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RESEARCH ARTICLE

Comparative study of the combustion properties of briquettes produced from blends of mung beans shell, uncarbonized and carbonized sawdust

Chinyere E. Umeocho[1,2,*] **Cletus O. Ezidi**[2] **Eucharia N. Nwosu**[2] **Clementina I. Nwankwo**[3] **Kingsley C. Ezejiegu**[4] **Theresa U. Onuegbu**[1]

[1] Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka, Nigeria
[2] Bioresource Development centre, National Biotechnology Research and Development, Abagana, Anambra State, Nigeria
[3] Chemistry Education department, Federal college of Education (Technical), Umunze, Anambra State, Nigeria
[4] Department of Agriculture and Forestry, Shenyang Agricultural University, China

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Correspondence to: Chinyere E. Umeocho, Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka, Nigeria;
E-mail: chinyereumocho@gmail.com

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Abstract: In this research, the combustion properties of the briquette produced by blending mung beans shell (MBS) with carbonized danta wood sawdust was compared with that of the briquette produced by blending MBS with uncarbonized danta wood sawdust. The briquettes wereproduced atdifferentsawdust to biomass ratios (100%:0, 70%:30%, 50%: 50%, 30%: 70% and 100%:0). Cassava starch was used as a binder. Proximate analysis (moisture content, ash content, volatile matter and fixed carbon) and combustion properties (calorific value, ignition time, burning time, burning rate, specific fuel consumption and thermal efficiency) were calculated using standard methods. The results of the analyses showed that 100% sawdust briquette samples had the lowest moisture content, 4.74±0.00 for carbonized sawdust and 6.76±0.02 for uncarbonized sawdust.100% uncarbonized and carbonized sawdust briquette samples had a fixed carbon of 68.93±0.02 and 87.46%, Ash content:3.70±0.00% and 2.18±0.04%,volatile matter: 20.61±0.00 and 5.61±0.04 and calorific value: 29.401±0.0 MJ/Kg and 32.532±0.05 MJ/Kg respectively.The ignition time increase with increase in biomass load for uncarbonized sawdust samples and decrease with increase in biomass load for carbonized sawdust briquette samples. The burning time decreased from 86±0.57 mins (70% sawdust + 30% biomass) to 70±0.57 mins (100% biomass) for the carbonized sawdust briquette samples and for the uncarbonized, it ranged from 68±0.00 (70% sawdust + 30% biomass) to 71.6±0.57 mins (30% sawdust+ 70% biomass) and then dropped to 68±0.57 (100% biomass load). The burning rate decreased in carbonizedbriquette samples and increased in uncarbonized briquette samples with increase in biomass load. The specific fuel consumption for carbonized and uncarbonized sawdust briquette sample decreased with increase in MBS load. 100% carbonized and uncarbonized sawdust briquette samples had a thermal efficiency of 8.78 and 16.47 respectively. It can be concluded that blend of carbonized sawdust and mung beans shell will make a better fuel due to better combustion properties than the uncarbonized sawdust samples.

Keywords: briquette, mung beans shell, proximate analyses, combustion analyses

1 Introduction

Poor management of wastes is one of the major challenges in our society today. Wastes, when not treated or properly managed, can lead to global sustainability challenge. Most rural areas in Nigeria depend solely on farming as means of livelihood. As a result, millions of tons of biomasses are generated annually. According to Ikelle & Philip Ivoms [1], agricultural wates are the commonest waste in rural areas due to farming practices and these agricultural wates are regarded as renewable energy sources and are thought to be better options than non-renewable energy sources. Adeyi [2] defined agricultural wastes as all forms of plant-derived or animal-derived material that are considered useless either because they have no known positive economic importance or because they are not grown/raised for any specific purpose. This includes woods, herbaceous plants, crops and forest residues, animal wastes etc.

Due to the high cost of cooking gas and kerosine, most rural and semi-rural dwellers depend solely on fuel wood (firewood, charcoal, and sawdust) as their primary sources of energy for the past decades [3]. Several countries, particularly in Africa and Asia derive over 90% of their primary energy supply for cooking and heating from firewood, twigs and charcoal [4].

Some Federal Ministries and Government Agencies like National Biotechnology Development Agency and Ministry of Agriculture also engage and promote farming activities in Nigeria. All these activities have resulted to increased and constant production of agricultural wastes.

Mung beans shell is one of the major wastes generated from Bioresource Development Centre Abagana and there is need to device a means for the proper management of this waste. The invention of briquette technology has given room for efficient biomass utilization as a green energy source. The objective of this research is to produce an environmentally friendly biofuel using a blend of mung beans shell, carbonized and uncarbonized sawdust and also to compare the combustion properties of carbonized and uncarbonized briquette blends.

2 Materials and methods

2.1 Preparation of the samples

Sawdust was sourced from timber shade, Umuokpu, Awka. The mung beans shell was sourced from Bioresource Development Centre Abagana (production unit). The biomasses were air dried to reduce the moisture content, chopped into smaller sizes, ground with an electric grinder and sieved with 2.8 mm standard mesh sieve size and stored. Part of the sawdust was carbonized and stored.

2.2 Preparation of the briquette samples

The briquettes were produced following the procedure of Onuegbu et al. [5] The production was done at Nnamdi Azikiwe University, Awka with a locally made manual briquetting machine of pressure 13.4kPa. The following sawdust to biomass ratio were used; 100:0, 70:30, 50:50, 30:70, and 0:100. About 10% cassava starch based on the entire mass of the mixture was added as a binder.

2.3 Characterization of the briquette blends

2.3.1 Calorific value

An oxygen bomb calorimeter, model XRY-IA was used in determining the calorific values of the raw materials.

The heating value of the briquette was calculated using the formula:

Calorific value (J/kg) $\frac{\mathrm{Edt-Q-V}}{\mathrm{M}}$

where M = mass of the sample (kg), dt = change in temperature (Tf-To), E = energy equivalence of calorimeter per degree Celsius (E = 13039.308J), Q = change in the length chromium wire, V = titre value (i.e., volume of alkali solution used).

2.3.2 Ignition time (mins)

This was determined following the procedure described by Davies [6]. It was calculated by igniting the base of briquette and noting the time the base of the briquette took to ignite properly using a stop watch.

2.3.3 Burning time and rate

The procedure described by Davies [6] was used in determining the burning time and rate.

Burning time (minutes) = ashing time – ignition time. Burning rate was calculate using the method adopted by Onuegbu [5].

Burning rate (g / min) = $\frac{\text{mass of fuel bunrt}}{\text{time taken to burn the fuel}}$

2.3.4 Water boiling test, specific fuel consumption, thermal efficiency

These were determined following the procedures of Kuti [7] and Birtwatker et al. [8]

Water boiling time = $t_2 - t_1$

Where t_1 is the time when the kettle was placed on the stove and t_2 is the time at which the water boils.

Specific fuel consumption (SHC) = $\frac{\text{mass(g)of the fuel burnt}}{\text{quantity of water used}}$

Thermal efficiency (%) = $\frac{\mathrm{MwCpdT}}{\mathrm{mfC}}$ X100

Where Mw = quantity of water in kg, Cp =

The specific heat capacity of water = 4.187kg-1K-1

dT = $T_{final} - T_{initial,}$mf = mass of fuel burnt (kg), C= calorific value (KJ/kg)

2.4 Proximate analysis

Proximate analyses of the briquettes were determined following the procedure of (3) for moisture content, (4) for volatile matter and (5) for ash content. The fixed carbon content was determined by difference according to the formular proposed by (9).

(1) Moisture content (MC) = $\frac{\text{initial weight of sample}-\text{final weight of sample}}{\text{initial weight}} \times 100$

(2) Volatile matter (VM) (%) = $\frac{W3-W\ 4}{W3}$ X 100

W_3= Weight of the residual Sample, W_4 = weight of the sample after cooling

(3) Ash content (AC) (%) = $\frac{W5}{W6}$ X 100

Where W_5 = weight of ash W_6 = initial weight of dry sample

(4) %Fixed carbon (Fc) = 100 – (%Ac +%Vm + %Mc)

Where Ac- ash content, Vm = volatile matter, Mc = moisture content

3 Results and discussion

Table 1 and 2 show that the calorific value of uncarbonized and carbonized sawdust briquette samples decreased with increase in biomass load. 100% carbonized anduncarbonized sawdust briquette samples had a calorific value of 32.532±0.05 MJ/Kg and 29.401±0.0 MJ/Kg respectively. MBS had a calorific value decreasing from 31.265±0.005 MJ/Kg (70% sawdust+ 30% MBS) to 25.543±0.004 MJ/Kg (100% MBS) and 28.212±0.03 MJ/Kg (70% sawdust+ 30% MBS) to 25.543±0.004 MJ/Kg (100% MBS for uncarbonized and carbonized sawdust briquette samples respectively. The lower calorific value observed with the uncarbonized briquette samples can be as a result of higher ash content observed in uncarbonized sawdust samples. The implication of high calorific value is that more thermal energy will be released by the carbonated sawdust briquette samples during combustion [9]. The result obtained for the calorific value is higher than that reported by Oyelaran & Tudunwada [10], 19.1-9.92 MJ/Kg for waste paper and groundnut shell.

Table 1 Combustion properties of uncarbonized sawdust and mung beans shell briquette sample

	Calorific Value (MJ/Kg)	Ignition Time (mins)	Burning Time (mins)	Burning Rat (kg/r)	Water Boiling Time (mins)	Specific Fuel Consumption	Thermal Efficiency
100% sawdust	29.401±0.05	17.66±0.68	66±0.57	0.33	16.3±0.57	0.4	8.78
70% sawdust + 30% MBS	28212±0.03	24.79±0.56	68±0.00	0.34	17.0±0.00	0.42	8.70
50% sawdust + 50% MBS	26.647±0.00	25.61±0.69	70±0.00	0.35	17.6±0.57	0.43	8.80
30% sawdust + 70% MBS	26.403±0.00	21.40±0.52	70±0.00	0.36	19.0±0.00	0.43	9.08
100% MBS	25.543±0.01	29.13±0.17	68±0.57	0.35	21.3±0.57	0.45	9.94

Table 2 Combustion properties of carbonized sawdust and mung beans shell briquette sample

	Calorific Value (MJ/Kg)	Ignition Time (mins)	Burning Time (mins)	Burning Rat (kg/r)	Water Boiling Time (mins)	Specific Fuel Consumption	Thermal Efficiency
100% sawdust	32.532±0.05	90.37±0.54	88±0.57	0.44	10.6±0.57	0.23	16.47
70% sawdust + 30% MBS	31.265±0.05	87.71±0.25	86±0.57	0.45	15.0±1.00	0.25	16.47
50% sawdust + 50% MBS	30.204±0.03	80.06±0.02	82±0.57	0.43	15.3±0.52	0.26	17.02
30% sawdust + 70% MBS	28.993±0.04	66.90±0.59	74±0.00	0.42	18±1.00	0.26	16.78
100% MBS	25.543±0.04	29.13±0.17	70±0.57	0.35	21.3±0.57	0.45	16.91

The ignition time of a material can be affected by the material composition, density and structure [11]. For the uncarbonized sawdust briquettes, the ignition time increased with an increase in the biomass load. 100% uncarbonized sawdust samplehad ignition time of 17.66±0.68 mins. The ignition time for MBS ranged from 21.40±0.52 mins (70% MBS + 30% sawdust) to 29.13±0.17 mins (100% MBS). For the carbonized sawdust briquettes, the ignition time decreased with an increase in the biomass load. 100% carbonized sawdust had ignition time of 90.37±0.54 mins. The ignition time for MBS ranged from 29.13±0.17 mins

(100%MBS) to 87.71±0.25 mins (30% MBS + 70% sawdust). The possible cause of the inverse relationship in the ignition time of the two briquette types can be the effect of carbonization.

For the uncarbonized sawdust briquette samples, the burning time increased with increase in biomass load up to 70% biomass load and decreased at 100% biomass load, while that of carbonized sawdust briquette samples decreased with increase in biomass load. The burning time for the 100% carbonized and uncarbonized sawdust briquette samples were 88±0.57 mins and 88±0.57 mins. MBS decreased from 86±0.57 mins (70% sawdust+ 30% biomass) to 70±0.57 mins (100% biomass), for the carbonized sawdust briquette samples and for the uncarbonized, it ranged from 68±0.00 mins (70% sawdust+ 30% biomass) to 71.6±0.57 mins (30% sawdust+ 70% biomass) and then decreased to 68±0.57 mins (100% biomass load). This result is in line with the findings of Citrasari et al. [11] who observed higher burning time for Carbonized bio-charcoal (48-63 minutes) than non-carbonized bio-charcoal (22–42 minutes).

The burning rate decreased with the increase in biomass load for the uncarbonized sawdust briquette samples and increased with increase in biomass load for the carbonized sawdust briquette samples. 100% carbonized and uncarbonized sawdust briquette samples had a burning rate of 0.44 and 0.33 respectively. The burning rate of MBS ranged from 0.35 (100% MBS) to 0.45 (70% sawdust + 30% MBS) and 0.34 (70% sawdust + 30% MBS) to 0.35 (100% MBS) for carbonized and uncarbonized briquette samples respectively. The increase in burning rate for the carbonized sawdust briquette samples could be as a result of increase in porosity with increase in biomass load and vice versa.

The water boiling time increased with increase in biomass load for both carbonized and uncarbonized sawdust briquette samples. This could be as a result of decrease in calorific value with increase in biomass load. The water boiling time of MB ranged from 15.0±1.00 mins (70% sawdust+ 30% MB) to 21.3±0.57 mins (100% MB) and 17±0.00 (70% sawdust+ 30% MB) to 21.3±0.57 mins (100% MB) for carbonized and uncarbonized sawdust briquette samples respectively. 100% carbonized and uncarbonized sawdust briquette had a water boing time of 10.6±0.57 mins and 16.3±0.0 mins respectively.

Results in Table 1 and 2 show that more fuel is consumed with increase in biomass load for both carbonized and uncarbonized sawdust briquette samples. The specific fuel consumption for the 100% carbonized and uncarbonized sawdust briquette samples were 0.23 and 0.4 respectively. The specificfuel consumption for carbonized and uncarbonized sawdust briquette sample ranged from 0.25 (70% sawdust + 30% MB) to 0.45 (100% MB)and 0.42 (70% sawdust + 30% MB) to 0.45 (100% MB). The observed lower rate of fuel consumption in the carbonized danta wood sawdust briquette sample could be as a result of effect of carbonization.

The thermal efficiency for both carbonized and uncarbonized sawdust briquette samples decreased with increase in biomass load. 100% carbonized and uncarbonized sawdust briquette samples had a thermal efficiency of 8.78% and 16.47% respectively. The thermal efficiency of MB for both carbonized and uncarbonized sawdust briquette samples ranged from 16.47% (70% sawdust + 30% MB) to 16.91% (100% MB) and 8.7% (70% sawdust + 30% MB) to 9.94% (100% MB) respectively.

Table 3 and 4 show that the moisture content of the briquette samples increased with increase in biomass load in both carbonized and uncarbonized sawdust briquette samples but the uncarbonized sawdust briquette samples increased with greater percentage. 100% sawdust had the lowest moisture content, 4.74±0.00 for carbonized sawdust and 6.76±0.02 for uncarbonized sawdust. MBS had a moisture content ranging from 7.07±0.02% (70% sawdust + 30% MBS) to 7.77±0.00% (100% MBS) and 5.50±0.03% (70% sawdust + 30% MBS) to 7.77±0.01% (100% MBS) for uncarbonized and carbonized sawdust briquette samples respectively.

Table 3 Proximate analyses of uncarbonized sawdust and mung beans shell briquette sample

	Moisture Content	Ash Content	Fixed Carbon	Volatile Matter
100% sawdust	6.76±0.02	3.70±0.00	68.93±0.02	20.61±0.00
70% sawdust + 30% MB	7.07±0.02	5.97±0.02	65.03±1.27	22.67±0.05
50% sawdust + 50% MB	7.38±0.02	6.59±0.04	59.74±0.22	26.44±0.03
30% sawdust + 70% MB	7.70±0.02	6.98±0.03	57.17±0.04	28.13±0.02
100% MB	7.77±0.00	7.67±0.04	55.33±0.11	28.13±0.02

The observed Increase in moisture content with increase in biomass load can be as a result of the hygroscopic nature of biomass due to their chemical composition. The observed higher moisture content in uncarbonized sawdust briquette samples than the carbonized briquette samples can be due the decomposition of the components of biomasses which are hemicellulose,

Table 4 Proximate analyses of carbonized sawdust and mung beans shell briquette sample

	Moisture content	Ash content	Fixed carbon	Volatile matter
100% sawdust	4.74±0.00	2.18±0.04	87.46±0.06	5.61±0.04
70% sawdust + 30% MB	5.50±0.03	2.33±0.05	82.15±0.63	10.07±0.01
50% sawdust + 50% MB	6.40±0.03	2.49±0.02	79.91±0.01	11.21±0.01
30% sawdust + 70% MB	6.99±0.04	5.78±0.03	68.46±0.07	18.76±0.02
100% MB	7.77±0.00	7.67±0.04	55.33±0.11	28.13±0.02

cellulose and lignin during carbonization (at different temperatures) converting the biomass from being hygroscopic to hydrophobic nature.

The ash content of the briquette samples, as shown in Table 3 and 4, increased with increase in biomass load in both carbonized and uncarbonized sawdust briquette samples. Ash content for 100% uncarbonized and 100% carbonized sawdust briquette samples were 3.70±0.00% and 2.18±0.04% respectively. It was observed that the carbonized sawdust briquette samples had lower ash content than the uncarbonized sawdust briquette samples. That was because the materials that did not pass through the carbonization process still had a lot of compounds that easily evaporated. The ash content values obtained for both carbonized and uncarbonized danta wood sawdust briquette were lower than that obtained by (12) 28.1% for sawdust briquettes.

The volatile matter of both carbonized and uncarbonized sawdust briquette samples increased with increase in biomass load. MBS had a volatile matter ranging from 22.67±0.05 (70% sawdust+ 30% MBS) to 29.17±0.00% (100% MBS) and 10.07±0.05% (70% sawdust+ 30% MB) to 29.17±0.00% (100% MBS) for carbonized and uncarbonized sawdust briquette samples respectively. 100% uncarbonized sawdust and 100% carbonized sawdust briquette samples had a volatile matter of 20.61±0.00 and5.61±0.04 respectively.it was observed that carbonization resulted in decrease in volatile matter content. High volatile matter of the uncarbonized sawdust briquette samples implies that they will readily ignite more than the carbonized sawdust briquette samples.

The fixed carbon of the uncarbonized and carbonized sawdust briquette samples decreased with increase in biomass load. 100% uncarbonized and carbonized sawdust briquette samples had a fixed carbon of 68.93±0.02 and 87.46% respectively. MBS had a fixed carbon ranging from 55.39±0.11 (100% MBS to82.15±0.63 (70% sawdust + 30% MBS) to 55.39±0.11 (100% MBS) and 55.39±0.11 (100% MBS) to 65.03±1.27 (70% sawdust + 30% MBS) for uncarbonized and carbonized briquette samples respectively. The fixed carbon content values obtained for the briquettes were inline with that reported by (14) 73.3% for wood charcoal.

4 Conclusion

Proximate analyses of the briquettes show that mungbeans shell increased the ash content, moisture content and volatile matter of both carbonized and uncarbonized sawdust and reduced the fixed carbon of the sawdust briquettes, but the carbonized sawdust and MBS blends had lower ash content, moisture content, volatile matter and higher fixed carbon which made it a better blend. It was also observed that carbonization improved the combustion properties of the sawdust, such as the calorific value, thermal efficiency, burning time, specific fuel consumption, among others. Therefore, blending MBS and carbonized danta wood sawdust will give a better biofuel than blending it with uncarbonized danta wood sawdust.

Conflicts of interest

The authors declare that they have no conflict of interest.

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