International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

Experimental Investigations on Briquettes Produced Frommaize Cobs and Rice Husks

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ABSTRACT

Maize cobs and rice husks are the two most commonly available agricultural residues that can be utilized for the production of briquettes. They were carbonized using a locally made metal carbonization kiln. Numerous experiments were conducted to investigate the effects of briquetting pressure, binder ratio and maize cob composition on the physicochemical properties of the briquettes. The physical and chemical properties of the raw materials were also investigated. Furthermore, the binding agent used for the production of briquettes was extracted from cassava root tubers.

It was found that all the parameters considered were affecting the physicochemical properties of the briquettes mainly density, stability, durability and heating value. The compressed density of the briquettes was in the range of 865 to 1 123 kg/m^3 while the relaxed density of the briquettes varied from 438 to 513 kg/m^3. With regard to briquette stability, the maximum and minimum axial expansions were 6.62 % and 3.44 % while the lateral expansions were 3.44 and 0.53 % respectively. The durability of the briquettes ranged from 32.16 to 76.47 %.

From the chemical properties, maize cob has volatile matter of 73.28 %, ash content of 0.79 % and fixed carbon content of 10.89 % while rice husk has 60.19 %, 22.24 % and 8.59 % in the order of volatile matter, ash content and fixed carbon respectively. The heating values of maize cobs and rice husks were found to be 16.25 and 15.80 MJ/kg respectively. With regard to briquette, the calorific values ranges from 19.04 to 26.15 MJ/kg.

Thus, maize cob briquettes have more positive attributes of biomass fuels than briquettes produced from mixtures of rice husks and maize cobs. However, maize cobs and rice husks could be alternative feedstock's for briquette production and the briquettes produced in this way are well suited for domestic applications.

keywords: Briquettes, Physicochemical properties, Maize cobs, Rice husks

1. INTRODUCTION

According to the world's energy scenario, it is widely accepted that fossil fuel depletion, fuel increasing price, global warming including other environmental problems are becoming critical issues. Hence, alternative energy sources are expected to substitute fossil fuel in the future. Among these energy sources, biomass is the only carbon-based renewable energy and the wide variety of biomass enables it to be utilized by most people around the world. It accounts for approximately 14 % of total energy consumption in the world [1].

Biomass energy provides basic energy requirements for space heating, power generation and cooking and heating of rural and urban households' particularly in developing countries. It is the primary fuel for cooking close to 2.5 billion people, or 52 % of the population in developing countries [2]. Over half of these people live in India, China and Indonesia. Nevertheless, the proportion of the population relying on biomass is highest in sub-Saharan Africa. Without new policies, the number of people that rely on biomass fuels is expected to increase 2.6 billion by 2015, and 2.7 billion by 2030 due to population growth [3].In Ethiopia, biomass fuels had accounted for 94 % from the total final energy consumption (77 % from fuel wood and charcoal while another 17 % consisted of agricultural residues); only roughly 5 % was met by modern energy sources such as petroleum and only 1% of the population utilized electricity for cooking [4].

Thus, it is expected that introducing agricultural residues based-briquettes is one of the strategies to the fuel wood crisis in Ethiopia. Therefore, the aim of this work is to investigate experimentally the production of briquettes from agricultural residues and analyze the effect of processing parameters like briquetting pressure, binder ratio and maize cob composition on the quality attributes of briquettes.

2. MATERIALS AND METHODS

Rice husks were obtained from local "rice milling located in Woreta town, while maize cobs were collected from local farmer located at Woramit Kebele, Amhara region. After gathering the raw materials, they were processed into compact briquettes following -a simple process. The maize cobs and rice husks were carbonized, then grinded into char powders of interest and finally compressed. The moisture content, bulk density, proximate analysis, ultimate analysis and calorific value of the raw materials were determined based on ASTM standards prior to carbonization.. The briquettes obtained in this study were cylindrical in shape with a central hole as shown in Fig. 2.1.

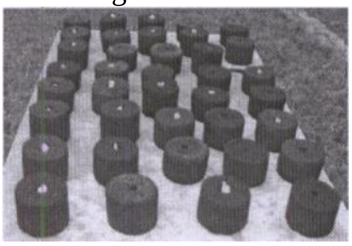

Figure 2.1: Briquettes models

The procedures for all the tests were obtained from various published source. The physical properties of the briquettes like compressed and relaxed density as well as stability were determined by measuring their mass and dimensions after removal from the briquetting machine. The mechanical properties tests include impact resistance, water resistance, compressive strength and durability. The impact resistance of the briquettes was determined by dropping them twice from a height of 1.83m onto a concrete floor so that the number of pieces that briquettes broken into were recorded [5]. The water resistance of the briquettes was measured as the percentage of water absorbed by a briquette when immersed in water as reported by Lindley and Vossoughi [6]. The durability was determined based on an impact resistant test as reported by Khankari et al. [7].

The proximate analysis of the briquettes including the moisture, volatile matter, fixed carbon and ash contents was performed using furnace. The ultimate analysis which consists of estimation of the chemical elements like carbon, hydrogen, nitrogen and oxygen contents were also investigated. The calorific value was determined using a bomb calorimeter and based on the values of their proximate analysis. The procedures for proximate analysis and calorific value were determined based on ASTM standards. The combustion properties of the briquettes like heat release, combustion rate and water boiling test was determined using a locally made stove.

Figure 2.2: Cassava flour during gelatinization process

The gelatinization process was done by mixing dried cassava flour with water in a water bath and heated at a temperature of 50 °C for 10 minutes as shown in Fig. 2.2. The char powder-binder mixture was measured, then mixed before hand-fed into the lever arm briquetting machine and compression testing machine. Then, the mixtures were compressed and retained at a fixed dwell time of 30 sec and then removed from the machine. Finally, the briquettes produced in this way were dried in order to carry out their various physicochemical properties. In this study, experiments were designed to investigate the effect of processing variables such as briquetting pressure, binder ratio and maize cob composition on physicochemical property of the final briquettes. The experimental design was employed based on factorial design for three factors at two levels. The factors were compressive force (1,470 N and 8,000N) corresponding with pressure (47 and 255 kPa), binder ratio (20 and 30 %) and maize cob composition (50 and 100 %) by weight.

3. RESULTS AND DISCUSSIONS

3.1. PHYSICAL PROPERTIES

3.1.1. Compressed Density

The average compressed density of the briquettes obtained in this study varied from 865 to 1123 kg/m^3. These values were more than the minimum value of 600 kg/m^3 recommended for efficient transportation and safe storage [8].

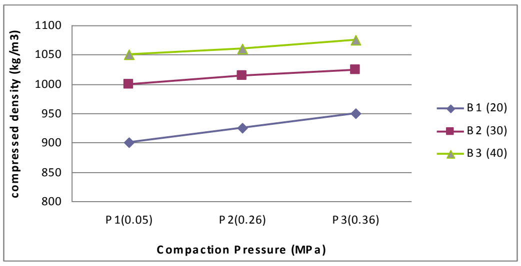

Figure 3.1 Effect of pressure and binder ratio on compressed density for maize cob briquettes

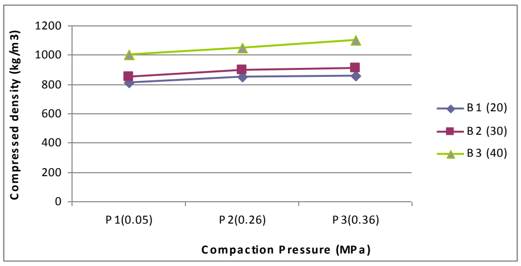

Figure 3.2 Effect of pressure and binder ratio on compressed density for maize cob-rice husk briquettes

The highest value was obtained in briquettes produced with 0.26 MPa compaction pressure, 20 % binder ratio and 100 % maize cob composition by weight. As it can be seen in Fig. 3.1 and 3.2, it was observed that the density of the briquettes increased when the compaction pressure increased.It was also observed that the maximum density decreased with increasing binder ratio from 20 to 40 % and with decreasing maize cob composition. The reason might be expected that the increased amount of binder ratio resists more during compression so that much pore spaces per unit volume obtained and hence brings low density.

3.1.2. Relaxed Density

The results of this study showed that the mean relaxed density of the briquettes ranged from 438 to 513 kg/m^3. These values were lower than 865 to 1123 kg/m^3 obtained in this study for the maximum densities. This is due to the expansion in dimensions that takes place after removal from the briquetting machine which will increase the volume of the materials. Therefore, the briquette that expands more after extrusion will have the least relaxed density.

The experimental results of this study showed that a general trend of increase in the relaxed density was observed with increased pressure. The increase in relaxed density with increased pressure could be due to the possible compactness of the char powder-binder mixture as pressure increases and the reduction in elastic recovery during relaxation of the formed briquette. The relaxed density of the briquettes was also increased generally as the binder ratio increases. The effects of pressure and binder ratio (% by weight) on the relaxed density for briquettes observed in this study were presented in Fig. 3.3-3.4.

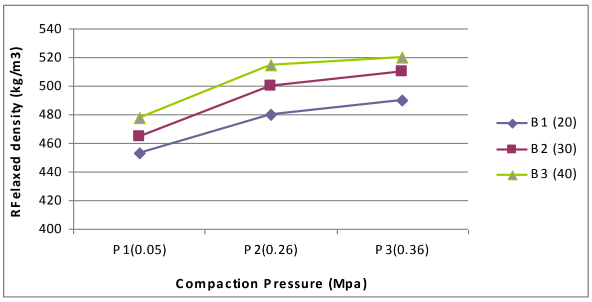

Figure 3.3 Effect of pressure and binder ratio on compressed density for maize cob Briquettes

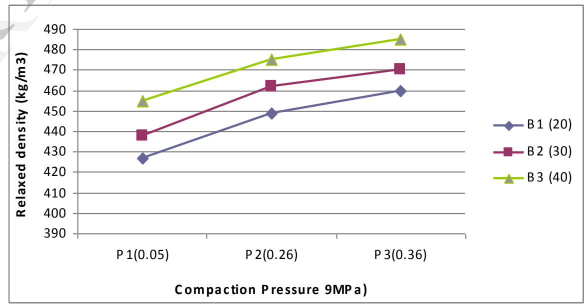

Figure 3.4 Effect of pressure and binder ratio on compressed density formaize cob–Rice husk briquettes

The maximum and minimum relaxation ratios of briquettes produced were found to be 2.32 and 1.89 for maize cob 50 and 100 composition by weight. These values were compared favorably well with the values reported by Olorunnisola, A.O. a relaxation ratio in the range of 1.80 and 2.25 for coconut husk briquette and Oladeji et al. gave the relaxation ratio values 1.97 and 1.45 for groundnut and melon shell briquettes respectively. A relaxation ratio of 2.33 was obtained during briquetting of rice husk Oladeji. Therefore, the lower relaxation ratio of maize cob briquette is an indicator to the superiority of maize cob briquette over its maize cob-rice husk counterpart[9,10,11,12].

3.2. MECHANICAL PROPERTIES

3.2.1. Impact Resistance

The impact resistance of the briquettes in this study was investigated by dropping them twice from a height of 1.83 m onto a concrete floor and calculating an impact resistant index as stated by Richards [13]. Thus, 62.5 % of the briquettes produced in this study were passed the test. The value can be used to determine the safe height during storage. The resistance of the briquettes to impact was increased as the compaction pressure increased. The results also showed that briquettes produced with 30 % binder ratio have more impact resistant than briquettes containing 20 % binder ratio by weight. This is due to the increment of bond strength between particles as the binder ratio increases.

3.2.2. Durability

In this study, durability was determined based on an impact resistant test. The experimental results showed that the durability of the briquettes were in the range of 32.16 to 76.47 %. These values were close to values between 46.5 and 88.4 % as reported by Wamukonya and Jenkins [14] for sawdust and wheat straw briquettes. The results also showed that increasing the binder content increases its briquette durability which is supported by the works of Chin, O.C. and K.M. Siddiqui [15]. The effect of binder content on briquette durability is shown in Fig. 3.5.

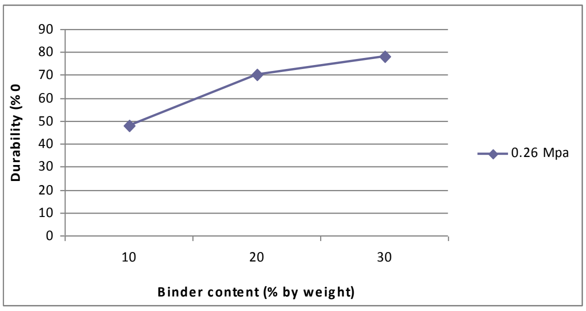

Figure 3.5 Effect of pressure and binder ratio on compressed density for maize cob briquettes

3.2.3.Water Resistance

The water e water resistance or the briqueues was done by immersing the briquettes in water for 60 minutes and measuring their weight every 10 minutes. The maximum a minimum resistances of the briquettes water were 84.2 and 67.4 % respectively. With regard to water absorption capacity the values ranged from 15.8 to 32.6 %.

More than 75 % of the briquettes didn't show disintegration in water for the first 6 minutes. The time for the briquettes to full; disintegrate in water ranged from 78 to 335 minutes. The high resistance of the briquettes to water was observed for briquettes produced from 0.26 MPa compaction pressure, 30 % binder ratio and 100 % maize cob composition by weight. The results of the study showed that increasing briquetting pressure improved water resistance. The water resistance of the briquettes also increased with increasing binder content by weight. The high resistance of the briquettes to water obtained in this study showed that a moderate exposure to moisture or water would not have any serious disintegrating effect on them during transport and storage.

3.2.4.Compressive Strength

The compressive strength of the briquettes obtained in this study was ranged from 0.013 to 0.046 MPa. These values were between 1.07 and 2.34 kPa as reported by Oladeji, J.T. [16] for rice husk and corn cob briquettes and 0.34 and 0.52 MPa as stated by Nasrin et al. [17] for 100 % pulverized Empty fruit bunch and pulverized Empty fruit bunch and sawdust (50:50) respectively. The maximum value of compressive strength was obtained at compaction pressure 0.26 MPa, 20 % binder ratio and 100 % maize cob composition by weight. The implication of this is that, this briquette will suffer damage during transportation and storage than the rest briquettes. The results of the study showed that as the briquetting pressure increases the compressive strength of briquettes increases as a result of the plastic deformation. The mechanical strength of the briquettes was also found to be decreased with increasing moisture content as reported by Siritheerasas et al. [18].

3.3. CHEMICAL PROPERTIES

3.3.1.Proximate Analysis

The moisture content of the briquettes was ranged from 2.249 to 3.891 % as shown in Table 3.1. The moisture content had increased as binder ratio increases and decreases as pressure is increased. When the compaction pressure increases, more water is expelled out thereby decreasing its moisture content. As shown in Table 3.1, the volatile matter of the briquettes increased from 28.00 to 42.23 %. In terms of quality specification, the low volatile matter implies that the briquettes might not be easy to ignite, but once ignited they will burn smoothly with clean flame without smoke.

The briquettes produced with 0.05MPa compaction pressure, 20 % binder ratio and 50 % maize cob composition showed that highest ash content among the eight types of briquettes thereby might not relatively be a good candidate for fuel briquette. The implication is that high quantity of rice husk has a significant effect on the ash content of the briquettes. The lowest ash content was obtained when the blending ratio of char powder to binder was 10:3. Thus, the low ash content recorded is a reflection of the high heating value obtained in the briquettes.

Table 3.1: Proximate analysis of the briquettes in weight percentage

Briquettes samples	**Moisture content (%)**	**Volatile matter (%)**	**Ash content (%)**	**Fixed carbon(%)**
$A_{0.26}B_{20}C_{100}$	2.249	37.268	0.057	60.426
$A_{0.26}B_{30}C_{100}$	2.822	38.437	0.045	58.696
$A_{0.26}B_{20}C_{50}$	2.284	28.235	30.903	38.578
$A_{0.26}B_{30}C_{50}$	2.767	40.400	24.612	32.221
$A_{0.05}B_{20}C_{100}$	3.411	35.534	5.879	55.176
$A_{0.05}B_{30}C_{100}$	3.891	42.225	4.205	49.678
$A_{0.05}B_{20}C_{50}$	2.419	28.000	31.024	38.557
$A_{0.05}B_{30}C_{50}$	3.115	40.204	25.823	30.859

The fixed carbon of the briquettes varied from 30.859 to 60.426 %. The highest percentage fixed carbon of 60.426 % was obtained when the maize cob char powder to binder was 5:1.

3.3.2.Ultimate Analysis

The analysis in this study was determined based on the experimental values of its proximate analysis as shown in Table 3.2.

Table 3.2: Ultimate analysis of briquettes in weight percentage

Briquette samples	**Carbon (%)**	**Hydrogen (%)**	**Nitrogen (%)**	**Oxygen(%)**
$A_{0.26}B_{20}C_{100}$	83.399	5.363	1.355	9827
$A_{0.26}B_{30}C_{50}$	82.224	5.392	1.331	11.008
$A_{0.26}B_{20}C_{50}$	53.704	3.534	1.535	10.325
$A_{0.05}B_{30}C_{100}$	56.228	4.397	1.292	13.471
$A_{0.05}B_{20}C_{100}$	76.052	4.953	1.389	11.726
$A_{0.05}B_{30}C_{50}$	75.268	5.335	1.256	13.937
$A_{0.05}B_{20}C_{50}$	53.436	3,509	1.540	10.491
$A_{0.05}B_{30}C_{50}$	54.496	4.315	1.296	14.071

3.3.3.Calorific Value

Table 3.3: Calorific values of the briquette in [MJ/kg]

Briquette sample	**Volatile matter(%)**	**Fixed carbon**	**Calorific value (MJ/kg)**	
			Experimental	Theoretical
$A_{0.26}B_{20}C_{100}$	37.268	60.426	-	25.963
$A_{0.26}B_{30}C_{100}$	38.437	58.696	26.151	25.623
$A_{0.26}B_{20}C_{50}$	28.235	38.578	-	21.681
$A_{0.26}B_{30}C_{50}$	40.400	32.221	-	20.434
$A_{0.05}B_{20}C_{100}$	35.534	55.176	-	24.933
$A_{0.05}B_{30}C_{100}$	42.225	49.678	-	23.856
$A_{0.05}B_{20}C_{50}$	28.000	38.557	19.859	21.676
$A_{0.05}B_{30}C_{50}$	40.204	30.859	-	20.167

Two methods were employed for calorific value determination: using an adiabatic bomb calorimeter and correlations based on experimental values of their proximate analysis. The calorific values of the briquettes from bomb calorimeter ranged from 19.039 MJ/kg to 26.151 MJ/kg. These values were favorably compared well with 20.890 MJ/kg as reported by Oladeji, J.T. [16] for corn cob briquettes. They also compared well with most biomass energy sources: groundnut shell briquette 12.6MJ/kg, cowpea 14.372 MJ/kg, and soybeans 12.953 MJ/kg [19].

From the calorific value test, it was found that the briquette produced with 0.26 MPa, 30 % binder ratio and 100 % maize cob composition had relatively high energy content as compared to the rest briquettes. This is due to the relatively high relaxed density of the briquette. It was also obtained that the calorific values obtained from their proximate analyses varied from 20.17 to 25.96 MJ/kg were compared well with experimental values as shown in Table 3.3.

3.4. COMBUSTION PROPERTIES

3..4.1.Combustion Rate

In this study, the combustion rate of the briquettes ranged from 0.0624 to 0.0757 g/min. These values were higher than 0.0528 to 0.0555 g/min as reported by Mohd Faizal Bin Hasan [20] for briquettes with ratio 60:40 (Empty fruit bunch fibre: Mesocarp fibre) compacted at 5MPa pressure. The lowest burning rate was observed in briquettes produced with 0.26 MPa, 20 % binder ratio and 50 % maize cob composition by weight. The combustion rate of the briquettes decreased as the compaction pressure increased (Fig. 3.8) which is in agreement with the values reported by Chin, O.C. and Siddiqui, K.M. [15].

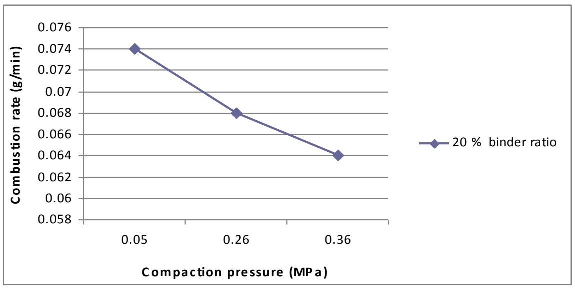

Figure 3.8: Effect of compaction pressure on the combustion rate of maize cob briquettes

The ignitability of the briquettes was also increased as the binder content increased thereby increased in combustion rate as shown in Fig. 3.9.

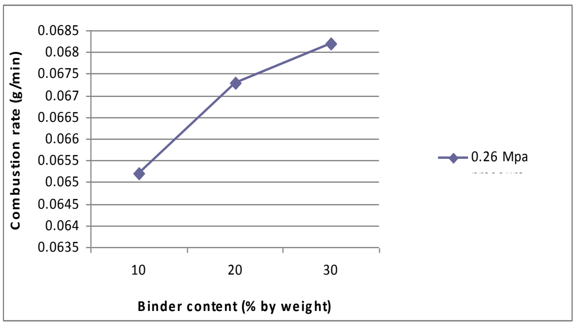

Figure 3.9: Effect of binder content on the combustion rate of maize cob briquettes

3.4.2.Heat Release

The heat release of the briquettes obtained in this study was ranged from 22.19 to 30.36 W. The lowest heat release was obtained in briquettes produced with 0.26 MPa compaction pressure, 30 % binder ratio and 50 % maize cob composition and has a calorific value of 20.4343 MJ/kg. However, the briquette produced with 0.05 MPa compaction pressure, 20 % binder ratio and 50 % maize cob composition was released more heat (24.17 W) than the former even it has less calorific value. This suggests that not only calorific value but also burning rate of the briquettes have a significant influence on the heat release of the briquettes. Thus, the higher burning rate has made it possible to release more heat.

3.4.3.Water Boiling Test

It is a well known method that measures the time it takes a given quantity of briquette to heat and boil a given quantity of water. In this study, one briquette (central hole) was stacked at a time in a locally made stove. The briquette sample-3, as shown in Fig. 3.10, which was produced with 0.26 MPa compaction pressure, 30 % binder ratio and 50 % maize cob composition attained a temperature of 75 °C in 50 minutes while briquette sample-4, 0.05 MPa, 30 % binder ratio and 50 % maize cob composition attained 78.1 °C at the same interval of time.

As shown in Fig. 3.10, the briquette is produced with 0.26 MPa pressure, 20 % binder ratio and 50 % maize cob composition, briquette sample-2, took the is longest time to attain a temperature of 73.3°C (50 min) while the briquette sample-1, produced with 0.26 MPa pressure, 30 % binder ratio and 100 % maize cob, composition took the shortest time to attain a temperature of 81.5 °C (40 min). This shows that briquette sample -2 has the least cooking efficiency. Thus, it is expected that i much quantity of it was needed to boil water. This is because of the fact that the briquette burns slowly, therefore, lots of the heat released was lost before the water boils. In general, the burning rate (how fast the fuel burns) and the calorific value (how much heat released) are two combined factors that controlled the water boiling time of briquettes

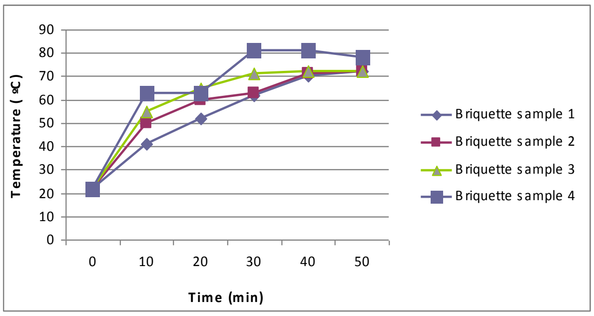

Figure 3.10: Water boiling time of the briquettes

4. CONCLUSIONS

It was observed that the physicochemical properties of the briquettes were highly affected by the briquetting pressure, binder ratio and maize cob composition by weight. It also showed that maize cob briquettes has more positive attributes of biomass fuels than briquettes produced from mixtures of rice husks and maize cobs. However, maize cobs and rice husks could be alternative feedstocks for briquette production and the briquettes produced in this way were well suited for domestic applications.

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