Investigations into the Effects of Different Binding Ratios on some Densification Characteristics of Corncob Briquettes

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Abstract: Corncobs utilized in this experiment were obtained from corn processing mill. They maize were chopped into pieces, sieved and particles of 2.40mm representing medium series were selected. The compaction pressure was fixed at 6.60 MPa. Starch mutillage of 20 (B_1), 25 (B_2) and 30 (B_3) % by weight of the residue was separately added as binder. An existing briquetting machine was utilized to produce briquettes. A dwell time of 120 seconds was observed for the briquettes to form. The briquette formation was replicated three times. The initial, maximum and the relaxed densities of the briquettes were determined using the mould dimension, the relaxed briquette's dimension and ASAE standard method of determining densities. The compaction, density as well as relaxation ratios were also determined. The briquette dimensions (length, breadth and height) in cm after extraction from the mould were measured and through this the briquettes stability was determined by calculating the axial and lateral expansions of the briquettes. The mean bulk density of the unprocessed corncob residue was 50.32 kg/m^3, while the relaxed densities of the briquettes with the percentage binder ratio B_1, B_2 and B_3 were 377, 365 and 328 kg/m^3 respectively and this translates to percentage volume reduction of about 749, 725 and 652 %. The maximum densities for percentage binder ratio B_1, B_2 and B_3 varied from 570 to 802 kg/m^3. The compaction, density and relaxation ratios are 3.63, 0.56, 1.78; 3.01, 0.56, 1.78; and 2.65, 0.53, 1.89 for varied from 2.65 to 3.63 for percentage binder ratios B_1, B_2, and B_3 respectively. The study concluded that of all the three percentage binder ratios examined, percentage binder ratio B_1 (20 %) exhibited the most positive attributes of biomass energy than the other two.

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1. Introduction

Energy is an important, if not the most critical factor in developmental activities of any nation. However, there is a problem of energy worldwide and this is mainly due to growing world, industrialization, technological advancement and transportation. This had brought energy demand under an increased pressure (Agbontalor, 2007). The world's energy markets rely heavily on the fossil derived fuels whose reserves are finite. Hence, there is the need to generate energy from biomass and in this regards agricultural residues can play a significant role in alternative energy generation on a renewable basis.

The importance of binder in briquetting of agro-residues cannot be overemphasized. This is because, without proper agglomeration, the briquettes may eventually disintegrate. Kaliyan and Morey (2009) in their investigations into some factors affecting quality of densified biomass products mentioned binder as one of the major determinants as far as the quality of briquettes produced from agro-residues is concerned. Furthermore, Oladeji (2011) noted that employment of binder is necessary especially during briquetting under low-pressure technique.

A binder or otherwise called additive can be a liquid or solid that forms a bridge, film, matrix, or causes a chemical reaction to make strong inter-particle bonding. According to Tabil, (1997), binders can be divided into three by their function. These are:

- Film binders: - They are like glues and usually depend upon the evaporation of water or some solvent to develop their strength e.g. tar, petroleum asphalt and portland cement.
- Matrix binders: - This type of binder usually imbeds the particles into a substantially continuous binder phase. The properties of the briquettes therefore, are largely determined by the properties of the binders. Examples of such are coal, and sodium silicate.
- Chemical binders: - They can be film or matrix types e.g. pitch water, sodium silicate and lignosulfonates. The chemical binders used for foundry sands are good examples of the film type binder.

The study by Dobie (1975) showed that grass hay could not be formed into good quality cubes without the application of a good bonding agent. Cubes produced from blue panic grass, Timothy grass, range hay, Pangola grass, and Congo grass without a binder had durability of 15-44%. By adding 5.0 – 10% (by weight) of a liquid binder (containing ammonium lignin sulfonate, wood sugars, 2.4% nitrogen in the form of ammonia, and 50% water), durability of cubes increased to 93 – 97%. Addition of about 5% (by weight) of the same liquid binder to bagasse pitch increased the durability of the cubes from 88.8 to 99.3%.

Singh and Singh 1998 reported that adding 10 – 25% (by weight) of molasses or sodium silicate, or a mixture of 50% sodium silicate with rice straw produced briquettes with 40 – 80% durability at a particle size of 0.15mm and a forming pressure of 29.4MPa. The higher the amount of binders added, the higher the briquette durability. Binding of molasses might occur due to solid bridges created by re-crystallization of sugars or glass transition after cooling/drying of pellets (Thomas, et al., 1998).

The broad aim of this paper was to investigate the effects of percentage binder ratio on some of densification and physical characteristics of briquettes produced from the blend of ground corncob and cassava starch gel.

2. Materials and Methods

Maize cobs utilized in this experiment were obtained from corn processing mill. The maize residue was chopped into pieces. Next, they were sieved and particles of 2.40mm representing medium series were selected. The maize cobs particles as raw material were then mixed with cassava starch gel as a binder. Also in order to examine the effect of percentage binder by weight only, the specified compaction pressure was fixed at 6.60 MPa. Starch mutillage of 20 (B_1), 25 (B_2) and 30 (B_3) % by weight of the residue was separately added as binder. An existing briquetting machine was utilized to produce briquettes. A dwell time of 120 seconds was observed for the briquettes to form. The briquette formation was replicated three times. The initial, maximum and the relaxed densities of the briquettes were determined using the mould dimension, the relaxed briquette's dimension and ASAE standard method of determining densities. The compaction, density as well as relaxation ratios were also determined. The briquette dimensions (length, breadth and height) in cm after extraction from the mould were measured and through this the briquettes stability was determined by calculating the axial and lateral expansions of the briquettes. The percentage volume reduction was calculated from equation 1 :

$$\%\ \text{Volume Reduction} = \frac{\text{Bulk Density of Relaxed briquettes}}{\text{Bulk Density of Unprocessed briquettes}} \quad (1)$$

3. Results and Discussion

Table 1 shows the bulk density of raw corncob, initial density of processed corncob and maximum and relaxed densities of briquettes produced from corncob under three different percentage binder ratios.

Table 1. Densities of raw corncobs and briquettes

Density (kg/m^3)	Binder ratio (%)		
	B_1 (20)	B_2 (25)	B_3 (30)
Bulk (Raw cob)	50.32	50.32	50.32
Initial (Processed)	185	216	233
Maximum	802	692	570
Relaxed	377	365	328

The mean bulk density of the unprocessed corncob residue was 50.32 kg/m^3, while the initial densities of the processed residue with the percentage binder ratio B_1, B_2 and B_3 were 185, 216 and 233 kg/m^3 respectively. The maximum densities for percentage binder ratio by weight B_1, B_2 and B_3 varied from 570 to 802 kg/m^3 for briquettes as shown in Table 1. These values are higher than the initial density of the uncompressed, but processed mixture of between 185-216 kg/m^3. It was observed that the higher the percentage binder ratio by weight, the lower the maximum density i.e. that the maximum density decreased with increasing percentage binder ratio by weight. The same thing could be said of relaxed density. The values of maximum densities obtained with percentage binder ratio B_1 and B_2 are more than the minimum value of 600 kg/m^3 recommended by Mani et al. (2006) and Gilbert et al. (2009) for efficient transportation and safe storage. The implication of this is that using percentage binder ratio more than 25% will result in briquettes of low quality in term of density.

Table 2 shows the compaction, density and relaxation ratios obtained for corncob briquettes under three different percentage binder ratios.

Table 2. Compaction, density and relaxation ratios for corncob briquettes

Ratio	Binder ratio (%)		
	B_1 (20)	B_2 (25)	B_3 (30)
Compaction	3.63	3.01	2.65
Density	0.56	0.56	0.53
Relaxation	1.78	1.78	1.89

The results showed that compaction ratio varied from 2.65 to 3.63 for the three percentage binder ratios by weight examined in this study with percentage binder ratio B_1 (20%) having the highest. Higher compaction ratio implied more void in the compressed materials. Higher figure indicates more volume displacement, which is good for packaging, storage and transportation and above all, it is an indication of good quality briquettes. From Table 2, it was observed that the compaction ratio decreased with increasing percentage binder ratio by weight and in this regards, the lowest percentage binder ratio B_1 exhibited the best result. Furthermore, the values of compaction ratio obtained in this study compare and compete favourably well with notable biomass residues. For example, compaction ratio of 3.80 was obtained during briquetting of rice husk (Oladeji, 2010); while compaction ratios of 4.2 and 3.5 were obtained during briquetting of groundnut and melon shells respectively (Oladeji et al., 2009). In the similar manner, compaction ratio of between 3.20 and 9.70 was obtained by Boluwafi (2008) during briquetting of guinea corn residue.

The mean values of density ratio with percentage binder ratio by weight B_1, B_2, and B_3 are 0.56, 0.56 and 0.53 respectively. The higher the value of the density ratio for a given mass, the less relaxed the briquettes are. There is practically little difference in the value of density ratio obtained for the three percentage binder ratios examined in this study.

The mean relaxation ratios of briquettes produced were found to be 1.72, 1.78 and 1.89, for percentage binder ratio by weight B_1, B_2 and B_3 respectively (Table 2). Lower value of percentage binder ratio indicates a more stable briquette, while higher value indicates high tendency towards relaxation i.e. less stable briquette. The values of relaxation ratio obtained in this study indicated that briquettes produced with binder ratio B_1 are more stable than briquettes produced with the two other percentages binder ratios. A reciprocal relationship was observed between density ratio and relaxation ratio of the briquettes.

The stability of the briquettes, which is expressed in terms of percentage axial and lateral expansions, is presented in Table 3.

Table 3. Axial and Lateral expansions for corncob briquettes

Expansions (%)	Binder ratio (%)		
	B_1 (20)	B_2 (25)	B_3 (30)
Axial	1.07	2.56	4.15
Lateral	0.88	1.42	1.76

From Table 3, it was observed that briquettes expanded largely in the axial direction than in the lateral direction. The change in briquette dimensions in the axial direction was up to 4.15% compared to maximum of 1.76 % in the lateral direction. Similar expansion trend was also reported by Al-Widyan et al. (2002) during briquetting of olive cake. The axial expansion of briquettes increased as the percentage binder ratio increased. The lowest percentage binder ratio by weight B_1 (20%) has the least axial and lateral expansions. The implication of this is that, the lower the percentage binder ratio, the more stable are the briquettes produced.

Conclusions

The present work investigated the effects of percentage binder ratio by weight on physical and densification characteristics of briquettes produced from corncobs. Based on the results and the findings of this study, the following conclusions can be drawn:

- This study has found that, the percentage ratio by weight has correlation effects on the physical and densification characteristics of briquettes produced from corncob.
- Of all the percentage ratios examined, percentage ratio by weight B_1 (20 %) exhibited the most positive attributes of biomass energy than the other two percentage ratios by weight. It can then be concluded that, the higher the

percentage ratio by weight is, the more positive attributes of good quality briquette such percentage by weight has.

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