

Combustion Profiles of Fuel Briquettes Produced from Alkali Treated and Untreated Sugarcane Bagasse.

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ABSTRACT: There is need to discover better energy sources, that can help to sustain human life and achieve overall social, economic and environmental aspects of human development. In order to achieve this, this study was carried out to investigate the performance of biomass briquettes produced from sugarcane bagasse (SB) solid wastes and treated sugarcane bagasse (TSB) solid wastes respectively. The briquettes, comprising of 4 ratio 1 (80g: 20g) of the samples and starch were molded and analyzed. Proximate analysis, Fourier Transformed Infrared (FTIR) analysis, Scanning electron microscopy (SEM), Calorific values, density and compressive strength, among other properties, were determined for the briquettes fabricated. The briquettes developed had calorific values between 31.127MJ/Kg (SB) and 34.591MJ/Kg (TSB). The compressive strength values were 4.21kg/cm² SB to 37.77kg/cm² TSB. It took SB 3 minutes to boil 250mls of water, while TSB boiled same quantity of water in 2 minutes. The results obtained showed that both the treated and untreated sugarcane bagasse can be used for fuel briquette production. However the treated briquette samples had better performance when compared to the untreated briquette samples.

Keywords: briquette, energy, biomass, mercerization, alkalization, wastes.

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I. INTRODUCTION

To sustain human life and achieve overall social, economic and environmental aspects of human development, there is need to have access to energy.

Nigeria is blessed with quite a large number of energy resources such as coal, oil, biomass, solar, gas, wood, wind and hydro power [16]. Despite the abundant energy sources Nigeria is blessed with, there is still scarcity of energy. The availability of energy and its supply in Nigeria has become a source of constant conflict between the government and the governed. This is because, among the numerous energy resources available in Nigeria, only the oil and gas sector have been properly developed, while the industrial and domestic sectors of the economy still suffer perennial energy shortage, which has also led to acute energy crisis mostly at household levels [28]. Due to the shortfall in energy production against its demand, about 60 to 70% of the industries in Nigeria have relocated their businesses to other countries, such as China, India among others [6]; [31]. Since mid-seventies, natural energy resources have been running down and considerable attempts are being made to generate energy through renewable energy technologies because increase in energy demand can not be reduced by solely depending on natural resources in this period of industrialization and globalization [22].

Energy sources are broadly classified into renewable and non renewable energy. The renewable sources such as solar, wind, heat from the atmosphere, seas and rivers, plants and animals are considered better option because the non renewables like diesel, kerosene and gasoline among others would be expended and cannot be replenished [20]. Energy from renewable source is the fastest growing source of energy worldwide, because its consumption rate increases by 3% yearly. This is as a result of its environmental friendliness as against the environmental impacts of fossil fuel use [18].

Many Nigerian families rely solely on wood fuel for their primary energy source for cooking, as kerosene and cooking gas are becoming more expensive and most times unavailable. This resource has proven

to be unsustainable as wood is now in low supply due to its high demand. This has led to deforestation and other environmental problems such as pollution [12]. The use of fossil fuel and firewood for energy has tremendous adverse effects on both human and the ecosystem because they cause desert encroachment, deforestation which results to soil erosion, atmospheric pollution and global warming [11]. Consequently, there is need to intensify the search for other sources of energy in this era of modernization and industrialization. This prompted the desire to undertake this research.

One way of tackling the shortfall in energy generation as well as the health and environmental problems associated with burning of fossil fuel and firewood is producing briquette charcoal using sugarcane bagasse wastes.

II. MATERIALS AND METHODS

2.1 MATERIALS

2.1.1 Sample Collection and Treatment

Sampling of sugarcane bagasse was systematically carried out such that fresh bagasse samples were collected from various sugarcane selling points within Aliero town, Kebbi State. The starch used as a binding agent was obtained from Zuru in Kebbi State, and was used as received without further modification.

The collected samples were dried on direct sunlight to reduce moisture content before they were pulverized into powder form using mechanical grinding engine. The pulverized samples were sieved with a 2mm mesh to remove bigger particles that may prevent proper briquetting. Pulverization of the dried samples was necessary to increase the surface area of the components to enable thorough bonding during blending. The starch was prepared with hot water to facilitate proper mixing and blending.

2.1.2 Alkalization of the Sample

The sugar cane bagasse (SB) sample was treated with 5% sodium hydroxide (NaOH) solution for 24 hours at room temperature, in accordance with previous literature reported by [4]. The alkalization is aimed at removing the hemicellulose and lignin in the biomass as represented in the equation given below:



The treated sugarcane bagasse was washed severally with distilled water to remove the excess NaOH on the samples surface along with the lignin component of the biomass and dried in sunlight to remove moisture content.

Many briquettes were produced from both treated and untreated samples with the starch slurry using the same percentage of the binder content. Substrate to binder percentage was 80% to 20% (4:1) ratio.

Table 1. Sample Formulation

Sample type (%)	Sample code (%)	Weight of biomass	Weight of starch binder
Sugarcane Bagasse	SB	80	20
Treated Sugarcane Bagasse	TSB	80	20

2.1.3 Production of briquettes

80g of the samples were mixed with 20g of starch slurry prepared using hot water and blended. The thoroughly blended components were compressed into cylindrical briquettes. The briquettes were produced using a manual briquetting machine. Different combinations of 80g sugarcane bagasse (SB) and treated sugar cane bagasse (TSB) with 20g of starch binder were made. The mixture was fed into the briquetting machine and compressed for 5 minutes as reported by [25]. The briquettes produced were dried on direct sunlight for at least three weeks.

2.2 Proximate Analysis

2.2.1 Percentage Moisture Content (PMC)

The moisture content of briquette was determined by oven dry method. 2g of the briquette sample was kept in an oven at 105 °C for one hour. Then the oven dried sample was cooled in a desiccator and weighed. The process was repeated until the weight after cooling in a desiccator at room temperature was constant and was recorded as final weight, as presented in [1].

The percentage moisture content (PMC) of the briquette was calculated using the formula:

$$\text{PMC} = \frac{\text{Initial Weight of Sample} - \text{Final Weight of Sample}}{\text{Initial weight of sample}} \times 100 \dots \dots \dots (1)$$

2.2.2 Percentage Volatile Matter (PVM)

The percentage volatile matter (PVM) of the briquette samples was determined using muffle furnace. This is done by placing the dry residue of the briquette sample from moisture content into a muffle furnace in a

crucible at a temperature of 550°C for 10 min and weighed after cooling in a desiccator [1]. The PVM was then calculated using Equation below.

$$\text{PVM} = \frac{\text{FinalWeight}}{\text{OriginalWeight}} \times 100 \dots \dots \dots (2)$$

2.2.3 Percentage Ash Content (PAC)

The percentage ash content (PAC) was also determined by heating 2g of the briquette sample in the muffle furnace at a temperature of 550°C for 4 hours and weighed after cooling in a dessicator to obtain the weight of ash [1]. The percentage ash content was computed using the equation

$$\text{PAC} = \frac{\text{WeightofAsh}}{\text{InitialWeightofDrySample}} \times 100 \dots \dots \dots (3)$$

2.2.3 Percentage Fixed Carbon (PFC)

The percentage fixed carbon was determined by subtracting the percentage moisture, ash, and volatile matter contents from 100 [14], as shown in equation below:

$$\text{PFC} = 100 - (\text{PVM} + \text{PAC} + \text{PMC}) \dots \dots \dots (4)$$

2.3 Physical Properties

2.3.1 Density

Density of the briquettes was determined from the mass to volume ratio of the briquette in accordance to the method used by [30]. A cylindrically shaped beaker of 1000cm³ was used for the determination. The beaker was weighed empty to determine its mass and then it was filled with the sample and weighed again. The density was determined by dividing the mass of the briquette samples by the volume of the beaker, using the formula:

$$\text{Density} = \frac{\text{MassofBriquetteSample, (Kg)}}{\text{VolumeofMeasuringCylinder, (cm}^3)} \dots \dots \dots (5)$$

2.3.2 Compressive Strength

A sample of briquette to be tested was placed vertically in the compression test machine and a load was applied at a constant rate until the briquette failed by cracking [8].

2.4 Combustibility Properties

2.4.1 Calorific Value

The calorific value of the briquette samples was determined in accordance with [7]. About 0.4 g of each sample was burnt in the bomb calorimeter until complete combustion was obtained. The difference between the maximum and minimum temperatures obtained was used to compute the gross calorific values of the biomass materials as follows:

$$Q = \frac{(\text{Cwater} + \text{Ccal})(\text{T2} - \text{T1})}{\text{Wf}} \dots \dots \text{equation(7)}$$

Where: Q = Calorific value of species (kJ/kg); Wf = Weight of the briquette material sample (kg) Ccal = Heat capacity of the bomb calorimeter (kJ/kg°C); T2-T1 = Change in temperature (°C) Cwater = Heat capacity of water (kJ/kg°C)

2.4.2 Ignition Time (min)

The briquette samples were ignited at the edge of their bases with a Bunsen burner. The time taken for each briquette to fully catch fire was recorded as the ignition time using a stop watch [26]. The ignition time was computed using the formula below.

$$\text{Ignition Time} = t1 - t0 \dots \dots \dots (8)$$

Where,

T1= time the briquette ignited (min); T0= time the burner was ignited (min)

2.4.3 Afterglow Determination

The afterglow was determined to ascertain how long the individual briquette would burn before restocking when they are used in cooking and heating. The procedure of [24] was used.

2.4.4 Combustibility Test (Water Boiling Test)

This was carried out by comparing cooking efficiency of the briquettes. 100g of each briquette sample was used to boil 250ml of water using an aluminum kettle and domestic charcoal stove. The time taken for the briquettes to boil an equal volume of water under the same conditions was measured [19].

The structural properties (SEM and FTIR analyses), of the briquette samples were further investigated.

2.5 Scanning Electron Microscopy (SEM) Analysis

The effect of NaOH treatment on the surface morphologies of the treated and untreated samples were studied using PRO: X: Phenom world, Model 800-07334 scanning electron microscope. The specimens under test were prepared by putting a small quantity of the sample into the sample holder and placed on an IR, which

was retorted two times for it to appear in a compound microscope where it is leveled, changed into electron microscope to generate image. The image generated was contrasted before setting the image magnification.

2.6 Fourier Transformed Infrared (FTIR) Spectroscopy Analysis

The effect of NaOH treatment on the chemical structure of the treated and untreated samples was analyzed using FTIR.

The FTIR spectra with percentage transmittance (%T) versus wavelength (cm^{-1}) were recorded within the scanning range of $500\text{-}4000\text{ cm}^{-1}$.

III. RESULTS

Table 2: Proximate Compositions of the Briquette Samples

Sample	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)
S B	5.25±0.25	9.5±0.5	81±2	4.25±0.25
TSB	3.0±0.5	7.3±1.7	80.7±0.1	9.0±0.25

Values are mean standard deviation of triplicate results

Table 3: Physical Properties of the Briquettes

Sample	Compressive strength (Kg/cm^2)	Density (Kg/cm^3)
SB	4.21±1.12	0.4231±0.01
TSB	37.77±0.68	0.8125±0.05

Values are mean standard deviation of triplicate results

Table 4: Combustibility Test of the Briquettes

Sample	Calorific value (MJ/kg)	Ignition time (Min)	Combustibility Test (min)	Afterglow (sec)
SB	31.127±1.7	2.14±0.48	3	378±5.7
TSB	34.591±0.57	5.33±1.84	2	391±10.1

Values are mean standard deviation of triplicate results

IV. DISCUSSION

The idea behind briquette making is to ensure that all its good attributes will resonate with users so that they will consider using this fuel product over woody biomass or kerosene.

Proximate analysis of the charcoal briquettes was done to ascertain the moisture content, volatile matter present and ash contents, and to further get information on carbon content in the fuel briquettes. Determining the proximate properties is very important as it will help to know the characteristics of the briquettes.

4.1 Moisture content

Moisture content is the degree of wetness of the briquette. It was necessary to determine moisture content because according to [10], moisture has a negative effect on combustion strength of the briquette. The 5.25% of sugarcane bagasse and 3.0% of treated sugarcane bagasse fell within the 10 - 15% acceptable moisture content for storage and combustion reported by [21]. Therefore both the treated and untreated samples are good biomass materials for briquette production. However, the treated sample has lower moisture content compared to the untreated sample. This indicates that the hemicellulose decreased after the treatment.

4.2 Ash content

Ash is the non combustible material remaining after combustion of the briquette. The acceptable ash content for quality charcoal is within 1.2 - 8.9% [13]. The ash content 9.5% of sugarcane bagasse and 7.3% of treated sugarcane bagasse compared favorably with the accepted ash content for quality charcoal. The lower ash content in the treated sample makes it a better alternative energy source because according to [3], higher ash content affects combustion strength of the briquette. Therefore, the lower the ash content, the better the quality of the briquette.

4.3 Volatile matter

High percent volatile matter facilitates ignition and burning of the briquettes [33]. The volatile matter from briquettes of both samples is comparable with 75.50% of sugarcane peels briquettes reported by [15]. The high volatile matter observed in the untreated sugarcane bagasse briquettes indicates that they will ignite and burn faster than the treated samples.

4.4 Fixed carbon

Fixed carbon is the percentage of carbon available for combustion after removing volatile matter. It gives a rough estimate of heating value of the briquette and also acts the heat generator during combustion [3]. The high fixed carbon observed in the treated sugarcane bagasse, indicates that the treated sample will produce more heat than the untreated samples.

4.5 Density

The high density observed in the treated sample could be due to the fine particle size of the samples as a result of the treatment which encouraged strong bonding during compaction, as supported by the report of [29]. Briquettes density determines how long the briquette will burn; hence the treated samples with high density will take longer time to burn.

4.6 Compressive strength

The compressive strength of the treated briquettes was also higher than the untreated briquette samples. The improvement in the compressive strength of the 5% NaOH treated sample can be associated with the decrease in fibre diameter of the samples particles because of the loss of hemicellulose in the samples. Cellulose contributes to the compressive strength of a fibre through hydrogen bonding while lignin is responsible for the strength and stiffness of fibres[17]. The higher compressive strength is an indication that treated briquette samples can be transported through a long distance, and can be stored for longer period of time without damaging the briquettes energy quality.

4.7 Calorific value

The high calorific value observed in the treated briquette sample could be due to its low moisture content, high fixed carbon, and high density. This implies that the treated sample will generate more heat energy than the untreated sample.

This was confirmed in the combustibility test where the treated sample took shorter time to boil water under similar conditions.

4.8 Ignition Time

Biomass materials ignite and burn easily, but compacting biomass materials increases the density and delay ignition time of the briquette [34]. The higher ignition time observed in the untreated sample could be due to its low density caused by loose compaction.

4.9 SEM Morphologies of the Samples

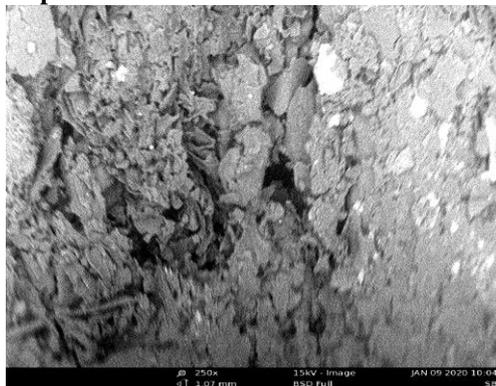


Figure 4.1: Morphology of Sugarcane Bagasse at 250x Magnification

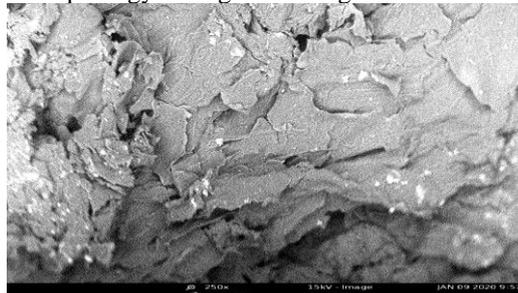
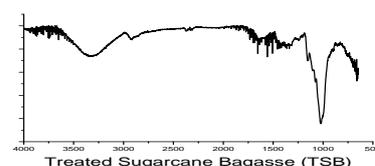
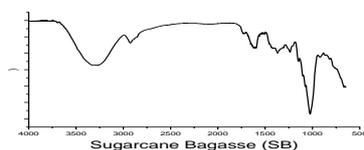


Figure 2: Morphology of Treated Sugarcane Bagasse at 250x Magnification

From the results, it can be observed that the untreated briquette sample have smooth and uniform surface. This could be due to the presence of hemicellulose, lignin and other impurities like wax and grease covering the biomass sample and protecting the cellulose inside [5]. The destructive and rough surface observed in the treated sample could be due to the penetration of NaOH into the sample to remove hemicellulose and lignin content of the biomass. The removal of the hemicellulose (OH group) provides better compaction of the fibre[9];[2].

4.10 FTIR Spectroscopy Analysis of the Briquette Samples



In order to confirm the removal of the hemicellulose from the treated sample, FTIR was used to investigate the structural change.

It was observed that the absorption around 3350cm^{-1} correspond to the hydroxyl group (OH) in both the treated and untreated samples [2]; [23]. It was observed that the intensity of OH group in the treated samples significantly reduced after SB was alkaline treated for 24hours, indicating that the alkali treatment breaks the hydrogen bonding in the OH group, and cause the reduction of the OH groups in the NaOH treated sample.

However, the absorption at 1000cm^{-1} for the untreated sample and treated samples, were attributed to C-O stretching in cellulose, hemicellulose and lignin [23]. The intensity of the bands in the samples did not show any significant change. This implies that there was no decrease in lignin content of the NaOH-treated sample because lignin is much more difficult to remove by mercerization compared to hemicelluloses [32]; [27].

V. CONCLUSION

This study examined and compared the combustion performance of treated and untreated SB wastes. The results of the tests and analysis carried out have shown that all the briquettes produced from both treated and untreated samples would make good biomass fuel. However, the briquettes produced from TSB have better attributes of bio fuel than SB. Therefore, it can be concluded that treating biomass samples is very suitable for optimum briquetting and briquette combustion performance. In view of this, an efficient alternative energy source can be obtained from waste biomass residues especially when treated and briquetted.

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