Journal of Engineering Research and Application www.ijera.com
ISSN : 2248-9622, PP 01-06

RESEARCH ARTICLE OPEN ACCESS

Study of Strength Properties and Combustion Characteristics of Blends of Castor Seed Shell and Coffee Husk Fuel Briquettes

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ABSTRACT: *Biomass has the highest energy generation potential to replace fossil fuel as it reduces the carbon emissions into the atmosphere. Agro residue is one of the important sources of biomass to produce Biofuels. This paper investigates and discusses the quality of fuel briquettes produced from the blends of two agro residues i.e. Coffee husk (CH) and Castor seed shell (CSS) in various mixing ratios of 20:80, 40:60, 60:40 and 80:20. The briquettes were produced at different briquetting pressures such as 60MPa, 70MPa and 80MPa at ambient temperature. The effect of briquetting pressure on compressed density, relaxed density, relaxation ratio, shattering index were evaluated. The mathematical regression model between the briquetting properties and the independent variables (mixing ratio and briquetting pressure) were developed using SPSS statistics software and briquette property values obtained from mathematical models compared with experimental values. The results suggest that the addition of more percentage of CH in the briquette decreases the mechanical property (shattering index) and is not desirable. Thus, the briquette produced with a mixing ratio of CH:CSS=20:80 at 80MPa had considered as a better property briquette and combustion characteristics such as proximate analysis, ultimate analysis, calorific value were determined for this sample; and compared with other briquettes. The results confirmed that the combustion characteristics of briquettes were comparable with other type of briquettes.*
Keywords*- Biomass, Briquette, Coffee husk and Castor seed shell.*

I. INTRODUCTION

The release of carbon from fossil fuels is not a fraction of the 'natural carbon cycle' and it will be a great burden for next generation. Hence, renewable energy is the core strategy with respect to future climate policies. Among the renewable energy resources, biomass is used for meeting myriad human requirements including energy and currently biomass resources amounts 14% of global energy and 38% of energy in developing countries [1]. Municipal waste, agricultural waste and energy crops are the three important sources of biofuels for the production of energy, but due to their low energy content per unit volume and low density, it is difficult to replace it with coal, this can be overcome by briquetting [2,3].Briquetting is a process of compacting low density biomass material into high density solid fuel of about 900 to 1300 kg/m^3 which reduces the problems of handling, storage ,transportation and improves the combustion performance because of a more uniform fuel size [4].

Lela et al. [5] done the optimization of composition of briquette using cardboard waste and sawdust for high calorific value, maximum compressive strength and low ash content. They concluded that calorific value of 17.41 MJ/kg, compressive strength of 149.54 N/mm and 6.62% of ash content were obtained when compressive force of 588.6KN and mass of sawdust 46.66% were used without any drying procedure. Okey and Kingsley [6] evaluated the fuel briquettes produced from rice husk with palm oil mill sludge as an additive and concluded that both combustion and physical properties of briquettes are good for a blending ratio of 1:1.

Of the biomass resources, agriculture sector generates huge amount of residues which can be considered as a major energy source for present and future. India is the number one producer of castor seed in the world and generated 17.33 lakh tones during 2014-15 with a residue production ratio 0.35 which was calculated in the present study, generates 6 lakh tones of castor seed shell [7]. Also India majorly contributes in the production of coffee in the world and produced 3.2 lakh tones of coffee with a residue production ratio of 1[8] generates 3.2 lakh tones of coffee husk [7].

In the above context, the objective of this work was to utilize the CH and CSS for the production of briquettes by mixing CH and CSS in the ratios of 20:80, 40:60, 60:40, and 80:20.

II. MATERIALS

Theraw materials coffee husk (CH) was collected from a coffee estate in Chikmagalur, Karnataka and castor seed shell (CSS) was collected from the local village near Davangere, Karnataka. The raw materials were sundried for several days to remove the moisture content and grinded using a hammer mill. The raw materials particle size of coffee husk and castor seed shell used in this study were 1mm or less.

III. METHODS

a. Production of briquettes

Cylindrical briquettes were produced using a multi briquetting die with a capacity of four briquettes was fabricated in S. R. Industries, Peenya II Stage, Bangalore. The components of the briquetting die are a solid circular block consisting of 4 cylindrical holes, pistons, horizontal metal plates and a hollow circular block. Place the briquetting die in the Universal Testing Machine (Fig 1) and the force generated by the UTM drive the pistons through the holes and compress the raw material in the holes. The ground raw material to be briquetted is put into the holes, the upward moving of circular block compresses the raw material at different pressure like 60MPa, 70MPa and 80MPa against the top horizontal plate. Once the raw material is compressed in briquetting die, release the pressure and replace the bottom horizontal plate by hollow circular block. Again apply force which drives the piston through the holes and remove the briquettes from the briquetting die.

Fig. 1. Multi briquetting die loaded in UTM

b. Properties of briquettes

The compressed density of the briquettes was determined immediately after ejection from the die as a ratio of measured mass over calculated volume [9]. Relaxed density (RD) of the briquettes was determined 30 days after removal from the press in accordance with [10]. Relaxation ratio is the ratio of compressed density to relaxed density of briquettes.

Shattering index of briquettes was measured according to ASTM D440-86[11] of drop shatter developed for coal. The test was conducted after two weeks of briquettes samples formation. All the briquetting properties were evaluated for three times and values represent averages of the results obtained from three independent experiments.

The mathematical regression models for briquetting properties were developed using IBM-SPSS statistics software with trial version.

c. Combustion characteristics of briquettes

Combustion characteristics such as the proximate analysis were estimated according to IS:1350[12], (Part-I,1984),the ultimate analysis were estimated according to Indian Standard(Determination of Sulphur, IS:1350[12], Part-III,1969;Determination of Carbon and Hydrogen, IS:1350[12], Part-IV/Sec1,1974; Determination of Nitrogen, IS:1350[16], Part–IV/Sec 2,1975) and the calorific value were estimated according to IS:1350[12], (Part-II,1970) which identifies the quality of fuel.

IV. RESULTS AND DISCUSSIONS

a. Effect of briquetting pressure on compressed density of briquettes

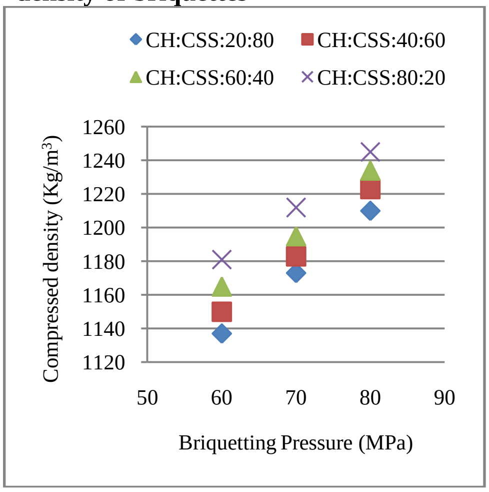

Fig. 2. Variation of compressed density of briquettes with briquetting pressure

The density of biomass briquettes depend on many parameters like density of original biomass, particle size of raw material, briquetting pressure, briquetting temperature and dwell time etc,. Fig. 2 describes the variation of compressed density of briquettes as a function of briquetting pressure. The results indicate that compressed density increases with the addition of coffee husk percentage in composition of CH and CSS briquettes at all pressures. The compressed density varies from 1137-1210 kg/m^3 for a mixing ratio of CH:CSS=20:80,1150-1223 kg/m^3 for a mixing ratio of CH:CSS=40:60,1165-1234 kg/m^3 for a mixing ratio of CH:CSS=60:40, while 1181-1245 kg/m^3 for a mixing proportion of

CH:CSS=80:20.The highest compressed density 1245 kg/m^3 was obtained for a mixing ratio of CH:CSS=80:20 at 80MPa and lowest compressed density 1137 kg/m^3 was obtained with a mixing ratio of CH:CSS=20:80.Similar result indicated by previous studies [13][14][15].The mathematical regression model for compressed density (CD) depends on mixing ratio (MR) and briquetting pressure (BP) with the R^2 and probability values of 0.996 and 0.000 respectively, is represented in Eq (1):

CD = 915.54 + 13.07MR + 3.488BP (1)

The theoretical and experimental values of compressed densities are shown in the Table 1

Table 1. Comparison of theoretical and experimental values of properties of briquettes.

Raw material mixing ratio (CH:CSS)	Pressure (MPa)	Compressed density(kg/m^3)		Relaxed density(kg/m^3)		Relaxation ratio		Shattering index (%)	
		Theoretical	Experimental	Theoretical	Experimental	Theoretical	Experimental	Theoretical	Experimental
20:80	60	1138	1137	949	952	1.2558	1.1943	83.77	86.55
	70	1173	1173	983	985	1.2606	1.1908	92.45	89.22
	80	1208	1210	1016	1021	1.2654	1.1851	101.13	95.00
40:60	60	1151	1150	967	965	1.2478	1.1917	71.83	73.91
	70	1186	1183	1001	998	1.2526	1.1853	80.51	84.38
	80	1221	1223	1034	1035	1.2574	1.1816	89.19	93.52
60:40	60	1164	1165	985	979	1.2398	1.1899	59.89	59.00
	70	1199	1195	1019	1011	1.2446	1.1819	68.57	69.30
	80	1234	1234	1052	1047	1.2494	1.1786	77.25	76.16
80:20	60	1177	1181	1003	1011	1.2318	1.1681	47.95	42.13
	70	1211	1212	1037	1041	1.2366	1.1642	56.63	58.72
	80	1246	1245	1070	1073	1.2414	1.1602	65.31	66.32

b. Effect of briquetting pressure on relaxed density of briquettes

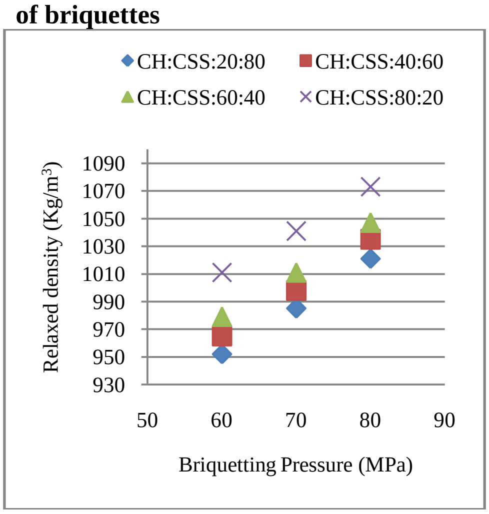

Fig. 3. Variation of relaxed density of briquettes with briquetting pressure

It can be seen that the relaxed density of briquettes are less than the compressed density due to disperse of biomass particles after ejection of briquette from the briquetting die to attain its final stability. Fig. 3 describes the variation of relaxed density of briquettes as a function of briquetting pressure. The results indicate that relaxed density increases with the addition of coffee husk percentage in composition of CH and CSS briquettes at all pressures. The relaxed density varies from 952-1021 kg/m^3 for a mixing ratio of CH:CSS=20:80,965-1035 kg/m^3 for a mixing ratio of CH:CSS=40:60,979-1047 kg/m^3 for a mixing ratio of CH:CSS=60:40, while 1011-1073 kg/m^{3}for a mixing proportion of CH:CSS=80:20.The highest relaxed density 1073 kg/m^3 was obtained for a mixing ratio of CH:CSS=80:20 at 80MPa and lowest relaxed density 952 kg/m^3 was obtained with a mixing ratio of CH:CSS=20:80 at 80MPa. Similar result indicated by previous studies [13][14][15].The mathematical regression model for relaxed density (RD) depends on mixing ratio (MR) and briquetting pressure (BP) with the R^2 and probability values of 0.982 and 0.000 respectively, is represented in Equation (2):

RD = 729.45 + 18MR + 3.363BP (2)

The theoretical and experimental values of relaxed densities are shown in the Table 1.

c. Effect of briquetting pressure on relaxation ratio of briquettes

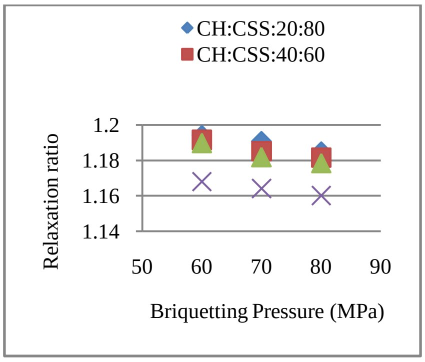

Fig. 4. Variation of relaxation ratio of briquettes with briquetting pressure

Relaxation ratio indicates the stability of briquettes with respect to density after removing the briquette from the briquetting die [13][6].Fig. 4 describes the variation of relaxation ratio of briquettes as a function of briquetting pressure. The results indicate that relaxation ratio decreases with the addition of coffee husk percentage in composition of CH and CSS briquettes at all pressures. The highest relaxation ratio 1.1943 was obtained for a mixing ratio of CH:CSS=20:80 at 60MPa and the lowest relaxation ratio 1.1602 was obtained for a mixing ratio of CH:CSS=80:20 at 80MPa.These results show that the increase of CH percentage in the briquette decreases the relaxation ratio which indicates the stability of briquette is high with more percentage of CH[6]. Similar result indicated by previous studies [14,13, 6]. The mathematical regression model for relaxation ratio (RR) depends on mixing ratio (MR) and briquetting pressure (BP) with the R^2 and probability values of 0.831 and 0.000 respectively, is represented in Equation (3):

RR = 1.235 – 0.008MR + 0.000481BP (3)

The theoretical and experimental values of relaxed densities are shown in the Table 1.

d. Effect of briquetting pressure on shattering index of briquettes

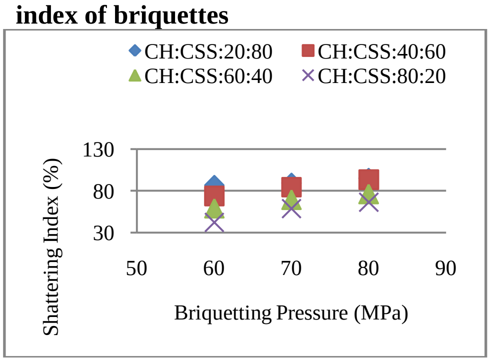

Fig. 5. Variation of shattering index of briquettes with briquetting pressure

Shattering index indicates the stability of briquette to resist mechanical stress during transportation, storage and handling. Fig. 5 describes the variation of shattering index of briquettes as a function of briquetting pressure. The results indicate that shattering index decreases with the addition of CH percentage in the composition of CH and CSS briquettes at all pressures. The shattering index varies from 86.55-95% for a mixing ratio of CH:CSS=20:80, 73.91-93.53% for a mixing ratio of CH:CSS=40:60, 59-76.16% for a mixing ratio of CH:CSS=60:40, while 42.13-66.32% for a mixing proportion of CH:CSS=80:20.The highest shattering index 95% was obtained for a mixing ratio of CH:CSS=20:80 at 80MPa and lowest shattering index 42.13% was obtained with a mixing ratio of CH:CSS=80:20 at 60MPa. According to [13], the shattering index of a briquette should attain a value equal or higher than 95% comes within the acceptable range for manipulation. Thus, the briquette produced with a mixing ratio of CH:CSS=20:80 at 80MPa attain a standard value of 95% comes within the acceptable range for manipulation. Similar result indicated by previous studies [13,14,15]. The mathematical regression model for shattering index (SI) depends on mixing ratio (MR) and briquetting pressure (BP) with the R^2 and probability values of 0.953 and 0.000 respectively, is represented in Equation (4):

SI = 43.63 – 11.94MR + 0.868BP (4)

The theoretical and experimental values of shattering index are shown in the Table 1.

From the above discussion on the properties of briquettes, it is concluded that the briquette produced with a mixing ratio of CH:CSS=20:80 at 80MPa has better briquette properties. Thus, proximate analysis, ultimate analysis and calorific value were estimated for this briquette sample and compared with other briquettes.

e. Combustion characteristics

Table 2. Comparison of combustion characteristics of rice husk and CH:CSS briquette

Property	Rice Husk Briquette[a]	CH:CSS (20:80)briquette[b]
Moisture	12.67	6.96
Volatile matter	67.98	70.38
Fixed carbon	13.40	13.99
Ash	18.60	8.67
C	42.10	58.54
H	5.80	6.34
N	0.38	0.69
O	33.07	18.9
Calorific value(MJ/kg)	13.38	15.52

[a][16]
[b][Present study]

The above Table 2 shows the comparison of proximate analysis, ultimate analysis, calorific value of briquette produced with a mixing ratio of CH:CSS=20:80 at 80MPa with rice husk briquette.

Apart from good calorific value of a fuel for an effective combustion, fuel should have low percentage of moisture and ash content; and high percentage of volatile matter and fixed carbon content [17]. From the above table it is clear that the CH: CSS briquette have low moisture content (6.96%) and ash content (8.67%) than that of rice husk briquette which has 12.67% of moisture content and 13.40% of ash content and have high volatile matter (70.38%) and fixed carbon (13.99%) than that of rice husk briquette which has 67.98% of volatile matter and 13.40% of fixed carbon.

The lower the level of oxygen, nitrogen, sulphur and higher the level of carbon,hydrogen are the desirable qualities of a good fuel. According to [18], if the nitrogen and sulphur content are less than 1% is an acceptable development to avoid pollution. The carbon (58.54%) content, hydrogen (6.34%) content of the CH-CSS briquette have higher than the rice husk briquette of 42.10% of carbon content and 5.8% of hydrogen content. The oxygen (18.62%) content of CH-CSS briquette is less than that of rice husk briquette of 33.07% and also nitrogen, sulphur content are less than 1% which comes in the acceptable range.

The very important inherent property of any fuel is its heating value which also decides the cost of fuel in the market. The calorific value of CH-CSS briquette is 15.52 MJ/kg which is better than rice husk briquette of 13.38 MJ/kg and also it is comparable with briquettes produced in the other studies [19-20].

V. CONCLUSION

This work concludes that increase of CH percentage in the proportion of CH and CSS briquettes lead to increase of compressed density and relaxed density but there is a significant decrease in the shattering index. However, limiting the usage of coffee husk percentage gives better density briquettes which fall within the acceptable range. Thus, briquettes produced with a mixing ratio of CH:CSS=20:80 at 80MPa is considered as a better quality briquette and the combustion characteristics were estimated for this sample. Results from the proximate analysis showed that moisture content was 6.96%, volatile matter was 70.38%, fixed carbon was 13.99% and ash content was 8.67%. Results from the ultimate analysis showed that carbon content was 58.54%.nitrogen content was 0.69%, hydrogen content was 6.34%, oxygen content was 18.62% and the caloric value was 15.52 MJ/kg.

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