International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 9 Sep. 2022, pp: 1177-1186 www.ijaem.net ISSN: 2395-5252

Production and Characterization of Cashew nut shells and Sugarcane Bagasse Composite Briquettesas an Alternative Source of Energy

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Date of Submission: 17-09-2022 Date of Acceptance: 28-09-2022

ABSTRACT

This research shows the resultsof a study on the determination of mechanical and combustion characteristics of briquettes from cashew nut shell and sugarcane bagasse composite using cassava starch as binder.Carbonization of cashew nut shell was conducted at a temperature of 250°C in a furnace. The charcoal produced after carbonization and the bagasse were hammer milled and sieved into three different particle sizes of 0.3, 0.6 and 0.9 mm. Briquettes were produced in the absence and presence of different binding ratio.Physical characteristics(bulk density and shattered resistance) and combustion characteristics were determined according to ASTMD standard. The optimal mix ratio that gives the best physical properties was Sample1 (40% CNS, 20% SCB, 40% binder and 0.3 mm particle size) with Bulk density of 422.46 kg/m^3, Shatter Resistance of99.61%. The optimal Sample with the best combustion characteristics was Sample 5 (50% CNS, 10% SCB, 40% binder 0.6m particle size) with the highest calorific value of 31.73MJ/kg,lowest ash content of2.4% and the highest fixed carbon of 90.02%.

Keywords: Biomass, cashew nut shell, sugarcane bagasse, Briquettes, cassava

I. INTRODUCTION

Fossil fuel is a major source of energy to many countries of the world even though the supply of the fossil fuel is limited. The usage of the fossil fuel depletes its non-replaceable natural sources and it usage is also accompanied by environmental degradation in the form of destruction to the ozone layer. It is the greenhouse gases emitted during the combustion of the fossil fuels that aid the destruction of the ozone layer (Ismaila, etal., 2013).There has been global effort towards identify replacement to fossil fuel as source of energy. Biomass is one of the most important renewable sources of energy which has been rated to be the world's fourth largest energy source after coal, crude oil, natural gas; this makes biomass as an important source of energy. Besides, biomass as an energy source is sustainable and its usage has the potential to lower greenhouse gas emission since the emission produced from the biomass is less (14% to 90%) compared to emission produced from fossil for electricity generation. (SadrulIslam and Ahiduzzaman, 2012). Biomass waste includes sugarcane bagasse, cashew nut shell, municipal solid waste, waste paper. However, the utilization of agricultural residue as solid fuel is often difficult due to the variation in their physical and combustion characteristics. If the waste is densified, they become compact to transport in addition to giving them regular shape and sizes. The dense biomass can also be tailored for efficient combustion. One of the methods of compacting biomass into a product of higher density than the original raw material is known as Briquetting (Santhosh and Sreepath, 2018).

Briquetting is a densify process used to convert biomass into a product of high density mass. It is a mechanical method for upgrades biomass into uniform solid fuel to achieve higher density, increased calorific value and less moisture content when the solid fuel is compared to its starting raw material biomass. The briquettes fuel can be used for households cooking and small scale industries for heat generation and in large industries for power generation. Briquettes help to reduce deforestation because it serves as compliment to firewood and charcoal for domestic cooking (Ajit, 2017). Cashew nut shell (CNS) and Sugarcane bagasse (SCB) were used for the production of briquettes.

Sugarcane bagasse (SCB) is the carbonaceous waste materials got after the juice has been extracted from the plant during the processing of sugar from sugarcane. The bagasse has also been used recently as a fuel in the boiler for power and heat generation due to its high calorific value which ranging between 15400 kJ/Kg to 17,700 kJ/Kg (Diannelet al., 2020) Cashew nut shell (CNS) also known as Anacardium occidentale is an important agricultural and economic crop that serve as nutritious food. It is popularly eaten throughout the world tropical region because it contains fat, proteins, and vitamin (Bart-llangeet al., 2012). Cashew nut has a reddish brown skin in between inner lining and the outer shell called testa which a holds a source of hydrolysable tennins with catechin and epitechin as the major polyphenols (Jekayinfa and Bamgboye, 2006). The energy content of cashew nut shell is remarkably high which make it as an excellent feed for gasification (Tippayawanget al., 2011). The shell has high calorific value of 24.2 MJ/Kg (Uamusseet al., 2014). Muazu and Stegemann (2015) reported that briquettes produced from pure material generated a lot of problem in terms of its usage, therefore, mixing of sugarcane bagasse and cashew nut shell together with binder were used to increase the quality of the fuel.

Binder such as starch, molasses, clays, tar is a substance with adhesive property that help in agglomerating the briquetting material to enhance its calorific value, improve its density, durability, and compressive strength (Kumutai and Kumutai, 2019). For this study, cassava binder is used to improve the strength of the briquettes.

The aim of this work is to characterize the briquettes produced from combination of CNS and SCB using starch as binder.

II. MATERIALS AND METHODS

2.1 Preparation of cashew nut shell and sugarcane bagasse composite

Cashew nut shell was obtained from Olam Edible nut industry in Afon, Asa Local Government, Kwara State and sugarcane bagasse was obtained at LafiagiKwara State, Nigeria. The two biomasses were sorted to remove impurities mixed with them such as stones, dirt etc. SCB was sun dried to reduce the moisture content to approximately 10% as suggested by Pandy and Dhakel (2013).CNS was sun dried for 4 days and then carbonized in a furnace at a temperature of 250 ^{0}C for 3 hours based on the literature of related (Kimutai and Kimutai, 2019). CNS and the dried bagasse were hammer milled and sieved to obtain samples of three different particle sizes: 0.3 mm, 0.6 mm, 0.9 mm

The starch obtained from cassava industry in Ilorin, Kwara State was turned into a smooth paste by dissolving the weight in gram of each of the binder in 12 cm^3 of water at ambient temperature and then 80 cm^3 of boiling water which was stirred gently while hot to form a smooth homogeneous gelatinized starch solution.Plate 1(a), 1(b), 1(c) show the prepared SCB, CNS and prepared starch.

Plate:1(a): Sugarcane Bagasse (SCB)**Plate1(b):** Cashew Nut Shell (CNS)

Plate 1(c): Prepared Starch

2.3 Briquettes Production Process

CNS, SCB and binder were mixed based on the ratio presented in Table 1and the values of parameter measured are presented in percentage which resulted in the total number of 15mixtures. 40g each of the mixture of CNS and SCB with and without binder was fed into a manual cylindrical briquetting fabricated mold of diameter 70mm. Four replicate of the briquettes of the mixture and also four replicate of each of the briquettes without binder were produced. The produced briquettes were stored under room temperature for 14 days to dryImeh (2017). The briquettes were produced at the Forestry Research Institute of Nigeria, Jericho Ibadan Nigeria and transported to Kwara State University Malete for analysis.

Table 1: Production of Briquettes at Different Mix Ratio and Particle Size

Sample	CNS (%)	SCB (%)	Binder (%)	Particle size(mm)
1	40	20	40	0.3
2	40	20	40	0.6
3	40	20	40	0.9
4	50	10	40	0.3
5	50	10	40	0.6
6	50	10	40	0.9
7	60	20	20	0.3
8	60	20	20	0.6
9	60	20	20	0.9
10	70	10	20	0.3
11	70	10	20	0.6
12	70	10	20	0.9
13	50	50	20	0.3
14	50	50	20	0.6
15	50	50	20	0.9

2.4 Charactrization of Briquettes

Characterization was done to detrmine the physical properties (bulk density, shatter resistance), combustion properties (moisture content, ash content, fixed carbon, volatile matter, calorific value) and elemental composition (carbon, hydrogen, nitrogen and oxygen contents) of CNS and SCB composite briquettes

❖ Briquettes Density determination

The density of the briquettes was determined using American Society of Agricultural and Biological Engineers (ASABE S269.4). The method was based by measuring the volume of each of the briquette and it is mass. The volume was measured by using the Venire calipers to measure the height and diameter of each of the briquettes. The average measurement was taken in each case (Ninoet al., 2010). Density of the briquettes was then calculated by using equation 1

$$P_b = \frac{M_b}{V_b} \quad 1$$

P_b = Density of the briquettes in kg/m^3
M_b = Mass of the briquettes in kg
V_b = Volume of the briquettes in m^3

❖ Shatter Resistance Determination

The resistance assists in determining the durability of the briquettes most especially when taking the briquettes from one place to another. Not only assisting in briquetting transportability but also assisting in determining the safe height of briquette production.

Shatter Resistance of the briquette was determined in accordance with the ASTM D440 – 86 (1998) method adopted by Law et al., (2018).

International Journal of Advances in Engineering and Management (IJAEM)
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The briquette samples were dropped onto a solid base from 1m height for 10 times. The fraction of the briquette retained was used as an index of briquette breakability. The remaining portion was reweighed; shatter resistance of the briquettes was conducted by using the equation 2

$$\text{Shatter Resistance} = 100\% - \left[\frac{m_0 - m_i}{m_0}\right] \times 100 \quad (2)$$

m_o= Initial mass of the briquettes
m_i = final mass of the briquettes

2.4.1 Proximate analysis of CNS and SCB composite briquettes

Proximate analysis of CNS and SCB composite briquettes were conducted to determine the percentage of moisture contents, percentage of volatile matter, percentage of ash contents and the percentage of fixed carbon

❖ Determination of Moisture Contents

Moisture content was determined based on ASTMD 3173-11 standard. One grams of each of the sample was oven dried for 24 hours until constant weight was achieved (Dickens, 2016). The percentage of moisture content is expressed using equation 3

$$\% Mc = \left(\frac{x_1 - x_2}{x_1}\right) \times 100 \quad (3)$$

Where x_1 =Initial mass of the sample in gram
x_2= final mass of the sample in gram
%Mc = Percentage of moisture content

❖ **Determination of Volatile Matter**

The percentage of volatile matter of the briquettes was determined using the standard method ASTMD3172. In this method, the previously oven dried briquettes were put in a covered crucible in order to avoid contact with air during the escape of volatile. The covered crucible was placed in a furnace at 925^{0}C and heated for 7 minutes (Manyuchiet al., 2018). The percentage of volatile matter (V_m) was calculated using equation 4

$$\%V_m = \frac{\Delta m}{mi} \times 100 \quad (4)$$

%V_m= Percentage of volatile matter
Δm= Change in weight in gram
M_i= Initial weight of the sample

❖ **Determination of Ash Content**

Ash content was determined in accordance with ASTME 830-87 standard where one gram of each of the sample was placed into muffle furnace and heated gradually to 725^{0}C for a period of 1 hour in a muffle furnace.(Dickens, 2016). The crucible was removed and put in desiccators and allowed to cool to room temperature.
The ash content can be expressed using equation 5

$$\% \text{Ash} = \frac{P - Q}{R} \times 100 \quad (5)$$

Where:
P = Mass of the crucible plus ash residual (g)
Q= Mass of the empty crucible (g)
R = Mass of the sample used (g)

❖ **Determination of Fixed Carbon**

The fixed carbon of the briquette was determined by subtracting the addition of percentage of the moisture content, volatile matter, and ash content from 100 as shown in equation 6

$$Fc = 100 - [M_c + A_c + V_m] \quad (6)$$

F_c = Fixed carbon in percentage

❖ **Determination of Calorific Value**

The calorific value of the briquettes was determined using the fixed carbon and volatile matter as it was discussed by Kimutai and Kimutai (2019) in equation 7

$$C_v = 2.32\,(1476F_C + 144V_m)/1000\text{MJkg} \quad (7)$$

Where:
C_v= calorific value of the briquette
F_c= fixed carbon
V_m= Volatile matter

2.4.2 Ultimate Analysis of CNS and SCB Composite Briquettes

Ultimate Analysis of CNS and SCB composite briquettes were conducted to determine the percentage of carboncontents, hydrogen contents, nitrogen contents and oxygen contents.

❖ **Determination of Carbon, Hydrogen, Nitrogen and Oxygen Content**

The carbon, hydrogen, oxygen, and nitrogen content of the briquettes were determined from the parameter of proximate analysis as it was discussed by Uamusseet al., (2014) in the determination of ultimate analysis of cashew nut shell. The carbon content, hydrogen content, nitrogen content and oxygen content can be expressed using equation 8, 9, 10 and 11

$$C = 0.97Fc + 0.7\,(V_m - 0.1A_c) - M_c\,(0.6 - 0.01M_c)\% \quad (8)$$

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$= 0.03F_c + 0.086(V_m - 0.1A_c) - 0.0035M_C^2 (1-0.02M_c)\%$

$N_2 = 2.10 - 0.020\ V_m\%$ 9

$O_2 = 100 - (C+H+N+A_c)\%$ 10

III. RESULTS AND DISCUSSION

Production and Characterization of Fuel Briquettes from CNS and SCB Composite

Sixty (60) circular shape briquettes of diameter 70 mm and length 28 mm were produced. The results are shown in plate 2

Plate 2: Briquettes Produced

3.1 Bulk Density

The result obtained in Table 2.shows that the bulk density is inversely proportional to the particle size. Samples 1,4 and 10 of particle size 0.3mm have highest bulk density of 420.46, 420.25, and 422.40 kg/m^3 but reduced to 319.57, 302.825 and 322.43 kg/m^3 as insample 2 of particle size 0.6 mm, samples 3 and 6 of particle size 0.9 mm. the smaller the particle size, the larger the bulk density of the briquette produced. This is due to the fact that the porosity index of the smaller particle size (0.3 mm) is lower than medium (0.6 mm) and larger particle size (0.9 mm) .This agrees with finding of Dickens (2016) that density reduced with increase in particle size.The results in Table 2 also show that the briquettes without binder have the least bulk density as in samples 13,14 and 15 respectively. The result showed that the addition of binder increasesthe bulk density of briquettes.

3.2 Shatter Resistance

Table2Showed that particlesize of the briquettes is inversely proportional to the shatter resistance. This is explained from the result obtained in Table 2 where Sample 1 and 10 of the smaller particle size of 0.3 mm havethe highest shatter resistance of 99.61% and 99.60% and the larger particle size of 0.9 mm as in Sample 6 and 12 have the lowest particle size of 46.41% and 23.56%. Also the briquettes without binder with particle size of 0.9 mm has shatter resistance of 29.97%.Decrease in particles size leads to increase in surface area which resulted in increased gelatinization and gives better binding. This result agrees with the Dickens (2016) where it was found that the smallest particles of 3mm has highest shatter index of 98.41%. The result also agrees with the research done by Habib et al., (2014) that larger particle briquette has low durability due to its coarseness.

Table 2: Physical Characteristics of CNS and SCB of composite briquettes

Run	CNS	SCB	Binder	Particle size	Bulk density	Shatter Resistance
1	40	20	40	0.3	422.46	99.61
2	40	20	40	0.6	319.59	99.50
3	40	20	40	0.9	302.825	98.04
4	50	10	40	0.3	420.25	99.4
5	50	10	40	0.6	396.52	57.72
6	50	10	40	0.9	322.43	46.41
7	60	20	20	0.3	368.61	97.58
8	60	20	20	0.6	349.56	96.05
9	60	20	20	0.9	334.11	94.21
10	70	10	20	0.3	422.4	99.60
11	70	10	20	0.6	353.31	77.05
12	70	10	20	0.9	337.65	23.56
13	50	50	20	0.3	27.81	37.26
14	50	50	20	0.6	25.91	30.43
15	50	50	20	0.9	22.63	29.97

3.3 Characterization of CNS and SCB composite briquettes

3.3.1 Moisture content

Moisture content affects the burning characteristics of the briquettes as high moisture content consumed a lot of heat in drying the fuel. Sample 2 from Table 3 (40% CNS, 20% SCB, 40% binder, and 0.6 mm particle size) has highest moisture content of 9.41% and Sample5 (50% CNS, 10% SCB, 40% binder, 0.6 mm particle size) has the lowest moisture content of 4.87%. The initial moisture content of the raw materials determines the moisture content of the briquettes produced as some of the moisture evaporated during the briquetting production processes. The result above shows that the moisture content of a fuel does not vary significantly with particle size. The moisture content was exceedingly high for the sample without binder with the moisture content of 11.95%. This agrees with finding of Kimutai and Kimutai (2019) that the addition of binder reduced the moisture content of the briquette. The above moisture content is still within the tolerance level as the tolerance level of moisture content for making briquettes is between 8-12%. Briquette with moisture content above the tolerance level reduces thermal efficiency and burning rate (Imehet al., 2017). Briquettes with high moisture content resulted in briquetting swelling and degradation occur easily(Zubairu and Gana, 2014).

3.3.2 Volatile Matter

The volatile matter in a briquette seems not to have bearing on the energy value of the briquette. A sample witha lowvolatile matter of 0.73% and another with the high volatile matter of 2.95% both have about the same calorific value of 29.5%, see samples 1 and 10 in Table 4. It is inconclusive whether the binder influences the volatile matter contents even though the sample without binder recorded the least percentage of volatile matter of 0.35% as in Sample 13. This result conflicts with the result obtained by Kimutai and Kimutai (2019) where the addition of binder reduced the volatile matter in the briquettes, but this may be due to equal proportion of CNS and SCB (50% CNS, 50%SCB) in their formulation.

3.3.3 Ash Content of CNS and SCB Composite Briquettes

The ash contents of the briquettes were dependent on the use of binder. Briquettes without binder have the highest ash contents up to 11.6% as shown in Sample 13 (50% CNS, 50% SCB, 0% binder, 0.3 mm particle size). Samples with binder have much reduced ash contents when compared to a briquette without binder. Of the samples with binder, Sample 10 has the highest ash content (7.8%) while Sample 1 has the lowest ash yield with a value of 2.01%. This agrees with a study by Kumutai and Kumutai (2019) that the addition of binder reduces the amount of ash produced when the briquette burns to produce energy. However,the ash yield in the briquettes presented in this work increases with increased content of cashew nut shellas in Sample 10 with 70% CNS and 0.3 mm particle size.

3.3.4 Fixed Carbon

The fixed carbon in a briquette defines how much of the briquette could burn to produce thermal energy. The thermal energy comes from the heat of combustion of the carbon to establish the calorific value of the briquette. Increased carbon contents of the briquettes mean reduced amount of the remaining materials in the briquette—see Table 3. The recommended amount of fixed carbon in a briquette is 80.5% if it is for domestic source of heating(Zubairu and Gana, 2014). Sample 5 has the highest fixed carbon with a magnitude of 90.02%. This is 9.5% more than the recommended amount of fixed carbon as against the 3.4% of the sample with the lowest fixed carbon contents sample 9. The high fixed carbon in the produced briquette implies that the combination of CNS and SCB is suitable for making briquettes for domestic application.This is desirable in that a briquette with high fixed carbon content will produce smokeless flame which enhances the heating value and combustion duration of the briquettes. This is follows from the workof Kimutai and Kimutai (2019) on the combustion properties of briquettes. The fixed carbon contents in a briquette areenhanced if the briquette is made with a binder material(Kimutai and Kimutai 2019).

3.3.5 Calorific Value

This is the most crucial factorin determining burning characteristics of the briquettes as a fuel. It describes the latent energy of a fuel material. The briquettes reported in this work have favorable calorific values when compared to the work of other researchers who have also made composite briquette using CNS but with mango seed shell, MSS, (Dickenson (2016). The briquette reported in this work has calorific values ranging between 26.33 MJ/Kg and 31.73 MJ/kg. The lower and the upper limit of the calorific value range surpass the 25.82 MJ/kg recorded by Dickenson (2016) by 0.51 MJ/kg and 5.91 M/kg respectively. This improved performance of the SCB and CNS composite briquette could be attributed to the reduced moisture content of 6.9% ± 1.9% across samples. Increased moisture content compromises the calorific value of briquettes, the sample with the highest moisture content (11.95%) shows the lowest calorific value of 26.23%. The low moisture content of sample 5 (4.87%) supports its high calorific value of 31.73 MJ/kg.

Table 3: Proximate analysis of cashew nut shell and sugarcane bagasse composite briquettes

Sample size (mm)	CNS content(%)	SCB content(%)	Binder	Particle Moisture	Ash	Volatile matter	Fixed carbon (%)	Calorific value (MJ/Kg)
1	40	20	40	0,37.96	2.01	2.95	87.08	29.58
240	20		40	0.69.41	4.50	1.53	84.56	30.49
3	40	20	40	0.96.25	3.1	1.8	88.50	30.91
450	10		40	0.39.02	4.02	2.47	84.49	29.76
5	50	10	40	0.64.87	2.4	2.71	90.02	31.73
650	10		40	0.96.60	5.39	2.68	85.33	30.11
760	20		20	0.36.35	5.99	2.07	85.59	29.61
860	20		20	0.66.51	5.47	1.6	88.50	30.91
960	20		20	0.96.60	6.70	2.79	83.91	29.74
1070		10	20	0.36.03	7.80	0.73	85.44	29.54
1170		10	20	0.65.16	6.76	2.1	85.98	30.27
1270		10	20	0.96.34	4.77	2.76	86.13	30.22
1350		50	0	0.35.60	11.6	0.35	78.34	26.94
1450	50		0	0.65.03	5.6	1.62	81.0	28.27
1550	50		0	0.911.95	5.03	1.97	74.48	26.23

3.4 Ultimate Analysis

The ultimate analysis provides the elemental composition of the briquettes to complement the results from the proximate analysis. The major elements recorded from the ultimate analysis are carbon, nitrogen, hydrogen, and oxygen. Carbon and hydrogen burn to give off high amount of thermal energy given that both elements have calorific values of 30.8 MJ/kg and 141.7 MJ/kg respectively. It is therefor expected that the briquette sample with higher amount of carbon and hydrogen should have high calorific value. However, hydrogen will burn to produce water/steam which may compromise the heating value of the flame produced. Nitrogen presence is undesirable because it burns to produce greenhouse gases as oxides of nitrogen (Kimutai and Kimutai 2019). Based on the aforementioned premise, the proceedingparagraphspresent the elemental distribution in the briquette samples, their respective calorific values and other indexes. (Table 4)

3.4.1 Carbon Content

The carbon content recorded from the briquette samples ranges between 67% and 86%. Sample 5 which have shown the highest fixed carbon content and calorific value present with the highest carbon content of 86.38%, this is much expected. The presence of binder seems to raise the carbon content as the binder-less briquettes have the least carbon contents of67–74%. Overall, the high percentage of carbon in the briquettes depict the briquettes produced could function as high grade fuel because carbon plays significant role in increasing the calorific value of the fuel. This resultagree with findings of Ismaila, et al, (2013) that high carbon content contributes positively to the heating value of the briquettes.

3.4.2 Hydrogen Content:

The results obtained show that Sample 5 has the highest percentage of hydrogen content of 3.38% while the briquette without binder has the least percentage of hydrogen content of 1.85%.The result obtained is favorable because hydrogen though has high calorific value of 141 MJ/kg it is desirable in small amount to reduce the moisture content of the samples.

3.4.3 Oxygen Contents:

Table 4 shows the sample 4 has the highest oxygen content of 12.65% and Sample5 has the least oxygen content of 5.81%. High oxygen is not advisable in the biomass as it reduces the calorific value of the fuel. The oxygen content can be controlled by the use of binder. Briquette without binder has more oxygen content compared to the one with binder. The result is in an agreement with the result obtained by Kimutai and Kimutai(2019) that the addition of binder reduces the oxygen content of the biomass. It will however be interesting to find out the optimum binder quantity that keeps the oxygen content to a critical minimum percentage. In the results presented in this work, a 40% binder seems to raise the oxygen contents to an average of 8% while a 20% binder gives and average of 7%.

3.4.5 Nitrogen Contents:

The result obtained in Table 4 shows that there is not much difference in the amount of nitrogen content both with binder and without binder. According to Kimutai and Kimutai (2019) who explained that nitrogen contentin the biomass increase the release of toxic gasses like (NO_x) and asphyxiants (HCN) which are not desirable in the biomass, and which endanger the life of living organism.

Table 4: Ultimate Analysis of CNS and SCB composite briquettes

Sample	CNS(%)	SCB(%)	Binder(%)	Particle size(mm)	C(%)	H (%)	N (%)	O (%)
1	40	20	40	0.3	82.25	2.66	2.041	11.04
2	40	20	40	0.6	78.02	2.89	2.069	12.521
3	40	20	40	0.9	83.53	3.21	2.064	8.096
4	50	10	40	0.3	78.80	2.48	2.051	12.65
5	50	10	40	0.6	86.38	3.38	2.046	5.81
6	50	10	40	0.9	80.74	3.12	2.046	8.70
7	60	20	20	0.3	80.65	3.08	2.059	8.22
8	60	20	20	0.6	81.08	3.07	2.068	7.712
9	60	20	20	0.9	79.35	1.88	2.044	10.0258
10	70	10	20	0.3	79.59	3.0	2.085	7.525
11	70	10	20	0.6	81.57	3.13	2.058	6.482
12	70	10	20	0.9	81.74	3.17	2.045	8.275
13	50	50	0	0.3	70.05	1.85	2.093	18.10
14	50	50	0	0.6	74.36	2.25	2.068	13.42
15	50	50	0	0.9	67.07	2.37	3.061	16.89

IV. CONCLUSION

It was observed that particles size, presence of binder had significant effect in the physical and combustion properties of briquettes.The optimal mix ratio that gives the best physical properties was Sample 1 (40% CNS, 20%

SCB, 40% binder and 0.3 mm particle size) with the highest Bulk density of 422.46 kg/m^3 and shatter resistance of 99.61% .This is due to the smaller particles of 0.3 mm in the mixture.

The optimal Sample with the best combustion characteristics were Sample 5 (50% CNS, 10% SCB, 40% binder 0.6m particle size) with the highest calorific value of 31.73 MJ/Kg, lowest ash content of2.4% and fixed carbon of 90.02 %.

The result obtained showed briquettes produce from combination of Sugarcane Bagasse (SCB) and Cashew nut shell (CNS) are good for domestic application since the calorific value obtained is 31.73 MJ/ Kg.

V. RECOMMENDATIONS

Further studies can be done to

1. Carbonize both SCB and CNS and then study the effect carbonization temperature on mechanical and combustion characteristics of the composite briquettes.
2. Study the effect of compaction pressure on mechanical and combustion characteristic of SCB and CNS.

REFERENCES

[1]. Ajit, K., Madhuka, R., and Krishnendu, K. (2017) Densification of biomass by briquetting. International Journal of the recent scientific research **8**, 20561-20568.

[2]. ASABE Standards 269.4 Cubes, “Pellets and Crumbles definitions and methods of determining density, durability and moisture content,” in ASABE standards, St. Joseph, MI, USA

[3]. Bart-Plange, A., Addo, A., Kumi, F., and Plegue, K. (2012)Some moisture dependent thermal properties of cashew kernel (AnarcardiumOccidentale “L), Australian Journal of Agricultural Engineer**3**, 65-69.

[4]. Dianne Plummer, M. Sc., P. E., Rémon, G., and Yanique, D. (2020) The experimental Production of Fuel Briquettes from Jamaican Biomass, Proceedings of the 18thLaccei International Multi-Conference for Engineering, Education and Technology, “Engineering Integration and Alliances for a Sustainable Development” “Hemispheric Cooperation or Competitiveness and Prosperity on a knowledge-Based Economy,” University of Technology, Jamaica

[5]. Dickenson, O. H., (2016). Determination of Mechanical and Combustion Characteristics and Mango Seed Shells Composite Briquettes

[6]. Imeh, E.O., Ibrahim, A., Mohammed, D., Alewo O.A., Stanley, I.R.O and Opeoluwa, O.F. (2017) Production and Characterization of Biomass Briquettes from Jannery Solid waste **2**, 17

[7]. Jenkayinfa, S. O., and Bamighoye, A. L. (2006) Estimating energy requirement on cashew (Anacardiumaccidentale L.) nut processing operations Energy **31**, 1305-13, doi:10.10161) energy. 2005.07.001

[8]. Kimutai, S. K., and Kimutai, I. K. (2019) Investigation of Physical and Combustion Properties of Briquettes from Cashewnut Shell and Cassava BinderInternational Journal of Education and Research **7**(11):15-26.

[9]. Manyuchi, M.M., M, Mbohwa, C. and Muzenda, E. (2018) Value addition of coal fines and sawdust to briquettes using molasses as a binder, South African Journal of Chemical Engineering **26**, 70-73.

[10]. Niño, A., Arzola, N. and Araque, O. (2020) Experimental Study on the Mechanical Properties of Biomass Briquettes from a Mixture of Rice Husk and Pine Sawdust, Jounal of Energy**13**, 1060

[11]. Pandey, S., Dhakal, R.P., (2013) Pine Needle BriquettesA Renewable Source of Energy, International Journal of Energy Science**3**(3): 254-260.

[12]. Santhosh U., and Sreepathi, L. K. (2018) Production and Quality testing of fuel briquettes made from pongamin and tamarind shell, Indian academy of science**58**.doi:10.1007/512046-018-0836-8

[13]. Sen, R., Wiwatpanyaporn, S., and Annachhatre, A. P. (2016) Influence of binders on physical properties of fuel briquettes produced from cassava rhizome waste, International Journal of Environment and Waste Management, **17**(2):158-175

[14]. Shankar, T. J. and Bandyopadhyay, S. (2006). Scanning Electron Microscope Study of Fish and Rice Flour Coextrudates in a Mendez-Vilas (Ed) Proceedings of Modern Multidisciplinary applied Microbiology, Exploiting Microbes, and their Interactions, Wiley-VCH, 791-795

[15]. Shankar, T. J., and Bandyopadhyay, S. (2005) Process variable during single screw extrusion of fish and rice flower blendsJournal of food processing and preservation**29**, 151-164
[16]. Shiferaw, Y., Tedla A., Mellese C., Mengistu, A., Merene E. and Awel, N. (2018) Conversion of Coffee residue waste and Eucalyptus globules leaf extract into an alternative solid fuel.
[17]. Shrivastava, M. (1990) Briquetting of Rice Husks under Hot Compression, Proceedings of the International Agricultural Engineering Conference and ExhibitionBankok, Thailand, 666-672.
[18]. Shuying, L. Guocai, W., and Delaquil, P. (2001) Biomass gasification for combined heat and power in Julin Province, People's Republic of China Energy for Sustainable Development, **1** 47-53.
[19]. Singh, R. N., Bhoi, P. R., and Patel, S. R., (2007) Modification of commercial briquetting machine to produce 35mm diameter briquettes suitable for gasification and combustion. Renewable energy**32**, 474-79
[20]. Sokhansanj, S.S., Mani, XiBi, Zaini, P., and Tabil, L. (2005)BinderlessPelletization of Biomass presented at the ASAE paper No 056061 ASAE 2950 Nile Road, St. Joseph Mi 49085-9659 USA.
[21]. Tabil, L. G., Sokhansaj S., Tyler, R. T. (1997). Performance of Different Binders during Alfalfa Pelleting, Canadian Agricultural Engineering, **39** (1): 17-23.
[22]. Tabil, L., and Sokhansaj, S. (1996). Process conditions affecting the physical quality of alfifapellets Transactions of ASAE, **12** (3): 92-99.
[23]. Thomas M., Van Vliet T., Vander Poel A. F. B., (1998). Physical Quality of Pelleted Animal Feed Technology
[24]. Thomas, M., Huijnen, P.T. H. J., Van Vliet, Van Zuilichem, T.D.J. and vanderPoel A. F. B.(1999) Effects of Process conditions during expander processing and pelleting on starch modification and Pellet Quality of Tapioca. Journal of the Science of Food and Agriculture 79, 1481-1494.
[25]. Uamusse, M.M., Persson, M/K., Tsamba, J.A., (2014) Gasification of Cashewnut shell using Gasifier Stoven Mozambique Journal of Power and Energy Engineering**2**, 11-18
[26]. UNEP, Converting waste management to a resources compendium of Technology, United Nations Environmental Programme, Japan 2009
[27]. Wahlund, B. Yan, J., and Wesermark, M. (2001) Comparison of Co_2 Reducing Alternatives for Heat and Power Generation: Co_2 capture and fuel shift to biomass in Greenhouse Gas Control Technology Proceedings of Fifth International Conference. Collingwood: CSIRO. Pp 229-234.
[28]. Wood, J. F. (1987), The Functional Properties of Feed Raw Material and the Effect on the Production and Quality of Feed Pellets, Animal Feed Science and Technology**18**, 1-17.
[29]. Yaman, S. M., Sahan, H., Haykiri-acmak and Kucukbayark, S. (2000) "Production of Fuel Briquettes from Olive Refuse and Papermill waste, Fuel Processing Technology, **68**, 23-31.
[30]. Yehia K. A. (2007) Estimation of Roll Press Design Parameter Based on the Assessment of a Particular Nip Region. Powder Technology, **177**, 148-153, 2007
[31]. Yoshid, Y., Dowaki, K., Malsumura, Y., Matsuhashi, R., Li, D., Ishitan, H., and Komiyama, H., (2003). Comprehensive comparison of efficiency and CO_2 emissions between biomass energy conversion technologies-position of super critical/water gasification in biomass technologies Biomass and Bioenergy**25**, 257-272
[32]. Zandersons, J. J., Gravitis, A. Zhurinah, A., KokOrevics, Kallavns, U., and Suzuki C. K (2004) Carbon materials obtained from self-binding sugarcane and Deciduous wood Residues Plastics, Biomass and Bioenergy**26**, 345-360.
[33]. Zhan, K., Chang, J., Guan, Y., Chen, H., Yang, Y., and Jiang, J. (2013)Ligonocellulobic biomass gasification technology in China Renewable Energy**49**, 175-184
[34]. Zubairu and Gana, S.A., (2014) Production and Characterization of Briquettes Charcoal by Carbonization of Agro-wasteJournal of Energy and Power, 4(2): 41-47.