CHEMICAL ENGINEERING TRANSACTIONS
VOL. 106, 2023

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Jeng Shiun Lim, Nor Alafiza Yunus, Peck Loo Kiew, Hon Huin Chin

ISBN 979-12-81206-05-2; **ISSN** 2283-9216

DOI: 10.3303/CET23106047

Briquette of Rice Husk and Bagasse Mixture with Variation on Adhesives Type and Mass Ratio of Raw Materials

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The abundance of agricultural waste of rice husk and sugarcane bagasse brings the environmental problem whereas this waste can be converted into alternative energy to solve energy depletion problem. This study aimed to determine the characteristics of the briquettes: moisture content, ash content, volatile matter content, fixed carbon, calorific value, and combustion test. The briquette (1,1.5,2) was produced with variation of adhesives type of tapioca flour (TF) and durian seed flour (DSF) with ratio of rice husk (RH) to sugarcane bagasse (SB) charcoal and conducted by carbonization method at 300 °C for 1 h. The briquettes with DSF adhesive gave the best result of briquettes with the lowest ash content value of 20.78 % and the lowest moisture content of 5.21 % was achieved in ratio RH:SB of 2. All samples met the Indonesia National Standard of moisture content (< 8 %) with the result in range 5.9 – 7.42 % and all samples with DSF adhesive met the ASTM D 1542-02.2003 the calorific value (> 15 MJ/kg) that the result in range 15.90 – 21.35 MJ/kg. The ignition time of all samples was in range 30 - 58 s, which was faster than ignition time of coal in range 286 s. Ash content, volatile matter and fixed carbon still did not meet the standard, but the addition of SB successfully decreased the ash content and increased the fixed carbon compare with the RH briquette. The ash content of RH:SB briquettes declined in the range of 20.78 – 37. 43 % from 34.86 – 48.37 % in RH briquettes and the fixed carbon of RH: SB briquettes improved in the range of 27.71 – 35.25 % from 25.35 - 25.94 %. The result indicated that the addition of SB on RH charcoal for briquette raw material could increase the calorific value and improve the briquette quality that fulfill the standards for commercial sales.

1. Introduction

Fossil fuel energy shortage causes encouragement to find other energy sources as alternative fuel. The alternative fuels that have a good prospect are charcoal and wood briquette. Biomass briquette is a cheap alternative fuel source that has a higher calorific value than firewood and bituminous coal. This energy efficiency of briquette enhance world consumption of wood briquette for industrial sectors. Besides the usage in the industrial sector, the trend of barbecue dishes in the world also driven demand gaining for wood charcoal and briquette. Indonesia is the world's main exporter of charcoal and wood briquette with a share reaching 20.3% in 2021. The value of Indonesian wood charcoal exports to the world in 2021 reached USD 292.1 million that grew significantly by 7.3 % compared to the segment in 2020 (ITPC, 2022). On the demand side, the Asian charcoal briquettes market stood at USD 952.5 million in 2019 and the market size is expected achieve 6.2 % during 2020-2024. The raising popularity of grilled food and the growing steel and cement industries, where heat supply is important parameter, are some of the key factors of the expansion of charcoal briquettes industry (PSI, 2020). Agricultural waste is a potential biomass as an alternative energy source briquettes becauseettes, because it has a high calorific value. Based on the Hanawan and Arlini (2019), agricultural waste has a calorific value 14.65 -25.12 MJ/kg which depend on the biomass sources.

Paper Received: 26 May 2023; Revised: 02 September 2023; Accepted: 22 September 2023
Please cite this article as: Putri R.W., Rahmatullah R., Len K.Y.T., Haryani N., Susanti S., Haryati S., Waristian H., Hadi A.A., Habsyari M.A., Aliyah S.T., 2023, Briquette of Rice Husk and Bagasse Mixture with Variation on Adhesives Type and Mass Ratio of Raw Materials, Chemical Engineering Transactions, 106, 277-282 DOI:10.3303/CET23106047

Sugarcane bagasse (*Saccharum officinarum L*) and rice husk (*Oryza sativa*) are the agricultural waste that abundance in Asia, especially in Indonesia with around 10 million ton/ year of bagasse and 12 million t/y of rice husk (APEC, 2008). As a biomass material, rice husk and bagasse have the potential to be used as a raw material for making briquettes due to the adequate calorific value of sugarcane bagasse (SB) (18.9 MJ/kg) and rice husk (RH) (16.08 MJ/kg) (Tjahjono et al., 2018). Briquettes from a mixture RH and SB are expected to enhance the calorific value and reduce agricultural waste. Some researchers have produced briquettes with several biomass raw materials. The different biomass materials lead different results, such as palm kernel shell with 29.60 MJ/kg calorific value (Abdillahi et al., 2017), cashew shell with 27.73 MJ/kg calorific value (Sawadogo et al., 2018), wastepaper with 16.32 MJ/kg calorific value (Tamilvanan, 2013), and rice husk with 16.08 MJ/kg calorific value (Yank et al., 2016).

Due to the low calorific value of RH based on Yank's research, in this research, RH was mixed with other biomass like SB that is expected to increase the calorific value of rice husk. Besides the mixture of raw materials RH and SB, the novelty in this work is the adhesive variation of tapioca flour (TF) and durian seed flour (DSF). An adhesive agent is needed to compact the briquette and increase the briquette quality. The application of starch like tapioca flour (TF) as adhesive agent in briquette caused problem related with competition between energy and food fulfilment. Several materials were suggested to use as adhesive and solve that problem such as coal tar, petroleum residues, synthetic polymers, plastic waste, and wood pulp waste liquor with limited result but generate emission when briquette was combusted (Zhang et al., 2001). Alternative binding agent like Durian seed flour (DSF) have high amount of amylose and amylopectin as parameter of good adhesive agent and can solve the problem of durian seeds waste in environment (Cahyono et al., 2017).

This work aimed to obtain the briquette from RH and SB with TF and DSF binder as an alternative fossil fuel for domestic or household purposes. In this work, the mixtures of RH from Jakabaring plantation and SB from sugar industry of PT. Pemuka Sakti Manis Indah were used for briquettes production with carbonization method at temperature 300 °C for 1 h. The variation of ratio RH to SB are 1, 1.5, 2, and as control (briquette RH without SB) by varied the adhesive agent of TF and DSF. This work objectives were to observe the best ratio of RH: SB mixture and to compare the briquette quality with TF and DSF adhesive agent.

2. Methods

2.1 Raw Material Pretreatment

Rice husks (RH) were collected from Jakabaring Plantation near Mariana, South Sumatera (2°53'35.1"S 104°49'40.6"E) and sugarcane bagasse (SB) were collected from sugar industry waste PT.Pemuka Sakti Manis Indah, Lampung (4°20'09.5"S 104°50'36.5"E). RH and SB were cleaned of impurities by washing and drying in the sun for ± 3 d to constant weight. The weight of wet and dried RH and SB were measured.

2.2 Carbonization Method

The dried RH and SB were put into the furnace (type FH-12, Daihan Scientific Co,Ltd,Korea) to be carbonized. The carbonization process took place at 300 °C for 1 h with heating rate 9.53 F/min. Biomass thermochemical conversion with carbonization was performed by heat application to start the decomposition of organic materials by cracking the hydrocarbonaceous bonds to transform it into a richer form of energy (Amer and Ahmed, 2020).

2.3 Binding and Casting Process

RH and SB charcoal was grinded using a mortar and sifted with a 60 mesh size into a powder. RH charcoal was mixed with SB charcoal in ratio 1, 1.5, 2, and briquette RH without SB as control. The mixture of RH and SB charcoal were glued with an adhesive until it is homogeneous and transparent with 20 wt% adhesive of varied tapioca flour (TF) and durian seed flour (DSF) and mixed as well. The briquettes were cast in cylindrical form.

2.4 Drying Process of Briquette

After the casting process, the casted briquettes were dried in 100 °C oven (Memmert Gmbh & Co, Germany) for 1 h. The briquette products were analysed for several characteristics such as proximate analysis (moisture content, ash content, volatile matter content, fixed carbon) and calorific value.

2.5 Analysis of Briquettes Quality

The moisture content determination was occurred by drying the sample with the UNB Memmert Oven 400 that has been calibrated at 105 °C – 110 °C, using the minimum free space and oven volume is 1.4 L. The gas flow rate was approximately 15 times/h at a volume of 350 mL/min and the lost mass after heating using briquettes ASTM D-3173 2017 standards by Eq (1).

$$Moisture\ \ Content\ \% = \frac{Wo - W}{Wso} x\ 100\ \% \quad (1)$$

where W_o is sample and saucer weight before drying (g), W is sample and saucer weight after drying (g), and W_{So} is the initial sample weight (g).
The measurement of ash content was conducted by weighed the samples before it heated in Carbolite Chamber Furnace AAF 1100 and weighed after cooled. The ash content values were calculated under the ASTM D-3174 2012 standard by the Eq(2).

$$Ash\ \ Content\ \% = \ 100 - \frac{Wo - W}{Wso} x\ 100\ \% \quad (2)$$

where W_o is sample and saucer weight before drying (g), W is sample and saucer weight after drying (g), and W_{So} is the initial sample weight (g).
The volatile matter was determined by heated the samples in Carbolite Chamber Furnace VMF 1000 at 900 °C for 7 min, and the volatile content was calculated using ASTM D-3175 2018 standard. The amount of volatile is calculated based on the weight loss after being reduced by moisture by Eq(3) and Eq(4) formulas.

$$Lost\ weight\ \% = \frac{Wo - W}{Wso} x\ 100\ \% \quad (3)$$

$$Vollatile\ matter\ \% = \ Lost\ weight - moisture\ content \quad (4)$$

where W_o is sample weight and initial cup (g), W is the weight of cup and ash after heating (g), and W_{So} is the initial sample weight (g).
The fixed carbon content was determined using the data previously obtained in the proximate analysis. In this study, based on García et al. (2012), the released moisture content was considered in the volatile matter by formula Eq(5).

$$Fixed\ Carbon\ \% = 100 - (\ Ash + Volatile\ Matter) \quad (5)$$

The calorific value was calculated according to ASTM-D5865-13. Equipment Parr 6200 and with bomb ID 39905 and M39889 bomb calorimeter were used to measure the calorific value of the briquette. One gram of the sample was palletized, placed in a sample holder (crucible), then transferred to a steel capsule from the bomb calorimeter.
The briquette samples were ignited with Bunsen burner. According to Onuegbu (2011), the time measured for each briquette to catch fire was recorded as the ignition time using a stopwatch. The ignition time was calculated with difference of ignited time (s) and the burner lighted time (s).

3. Result and Discussion

3.1 Proximate Analysis of Briquette

Briquette in this research was fabricated from mixture of rice husk (RH) and sugarcane bagasse (SB) charcoal. The ratio of RH to SB are 1, 1.5, 2. The 1: 0 ratio of RH to SB was needed as control of briquette pure rice husk. The types of binder were tapioca flour (TF) and durian seed flour (DSF). The quality test on fabricated briquette consisted of proximate analysis such as, inherent moisture, ash ratio, volatile matter ratio, and fixed carbon ratio. Briquette performance was analysed by calorific value determination and ignition time measurement. Table 1 and Table 2 represents the comparative result of proximate analysis and calorific value of briquette RH:SB with adhesive agent of TF and DSF.

Table 1: The quality of RH:SB briquette with TF

Ratio RH:SB	Moisture content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)	Calorific Value (MJ/kg)
1	7.18	29.27	35.48	35.25	15.61
1.5	6.77	28.99	38.22	33.12	15.49
2	6.74	37.43	29.58	32.99	13.81
Briquette RH without SB	7.42	48.37	25.96	25.94	12.63

Table 2: The quality of RH:SB briquette with DSF

Ratio RH:SB	Moisture content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)	Calorific Value (MJ/kg)
1	5.58	20.78	51.94	27.28	21.35
1.5	5.56	26.76	44.38	28.86	18.00
2	5.21	29.29	43.00	27.71	17.58
Briquette RH without SB	5.9	34.86	40.79	25.35	15.90

3.2 Moisture Content

The determination of water content aims to determine the hygroscopic properties of briquettes. Table 1 shows the water content of the RH and SB briquettes (ratio 1, 1.5, and 2) with the TF adhesive produced in this study ranging from 6.84 - 7.18 %. From Table 2, the addition of DSF adhesive on the briquettes results in lower water content than TF, which ranges from 5.21 - 5.58 % in ratios (1, 1.5 and 2). RH briquettes without SB have a higher moisture content with TF adhesive is about 7.42 % (Table 1). The highest water content is obtained from the treatment with the addition of TF since TF had a higher water content than DSF, 12.9 % (Maharani, 2022) and 8.39 % (Faridah et al., 2021). A good quality briquette must have a small amount of moisture to optimize storage lifetime and improve combustion performance. Water content in the briquettes leads to difficulties in the ignition process. When briquette have higher water content, the ignition of the briquettes will be longer because the existing heat will be used to evaporate the water in the briquettes and burn them (Praditya et al., 2022). Due to its phenomenon, the low water content in briquette will increase the calorific value of the briquettes (Xu et al., 2013). It means that briquettes mixed RH: SB with DSF give the best results in this research. In addition, the water content produced from this study meets the quality standards for briquette charcoal quality of Indonesian National Standards (INS) based on SNI 063730-95 (≤ 8 %) and ASTM D 1542-02.2003 (≤ 6.2 %).

3.3 Ash Content

Table 1 displays the resulting ash content ranging from 29.27 - 37.43 % with adhesive TF. Then, Table 2 reveals the lowest ash content of briquettes produced by adding the adhesive DSF (20.78 - 29.29 %) The outcomes of ash content in all samples does not reach the activated charcoal quality of Indonesian National Standards (INS) according to SNI 06-3730-95 (≤ 8 %) and ASTM D 1542-02.2003 (≤ 8.3 %) in all treatments. These high ash contents occur because the RH raw material includes a high ash content close to 20 % (Jongpradis et al., 2018). However, the variation in biomass waste by adding SB in RH charcoal has successfully reduced the ash content of RH briquette without SB. It is evident that rice husk briquette produced high ash content, about 34 % and 48 % with DSF and TF adhesive respectively. It is also in line with Maninder et al. (2012) mentioning the difference in ash content of briquettes is due to variation in biomass wastes and combustion methods. Ash content does not affect the combustion because ash is an incombustible material (Suryaningsih and Nurhilal, 2018).

3.4 Volatile Matter

The purpose of determining the volatile matter is to discover the volatile compounds of briquettes at 950 °C. Volatile matter can affect the combustion depending on its compound. Volatile matter consists of combustible and incombustible elements such as carbon, hydrogen, and oxygen, which are present in the biomass. If it is flammable material, it will help the ignition of the briquettes and amplify the flame, but if it is a non-flammable material, it will prevent the ignition process (Suryaningsih and Nurhilal, 2018).

The value of volatile substances revealed were in the range of 29.58 - 35.48 % of TF adhesive and the volatile matter with DSF in the range 43.00 – 51.94 % that represented in Table 1 and 2. The lowest volatile content is obtained from briquettes with addition of TF and without the addition of sugarcane bagasse (25.69 %). From the results of this study, some value of volatile substances produced were met standard of ASTM D 1542-02.2003 (19 – 28 %).

3.5 Fixed Carbon

The determination of fixed carbon content on briquettes is to measure the carbon content after the carbonization process. High value of fixed carbon indicates that the result is dominated from carbon (Adeleke et al., 2021). Table 2 explains that the fixed carbon content in this study is in a range between 32.99 - 35.25 % with TF adhesive and 27.71- 28.86 % with DSF adhesive. The lowest carbon content was produced by RH without SB with TF and DSF having the lowest fixed carbon around 25 %. The addition of SB gives carbon supply on RH briquettes and boosts up the fixed carbon in briquette mixture RH:SB to 27.71 % - 35.25 %. The result from all treatment in this study does not reach the requirement for charcoal of Indonesian National Standards (INS) on

SNI 06-3730-95 (≥77 %) and and ASTM D 1542-02.2003 (≥60 %). It is better to combine some hardwood material with high carbon to increase the fixed carbon of RH briquette.

3.5 Calorific Value

The calorific value is a number that shows amount of calories or heat in fuel in the combustion process and a number that considers the quality of a briquette. When the amount of heat is higher, the briquette quality is higher. Based on Table 1 and Table 2, RH:SB briquette calorific value has met the Indonesian National Standardization (INS) with minimum (≥ 20.93 MJ/kg). The calorific value of the briquette RH:SB ratio of 1 with DSF adhesive is 21.35 MJ/kg and with TF adhesive is 15.61 MJ/kg. All samples have also met the ASTM D 1542-02.2003 (≥16 MJ/kg) with value around of 12.63 – 21.35 MJ/kg.

3.6 The Effect of Ratio RH:SB on Ignition Time

The ignition time is taken as the average time required to reach a stable flame. Figure 1 shows the ignition time for the composite the resulting briquettes. The results reveal that the ignition time decreases with an increasing ratio of RH:SB content. It indicates that the higher content of RH:SB in briquettes increases pores that make the briquette ignite fast. Combustible materials must be easy to ignite, especially for households and cooking process. The ignition time of all samples is around 30.04 – 59.93 s. Based on Oladeji (2012), briquette in this study is faster than ignition time of coal by about 286 s. It is also in line with Praditya et al. (2022) stating the briquette with lower moisture content will be easy to ignite and has lower ignition time. The lowest ignition time is 30 s was achieved at ratio RH:SB of 2 with DSF adhesive agent that has 5.21 % moisture.

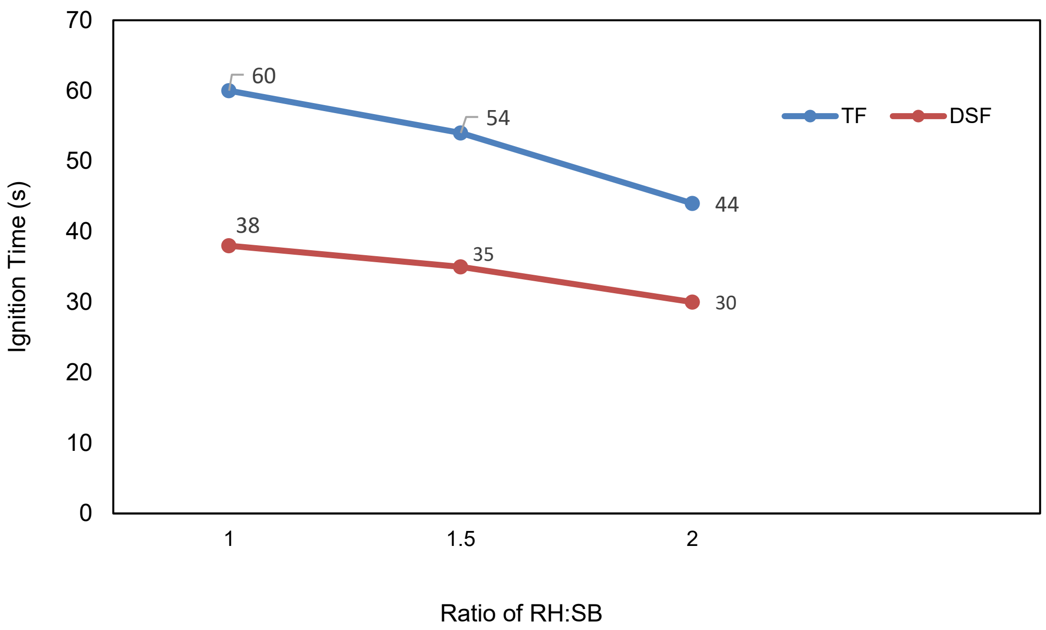

Figure 1: The effect of ratio RH:SB on ignition time

4. Conclusions

Durian seed flour (DSF) as adhesive agent is proven to be very competitive with tapioca flour (TF). The result shows the briquette RH:SB with DSF adhesive agent has a better quality than with TF adhesive agent, especially in moisture content and calorific value. The briquettes with DSF have the lower moisture content because DSF has less water content than tapioca flour. The lowest moisture content (5.21 %) also lead the lowest ignition time of 30 s, which indicates the briquette, is easy to ignite. All samples meet the moisture content standard of Indonesia National Standard (<8 %) with the results in the range 5.9 – 7.42 %. The mixture of RH with SB also successful elevated the calorific value. The highest calorific value of 21.35 MJ/Kg is achieved by ratio RH:SB of 1 with DSF adhesive, and all samples with DSF adhesive (15.90 – 21.35 MJ/kg) meet calorific value standard of ASTM D 1542-02.2003 (> 15 MJ/kg). DSF adhesive has a good impact on RH:SB briquette with the lowest ash content is 20.78 % and the highest fixed carbon of 35.25 %. The best result of volatile matter is achieved with TF adhesive in RH briquette with value of 25.96 % and in RH:SB briquette with value of 29.58%. In conclusion, briquettes with a mixture of RH:SB with DSF adhesive agent could be a proper candidate of alternative fuel especially for household and cooking activity that can be sold commercially.

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