbound moisture in the briquette. The effect of the binder concentration was significantly noticed on the compaction ratio of the briquette. There was an increasing trend effect with increased binder concentration of the briquette to non-binder briquette. This indicates a high-volume displacement, which enhances the briquette quality for handling, storage, transportation, and efficient combustion.

Table 1. Binder concentration and its corresponding density.

S/N	Bimder concentration (%)	Compressed density (gm^{-3})	Relaxed density (gm^{-3})	Compaction ratio
1	0	0.37	0.33	1.12
2	5	0.45	0.33	124
3	10	0.52	0.37	1.52
4	20	0.63	0.42	1.56

3.2 | Shatter Resistance Index

Briquette disintegration became increasingly hard with increasing binder concentration, as presented in *Table 2*. Adding gum Arabic binder to the corn cobs briquette was significantly noticed, resulting in a 51.84% higher shatter resistance index than non-binder briquette. It shows that adding gum Arabic binder significantly enhanced the durability and strength of the corn cob briquette. Interestingly, a marginal increase in shatter resistance index was observed when different concentrations of gum Arabic binder were added to the corn cobs briquette. This suggests that gum Arabic on its own has a great binding effect in enhancing the durability of the briquette.

Table 2. Shatter resistance index of different binder concentrations.

S/N	Bimder concentration (%)	Weight loss (%)	Shatter resistance (%)
1	0	51.90	48.10
2	5	2.10	97.90
3	10	0.42	99.58
4	20	0.13	99.87

3.3 | Water Resistance

Water-resistant properties are essential in evaluating briquettes' combustion and durability qualities. This is essential to guard against water absorption or high humidity during storing, handling, and transporting briquettes. Briquette exposure to high humidity or water poses ignition difficulty and affects combustion quality. The result presented in *Table 3* shows that the gum Arabic binder has high hygroscopic properties with the least water absorption capacity. In contrast, the non-binder briquette shows high water absorption capacity with the least hygroscopic properties. This result shows that the gum Arabic binder has a high water resistance capacity, indicating the briquette's good durability and combustion qualities.

Table 3. Water resistance index of different binder concentrations.

S/N	Bimder concentration (%)	Water absorbed By briquette (%)	Water resistance capacity (%)
1	0	89.87	10.13
2	5	62.67	37.33
3	10	28.76	71.24
4	20	14.48	85.52

3.4 | Mechanical Strength

Compressive strength is one of the key indicators used to measure the maximum pressure a briquette can bear during handling, storage, and transportation. The gum Arabic binder produced the highest compressive strength, 3.7 MPa, as shown in *Fig. 2*. *Fig. 2* depicts an increasing trend of the compressive strength with its corresponding binder concentration, while the non-binder briquette has the least compressive strength. This illustration is attributable to the high granular bonding effected by the gum Arabic and the good compaction of the briquette.

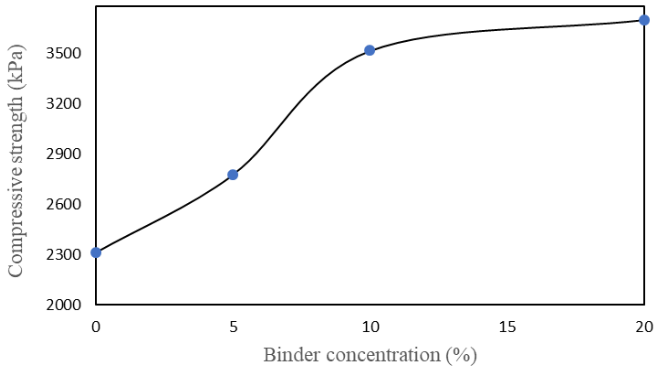

Fig. 2. A plot of compressive strength (kPa) versus binder concentration (%).

4 | Conclusion

This study investigated the effect of gum Arabic binder on the physico-mechanical properties of the briquette made from corn cobs. The briquette properties that affect durability and strength, such as density, shatter resistance capacity, water resistance capacity, and compressive strength, were all evaluated. The briquette demonstrated good qualities in terms of strength and durability and proved a great bonding effect with the gum Arabic used as a binder.

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Conflicts of Interest

The authors declare no conflict of interest.

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