IJFAC

Indonesian Journal of Fundamental and Applied Chemistry

Article http://ijfac.unsri.ac.id

Biocoal Characterization as an Environmentally Friendly Alternative Energy Innovation Composite Variations of Gasified Char with Coconut Shell Charcoal

Aria Yopianita[1], Aida Syarif[1]*, M. Yerizam[2] and Rusdianasari[1]

[1]Applied Master of Renewable Energy Engineering, Politeknik Negeri Sriwijaya
[2]Chemical Engineering Department, Politeknik Negeri Sriwijaya

Corresponding Author: aida_s@polsri.ac.id

Abstract

In accordance with the mandate of the Regulation of the Indonesian Minister of Energy and Mineral Resources for the use of cleaner coal through coal gasification projects, in the future the coal gasification industry will produce char as a by-product. This study aims to characterize coal gasification char using a prototype underground coal gasification (UCG) and the addition of coconut shell charcoal biomass as a raw material for making biobriquettes. By using coal as raw material from the Muara Tiga Besar Mine of PT Bukit Asam, five kinds of coal samples from different layers were obtained, which from the characterization results, both coal and char, did not have too significant deviations so that the research variables could be ignored. The results of the characterization of char from coal gasification results compared to the initial sample of coal showed an increase in calorific value, a decrease in sulfur content and a significant decrease in water content, so it can be concluded that char from coal gasification has good potential as a raw material for biobriquettes. By using char and coconut shell charcoal with the ratio of variations in the composition of char and coconut shell compositions is 100%:0%; 75%:25%; 50%:50%; 25%:75% and 0%:100% carried out the briquetting process. The results of the biobriquette characterization met the criteria of the Indonesian National Standard (SNI) 01-6235-2000 and Minister of Energy and Mineral Resources regulation No. 047 of 2006.

Keywords: Coal, Gasification, Biomass, Char, Briquette

Abstrak (Indonesian)

Sesuai dengan amanat Peraturan Menteri Energi dan Sumber Daya Mineral Indonesia untuk pemanfaatan batubara yang lebih bersih melalui proyek gasifikasi batubara, maka dimasa yang akan datang industri gasifikasi batubara akan menghasilkan char sebagai hasil sampingnya. Penelitian ini bertujuan untuk mengkarakterisasi char hasil gasifikasi batubara dengan menggunakan prototype underground coal gasification (UCG) serta penambahan biomassa arang tempurung kelapa sebagai bahan baku pembuatan biobriket. Dengan menggunakan bahan baku batubara dari Tambang Muara Tiga Besar PT Bukit Asam, didapatkan lima jenis sampel batubara dari lapisan yang berbeda, yang dari hasil karakterisasinya baik batubara maupun char, tidak memiliki deviasi yang terlalu signifikan sehingga variabel penelitiannya dapat diabaikan. Hasil karakterisasi char dari hasil gasifikasi batubara dibandingkan dengan sampel awal batubara menunjukkan adanya peningkatan nilai kalori, penurunan kadar sulfur dan penurunan kadar air yang cukup signifikan, sehingga dapat disimpulkan bahwa char dari hasil gasifikasi batubara memiliki potensi yang baik sebagai bahan baku biobriket. Dengan menggunakan char dan arang tempurung kelapa dengan perbandingan variasi komposisi char dan tempurung kelapa 100%:0%; 75%:25%; 50%:50%; 25%:75% dan 0%:100% dilakukan proses pembriketan. Hasil karakterisasi biobriket yang dihasilkan memenuhi kriteria Standar Nasional Indonesia (SNI) 01-6235-2000 dan Permen ESDM No 047 Tahun 2006.

Kata Kunci: Batubara, Gasifikasi, Biomassa, Char, Briket

Article Info

Received 15 May 2022
Received in revised 30 May 2022
Accepted 20 June 2022
Available online 25 June 2022

INTRODUCTION

Coal has three thermochemical conversion methods, namely combustion, gasification and pyrolysis. The difference between these types of conversion lies in the amount of air (oxygen) consumed during the conversion process. Combustion is the process of converting solid materials containing carbon into heat energy which is carried out with an unlimited supply of oxygen and is the simplest conversion process [1]. Gasification technology is a form of increasing the energy contained in coal through a conversion from a solid phase to a gas phase using a thermal degradation process of organic materials at high temperatures in incomplete combustion through a combustion process with limited air supply (about 20% -40% stoichiometric air). This process takes place in a reactor called a gasifier. In this gasifier, coal fuel will be inserted to be burned imperfectly. Water vapor and carbon dioxide from combustion are reduced to flammable gases, namely carbon monoxide (CO), hydrogen (H_2) and methane (CH_4) [2-3].

In the gasification process, the main product desired is syngas [4]. Syngas components that can be used to produce energy are hydrogen, methane and carbon monoxide which are called flammable gases. While the syngas content in the form of CO_2, N_2, and O_2 is a non-flammable gas.

In terms of the products produced, coal processing with gasification will be more profitable than processing with direct combustion, because with the gasification technique, coal processing products are more flexible because they can be directed into gas fuel or industrial raw materials which of course have a higher selling value and can minimize the global environmental burden, by increasing the use of clean coal through the coal gasification process [5]–[8].

Pyrolysis is a thermochemical decomposition process of organic material, which takes place without air or oxygen. Pyrolysis of biomass generally takes place in a temperature range of 300ºC to 600ºC [9]. In general, pyrolysis products can be classified into three types, namely [9]:

a. Solid product: in the form of solid residue rich in carbon (char)
b. Liquid product: the form of (tar, hydrocarbons, and water)
c. Gas products: (CO, H_2O, CO_2, C_2H_2, C_2H_4, C_2H_6, C_6H_6 etc).

In the gasification process, a byproduct called char is obtained, from the characterization results, it is found that the char gasification results have an increase in carbon value so that it can be an initial hypothesis that char still contains energy potential, and there is a significant decrease in sulfur content. With this initial hypothesis, the waste product in the form of char, in this study, will be a potential raw material for making briquettes.

Making briquettes from coal and biomass is a form of utilizing coal and biomass into environmentally friendly energy [10] and the use of char from the gasification process is an effort to recycle waste from gasification that has been done previously. The pilot project of coal gasification or down streaming coal to provide added value for coal in Indonesia will be held at PT Bukit Asam as a state-owned enterprise and has been confirmed in the law of the mineral and coal number 3 of 2020, mainly in article 102 paragraph 1 which is requiring for the mining industry to enhance the added value of minerals and coal which reads "IUP (mining license) or IUPK (special mining business license) holders at the production operation stage are required to increase the added value of minerals in mining business activities through: a) Processing and Purification of metal mineral mining commodities, b) Processing of non-metal mineral mining commodities, and c) processing of rock mining commodities" [11].

Where the gasification industry in the future will be one of the coal downstream programs, so that the utilization of char from coal gasification in the future will be one solution in the utilization of char waste from the coal gasification industry. judging from the laws and regulations that have been enacted, when the coal mining industry switches to downstreaming, it is conceivable that char waste will have the potential to become additional homework for the industry in the future. Management of char disposal as residue from an industry for future gasification plants is very important because the accumulation of char in a certain period of time as stockpile can have an impact on the environment [12]

Generally, the manufacture of briquettes uses agricultural and plantation waste residues with gasification pretreatment, the use of coal as raw material for briquettes is prioritized for optimizing low quality coal that is not economical for export or as raw material for power plants [13-14]. The manufacture of briquettes from char gasification of coal has not developed because the utilization of coal gasification is still at the pilot project stage of PT Bukit Asam.

Research similar to this research has been carried out, the research was taken from several references to research on making briquettes using coal as the main material, which has characters resembling char from gasification combustion, as well as other studies that use variations in the composition of coal and biomass as raw materials. raw material for biobriquettes, the references is research by Kasman et al. regarding the manufacture of briquettes using light coal (lignite) with the addition of coconut shell charcoal and corn cobs [14]. In addition, the research of Sugeng Slamet et al, regarding the manufacture of briquettes from the direct combustion of coal, where the direct combustion of the PLTU is in the form of bottom ash waste [15]. Another study conducted by Idzni Qistina et al. regarding the study of the quality of briquettes from a mixture of rice husk and coconut shell biomass [16]. All of these studies discuss the manufacture of briquettes using coal as raw materials and coconut shell biomass by testing their characteristics.

So in general, what distinguishes the proposed research from previous research as a research renewal is, this research tries to characterize biobriquettes using char as a by-product of coal gasification (recycle) with variations with coconut shell charcoal composites as a mixture of biomass and analyze the effect composition ratio of both on the quality of briquettes.

In an effort to increase the added value of coal by turning it into solid fuel through briquettes, by simply focusing on increasing the calorific value is not enough, apart from the nature of coal which has a lot of solid carbon, at the same time coal also has low volatile matter. This condition results in high ignition temperatures [17]. Therefore, to anticipate this problem, coal briquettes will be added with biomass (agricultural/plantation waste). This is because the volatile matter content of the biomass is very high, allowing ignition from low temperatures to save time and energy required for ignition [18-19]. Because it has a calorific value equal to the calorific value of coal and even exceeds it, coconut shell is chosen as an additive to increase the fuel value of biobriquettes [20]. So, in this study, the biomass that will be used as a supporting material is coconut shell, with the consideration that this biomass has good thermal diffusion properties and can produce heat around 6500-7600 kcal/kg. [21]. The following is the ultimate analysis table for various types of biomass:

Table 1. Biomass Ultimate Analysis (% dry weight)

Biomass	Ash	C	H	O	N	S
Wheat Straw	6.53	48.53	5.53	39.08	0.28	0.05
Barley Straw	4.30	45.67	6.15	38.26	0.43	0.11
Maize Straw	5.77	47.09	5.54	39.79	0.81	0.12
Rice Straw	17.40	41.44	5.04	39.94	0.67	0.13
Sugarcane Bagasse	3.90	46.95	6.10	42.65	0.30	0.10
Coconut Shell	1.80	51.05	5.70	41.00	0.35	0.10
Potato Stalks	12.92	42.26	5.17	37.25	1.10	0.21
Beet Leaves		40.72	5.46	39.59	2.28	0.21
Wheat Chaff	7.57	47.31	5.12	39.35	1.36	0.14
Barley Chaff	5.43	46.77	5.94	39.98	1.45	0.15

Source: [20]

Coconut (*Cocos Nucifera*) is the sole member of the Cocos clan of the aren-arenan tribe or *Arecaceae*. Coconut fruit consists of outer skin, husk, shell, flesh skin (*testa*), fruit flesh, coconut water and institutions. Mature coconuts have coir weight (35%), shell (15-19%), endosperm (28%) and water (25%) [22].

Physiologically, the shell is the hardest part compared to other coconut parts. The hard structure is caused by silicate (SiO_2) which is quite high in the coconut shell. The weight of the coconut shell is about (15-19) % of the total weight of the coconut, while the thickness is about (3-5) mm. The methoxyl content in the shell is almost the same as that in wood. In general, the calorific value contained in coconut shells is between 18200 kJ/kg to 19,338.05 kJ/kg [23].

Table 2. Coconut Shell Chemical Composition

Composition	Percentage (%)
Lignin	29.40
Pentosan	27.00
Selulosa	26.60
Air	8.00
Solvent Ekstraktif	4.20
Uronat Anhidrat	3.50
Abu	0.60
Nitrogen	0.11

Source: [23]

Briquetting is the process of mixing one or several crushed materials (such as sawdust, peanut shells, coconut husks, palm oil, rice husks, corn cobs, bamboo and other combustible materials) into solid compression materials under pressure and often using a binder such as cassava starch [24].

In Indonesia, the quality of coal briquettes is regulated in the regulation of the Minister of Energy and Mineral Resources, No. 047 of 2006. The following is a table of quality standards for briquettes with coal as raw materials.

Table 3. Coal Briquette Quality Standard

Types of Coal Briquettes	Moisture (%)	Volatille Matter (%)	Calorific value (Kcal/Kg)	Total Sulfur (%)	Breaking Load (Kg/cm2)
Lignite type carbonized coal briquettes	Max 20	Max 15	Min 4000	Max 1	Min 60
Coal briquette carbonized coal type but not lignite	Max 7.5	Max 15	Min 5500	Max 1	Min 60
Egg-type non-carbonized coal briquettes	Max 12	according to the original coal	Min 4400	Max 1	Min 65
Honeycomb type non-carbonized coal briquettes	Max 12	according to the original coal	Min 4400	Max 1	Min 10
Bio-coal briquettes	Max 15	according to the original coal	Min 4400	Max 1	Min 65

Source: [25]

In addition, the quality of briquettes with raw materials of charcoal, wood, hard skin and coconut shells has a standard, namely SNI (Indonesian National Standard) with SNI number 01-6235-2000.

Table 4. Charcoal Briquette Quality Standard

Properties of charcoal briquettes	Japan	England	American	INA
Moisture (%)	6-8	3.6	6.2	8
Volatille Matte (%)	15-30	16.4	19-24	15
Ash (%)	3-6	5.9	8.3	8
Fixed Carbon (%)	60-80	75.3	60	77
density(g/cm^3)	1-1.2	0.46	1	0
(g/cm3)	60-65	12.7	62	0
Calorific Value (cal/g)	6.000-7.000	7.289	6.230	5.000

Source: [26]

In the briquetting process, the raw materials that have been reduced to a certain size or preparation will then be added with adhesive so that the raw materials can be combined. Due to the nature of charcoal powder tends to separate from each other, with the help of adhesives or glue, charcoal grains can be brought together and shaped as needed so that the composition of the particles will be better, more organized and denser.

Determination of the type of adhesive used greatly affects the quality of the briquettes when ignited and burned. The price factor and its availability in the market must be considered carefully because each adhesive material has different adhesive characteristics [27]. Based on the test results, the type of adhesive that is good to use is tapioca flour, as follows:

Table 5. Adhesive Test Results

Proximate Analysis	SNI	Sago	Tapioca flour	Rubber	Arpus
Moisture (%)	≤ 8	4.46	1.19	1.49	2.06
Ash Content (%)	≤ 8	8.16	7.35	11	8
Volatile Matter (%)	≤ 15	20	15.34	26	27
Burning Time (m)	0	68	72	61	83
Calor (Cal/gr)	>5000	3614	60000	6807	6466.

Source: [27]

From Table 5. it is known that the water content with the four variations still meets SNI 01-6235-2000 with value of 8, the ash content in the four variations is only tapioca flour and arpus adhesive that meets SNI with a value of 8, while the content of volatile substances none of them meet SNI, but the variation of tapioca flour adhesive is close to SNI.

MATERIALS AND METHODS

Materials

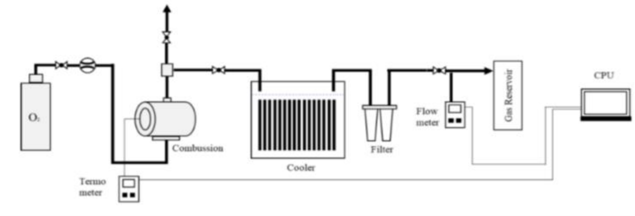
The coal used is obtained from the Muara Tiga Besar Mine of PT Bukit Asam Tanjung Enim, South Sumatra. Coal sampling at the mining front using the type of sampling method, namely front sampling. Sampling is carried out on exposed coal seams, such as walls or mine floors.

Coconut Shell Charcoal, obtained from charcoal craftsmen from Palembang, South Sumatra. On the packaging label it says can be used for industry.

The adhesive material for making briquettes is in the form of tapioca flour and water without special specifications.

Research Method

The coal gasification process is carried out using the Underground Coal Gasification prototype with a length of 21 cm and a diameter of 13 cm as shown in Figures 1 and 2 [28].



Source: [28]

Figure 1. Prototype Underground Gasification

Source: [28]

Figure 2. Underground Gasification Burner Circuit

The procedure for obtaining coal char and char characterization includes the following steps:

1. Stages of preparation and ignition of coal. First of all, the fuel to be used is coal obtained through outcrop sampling at PT Bukit Asam's Muara Tiga Besar coal mine, as much as 2,500 grams for one run. Before being used as fuel, it must be reduced in size so that it can be inserted into the reactor. Next is the ignition of the coal that has been inserted into the combustion tube of the Underground Coal Gasification prototype. Ignition of the fire using the help of a fire igniter, namely welding a blender for 5 minutes to 10 minutes, until the fire on the coal is confirmed to be really lit. Welding blender was chosen as the initial ignition of coal, because it can be adjusted the size and pressure of the fire you want to release, so that coal ignition can be done faster.
2. The coal combustion stage in the Underground Coal Gasification prototype, is preceded by closing the

initial ignition hole, so that the gasification process can take place. The air valve is left open and make sure the valve on the syngas pipe is closed. Oxygen as a gasification agent is fed through an injection pipe measuring ½ inch into the combustion chamber at a predetermined flow rate of 5 liters/min. The initial temperature at the 5th minute of burning is 167ºC and the last temperature at the 80th minute is 95ºC, with a burning time of 80 minutes, and the highest temperature is 240ºC at 35th minute. Then the pyrolysis process will occur and the char to be used will be formed in this process while the syngas produced will be removed through a heat-resistant brass pipe with a diameter ½ inch.

3. Stage off Gasifier. Oxygen as a gasification agent that flows into the combustion chamber will be closed to the oxygen cylinder regulator and the valve between the oxygen cylinder and the combustion chamber will be closed, the output valve and the valve on the gas reservoir flow are closed, this is done so that the air in the combustion chamber becomes airtight, make sure the coal fire really doesn't rekindle. Release the measuring instruments, namely the thermocouple and U pipe manometer. The feed valve is opened and all valves are fully opened. When the smoke has reduced and is not thick, remove the remaining combustion and ash from the ash storage room, then weigh it. After the reactor cools, the inside of the reactor and burner is cleaned to avoid hardening of the tar.
4. The char that has been obtained is then set aside for proximate analysis.

Figure 3. Coal Gasification Char Sample

5. Each of these samples will then be characterized to determine their quality. This characterization includes moisture content, ash content, sulfur content, volatile matter, carbon content and calories.

Meanwhile, the procedure for characterizing the shell charcoal includes the following treatments:

1. At first 10,000 grams of coconut shell charcoal obtained from charcoal craftsmen, first mashed with a size of 60 mesh.
2. Then the charcoal is first characterized, including: moisture content, ash content, sulfur content, volatile matter, carbon content and calories.

The next stage is the manufacture of biobriquettes from raw materials of char and coconut charcoal, as follows:

1. Char by-product of coal gasification is prepared by grinding and homogenizing its size using a sieve with a size of 60 mesh and weighing as much as 500gram.
2. Coconut shell charcoal as much as 2000 grams was prepared by grinding and homogenizing its size with a 60-mesh sieve and prepared for mixing.
3. The adhesive material in the form of tapioca flour is mixed with aquadest solvent. This mixture is then homogenized by stirring while heating for approximately 15 minutes to obtain a thick and sticky paste.
4. The homogenized char with a size of 60 mesh is mixed with a mixture of coconut shell charcoal biomass and adhesives with 5 variations of char and coconut shell composition as follows: 100%:0%; 75%:25%; 50%:50%; 25%:75% and 0%:100% until completely mixed and molded.
5. Each sample that has been obtained is then weighed and put into the briquette press.
6. The briquettes that have been formed are then dried in the oven at a temperature of 60-80oC for approximately 24 hours. Then after being removed from the oven, the briquettes are placed in a desiccator and allowed to cool. The briquettes that have been obtained are prepared for proximate analysis.
7. Below are briquettes with varying percentages of a mixture of char and coconut shell charcoal, by 100%: 0% (V1); 75%:25% (V2); 50%:50% (V3); 25%:75% (V4) and 0%:100% (V5).

Figure 4. Briquettes and Composition Variations

This characterization includes moisture, ash content, sulfur levels, volatile matter, fix carbon, and calorific levels.

1. Moisture
   a. The cup was weighed to determine the net weight. Then the sample is inserted into it.
   b. Furthermore, the cup and the sample were put into an oven that had been preheated at a temperature between 104ºC to 110ºC for approximately 1 hour.
   c. After the oven was opened, the sample was quickly put into an airtight bottle and cooled in a desiccator.
   d. As soon as the sample reaches room temperature, it can immediately be weighed.
   e. To calculate the value of water content can use the following formula [20]:

$$\text{Water content (\%)}=\frac{m_2\text{-}m_3}{m_2\text{-}m_1}\times 100\%$$

2. Ash Content
   a. The sample to be tested is put in a cup of known net weight, and heated in the furnace slowly until the furnace temperature reaches 700ºC-750ºC for approximately ±1 hour or until all samples are completely burned to ashes.
   b. After the ash formed, the cup was removed from the furnace, and cooled for 10 minutes in a desiccator.
   c. The ash that has reached room temperature is then weighed.
   d. To calculate the ash content can use the following formula. [20]:

$$\text{Ash Content (\%)}=\frac{m_3\text{-}m_1}{m_2\text{-}m_1}\times 100\%$$

3. Sulfur Level
   To calculate the sulfur content in the sample can be done using the Eschka method, as follows: [13]:
   a. A sample of 1000 grams is mixed with 3 grams of Eschka.
   b. After thoroughly mixed, the sample is heated into the furnace slowly until the temperature reaches 800ºC. the sample is heated at this temperature for approximately 1.5 hours until the mixture melts completely.
   c. Samples that have been cooled at room temperature, then dissolved again with 100 ml of hot water in a beaker heated on a hot plate for 1/2 - 3/4 hours while stirring occasionally.
   d. After obtaining a sample that is insoluble in hot water, the sample is filtered using approximation filter paper. Then wash again with hot water five times.
   e. The filtrate obtained was then diluted with a solution of 250 ml of methyl orange and neutralized with a solution of NaOH or Na_2CO_3, after that the HCl solution was added in a ratio of 1:9, after it was mixed evenly then boiled while adding 10 ml of $BaCl_2$ solution using a pipette slowly while stirring.
   f. After being allowed to boil for 15 minutes, the solution was then cooled by allowing it to stand overnight. Then the solution was filtered using ash-free filter paper (whatman filter paper no. 42) and washed with hot water until the filtrate did not form mud when added $AgNO_3$ solution.,
   g. Then the sludge-filled filter paper is put into a porcelain cup whose net weight is known, then it is burned gradually in a furnace until it reaches a temperature of 800^{0}C.
   h. After being cooled in a desiccator, then the precipitate was weighed. To calculate the sulfur content value, can use the following formula [20]:

$$\text{Sulfur Total Content (\%)}=\frac{(m_1\text{-}m_3)}{m_1}\times 13.738$$

4. Volatile Matter
   a. The sample to be tested is put into a closed cup whose net weight is known, then heated in a furnace with a temperature of 900ºC for approximately 7 minutes.
   b. After that, the cup was removed and allowed to cool on a metal plate for about 5 minutes, then the cup was put in a desiccator.
   c. After reaching room temperature, the cup is then weighed. To calculate the value of volatile matter levels, can use the following formula [20]:

$$\text{Volatile matter (\%)}=\frac{m_2\text{-}m_3}{m_2\text{-}m_1}\times 100\%\text{ - }M_{ad}$$

5. Carbon Level
   Fixed carbon values can be calculated using the results of other proximate analysis, namely by using the values of ash content, water content and volatile matter content. by using the following formula:

   Fixed Carbon = 100 %-(% M+%VM+%A)

6. Calorific Value
   The calorific value can be calculated using a device called a Bomb Calorimeter. The steps in using a bomb calorimeter are as follows:
   a. A total of approximately 1 gram of the sample is put into a cup whose net weight is known.
   b. The cup is then inserted into the bomb calorimeter
   c. The burner in the form of a 10 cm yarn burner is placed on the wire connecting the two poles of the bomb head, then twist the thread until the tip touches the sample, the bomb head which already contains the sample is then rotated until it is closed and locked.
   d. Then press the "start" button below, then press the button "continue", enter the code name or sample ID and then press enter, see the bomb ID, adjust to the bomb head code then press enter and type the sample weight then the tool will automatically analyze the sample and calculate it.

RESULTS AND DISCUSSION

As initial data, to determine the character and composition of coal to be used in the gasification process, coal samples were first tested for coal content with proximate analysis, with results as shown in the table below:

Table 6. Coal Sample Proximate Analysis

Proximate Analysis	Coal
Inheren Moisture (%, adb)	16.1
Ash Content (%, adb)	1.3
Volatile Matter (%, adb)	40.6
Fixed Carbon (%, adb)	42.00
Total Sulphur (%, adb)	1.18
Gross Calorific Value (Cal/gr)	5,804

After gasification was carried out and a byproduct was obtained in the form of char, then char and coconut shell charcoal were characterized to determine the potential of char as raw material for biobriquettes. Here are the results of the characterization of char and coconut shell charcoal:

Table 7. Coal Gasification Char Proximate Analysis

Proximate Analysis	Char
Inheren Moisture (%, adb)	12.00
Ash Content (%, adb)	0.70
Volatile Matter (%, adb)	40.00
Fixed Carbon (%, adb)	47.30
Total Sulphur (%, adb)	0.38
Gross Calorific Value (Cal/gr)	6,1830

Coconut shell charcoal as a composite of biomass material in the manufacture of biobriquettes, first a proximate analysis will be carried out to determine its chemical composition. Includes water content, ash content, volatile matter, carbon value and calorific value. The results of the proximate analysis of coconut shell charcoal are as follows:

Table 8. Shell Charcoal Proximate Analysis

Proximate Analysis	Shell Charcoal
Moisture (% adb)	5.8
Volatile Matter (% adb)	18.2
Ash Content (% adb)	2.1
Total Sulfur (% adb)	0.04
Fixed Karbon (% adb)	73.9
Calorific Value (cal/gr)	7,274

From the results of char characterization and compared with the results of the characterization of coal samples, it is known that their properties and potential are good as raw materials for biobriquettes, as can be seen from the decrease in water content and total sulfur as well as a significant increase in calorific value of coal and char samples. From the results of the proximate analysis of coal before gasification and char gasification, obtained an increase in gross calorific value and a decrease in the total sulfur value and inherent moisture. After char characterization result by proximate analysis, it is found that char experiences an increase in Gross Calorific Value grades from 5,804 cal/gr to 6,183 cal/gr and a significant decrease in sulfur levels from 1.18% to 0.38% and also a significant decrease of inherent moisture from 16.10% to 12%. Changes in quality for the better because the coal (lignite type) used is suitable as a raw material, The coal gasification performance with low thermal maturity is obvious better than the high rank coal with higher coalification [29]. The results of the briquette characterization can be seen in **Table 9**.

Table 9. Biobriquette Characterization

Parameter	Sample				
	V1	V2	V3	V4	V5
Moisture (%)	6.61	6.62	4.92	4.90	5.09
Volatile Matter (%)	16.6	17.7	17.5	17.9	19.3
Ash Content (%)	7.2	5.0	4.3	6.1	2.0
Total Sulfur (%)	0.81	0.47	0.38	0.48	0.19
Fixed Carbon (%)	69.59	70.68	73.28	71.10	73.61
Calori (Cal/gr)	6,321	6,587	6,818	6,517	7,007

From the comparison of the results of the proximate analysis of bio briquettes, it was found that there were differences in the results of the analysis are depicted in graphic form as follows. This difference is translated using linear regression data using the Microsoft Excel Software, which is considered easier and available in the Microsoft application. Linear Regression is a linear regression used to estimate or predict the relationship between two variables in quantitative research [30].

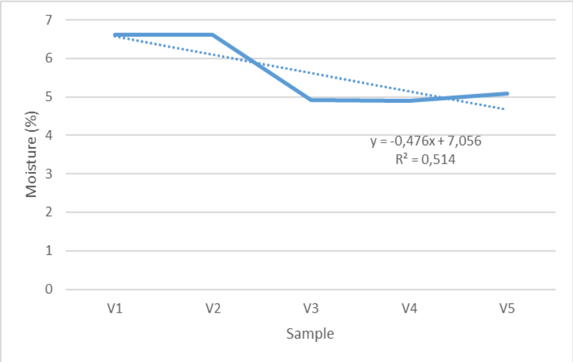


Figure 5. Moisture and Composition Variations

From the graph above, it is found that the highest water content value is in sample V1 of 6.61% and the lowest water content value is in sample V4 of 4.9%. By analyzing linear regression data using Microsoft Excel software, the R^2 value of 0.514 was obtained, with a linear regression value of less than 1, it can be said that variations in the composition of char and coconut shell charcoal affect the water content produced but it does not provide a significant effect.

From the graph above, it can be seen that the more the composition of coconut shell charcoal, the lower the water content, this is due to the low water content of the coconut shell charcoal composite material. This is in accordance with a study conducted by Triono [26] where, in coconut shell charcoal powder, the chemical components such as lignin, cellulose and hemicellulose were thought to have disappeared and what remained in the charcoal was the carbon content which was solid and porous.

Deviation occurs in sample V5. This deviation is very likely to occur due to differences in the size of the pores between particles that are able to absorb water. The high value of water content is thought to have a larger number of small particles compared to the others so that the water contained in the briquettes is higher, this is related to the hygroscopic nature of the briquettes, namely the ability to absorb water from the surrounding air [31]. This deviation can also occur due to the use of wheat flour adhesives, where the weakness of wheat adhesives is that they are not resistant to moisture. This is because tapioca has the property of being able to absorb water from the air [32].

From the **Figure 6**, the highest value of volatile matter was found in sample V5 of 19.3% and the lowest value of volatile matter was in sample V1 of 16.6%. By analyzing linear regression data using Microsoft Excel software, the R^2 value of 0.676 was obtained, with a linear regression value of less than 1 it can be said that variations in the composition of char and coconut shell charcoal affect the value of volatile matter produced but it does not provide a significant effect.

From the graph above, it can be seen that the more the composition of coconut shell charcoal, the higher the volatile matter content, this is due to the high volatile matter value of the char material, This is in line with research conducted by Iriany [33]. The volatile matter content greatly determines the combustion properties of biobriquettes. The higher the value of volatile matter content, the easier it is for coal briquettes to burn and ignite, so the rate of combustion will be faster [34]. The high and low levels of volatile coal biobriquettes produced are influenced by the raw material of the coal used, and the density of the biobriquette mass at the time of printing [34].

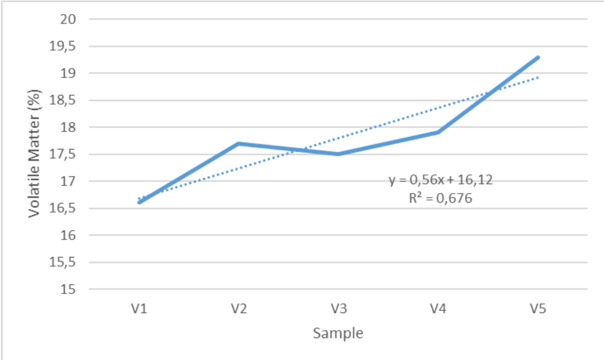


Figure 6. Volatille Matter and Composition Variations

Deviation occurred in sample V3. This deviation may occur, where the high and low levels of volatile substances in charcoal briquettes are thought to be caused by the perfection of the carbonization process and are also influenced by time and temperature in the biobriquette composing process. The greater the temperature and time of composing, the more volatile substances are wasted, so that when testing the volatile substance level, a low volatile substance will be obtained [26].

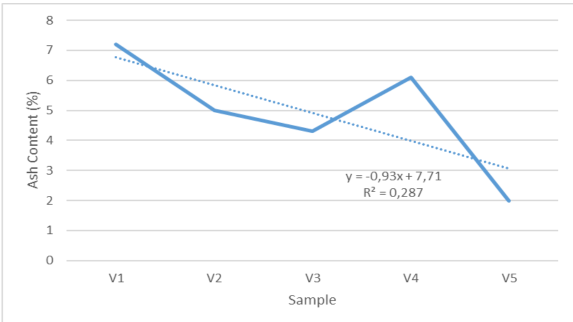


Figure 7. Ash Content and Variation in Composition

From the graph, it can be seen that the highest ash content value is in sample V1 of 7.2% and the lowest value of ash content is in sample V5 of 2%. With linear regression data analysis using Microsoft Excel software, the R^2 value is 0.287, with a linear regression value of less than 1 it can be said that variations in the composition of char and coconut shell charcoal affect the ash content with a very small effect.

It can be said that the more composition of coconut shell charcoal, the lower the ash content, this is due to the low ash content of the char material. This is in line with research from Natalia [31], that the higher the carbonization temperature, in this case the char from coal gasification, the higher the ash content of the briquettes. Ash content is the residue of combustion. High ash content can reduce the calorific value. Therefore, it is expected that the ash content of biobriquettes has the lowest possible value.

Deviation occurs in sample V4 (25% char and 75% coconut shell charcoal), this is very likely caused by impurities or external impurities originating from the handling process of sample V4, this difference in ash content can also be caused by mixing the adhesive and raw materials which are not homogeneous so that the adhesive material can increase the value of the ash content [35], other than that maybe the difference in the size of the briquette constituent particles also affects the ups and downs of the ash content of the briquettes, the larger the briquette particle size, the greater the ash content and vice versa the smaller the briquette particles, the smaller the ash content [33].

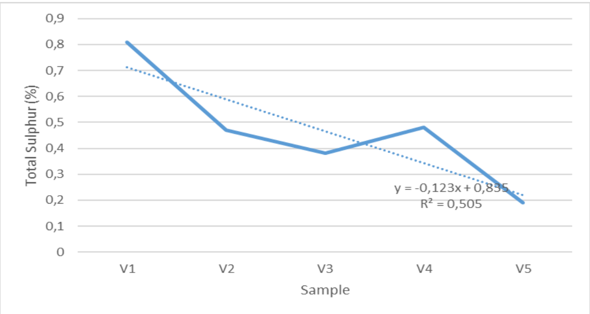


Figure 8. Total Sulfur and Variation in Composition

From the graph it is known that the highest total sulfur is in sample V1 which is 0.81% and the lowest total sulfur value is in sample V1 which is 0.19%. With linear regression data analysis using Microsoft Excel software, the R^2 value of 0.505 was obtained, with a linear regression value of less than 1 it can be said that variations in the composition of char and coconut shell charcoal affect the sulfur content produced but it does not provide a significant effect.

It can be said that the more composition of coconut shell charcoal, the lower the total sulfur, this is due to the low sulfur value of char and coconut shell charcoal it's self before before becoming briquettes.

Deviation occurs in sample V4, the same as the ash content in sample V4, this is most likely caused by impurities or external impurities originating from the handling process of sample V4.

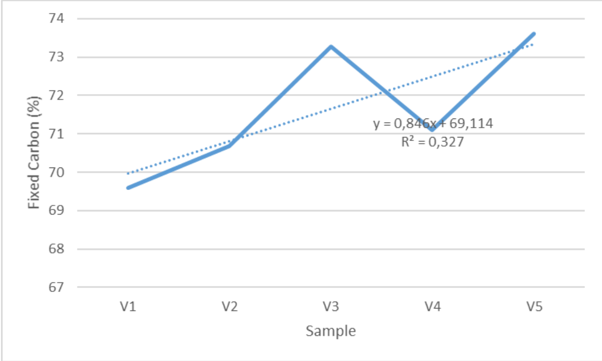


Figure 9. Fixed Carbon and Variation in Composition

From the graph it is known that the highest fixed carbon value is in sample V5, which is 73.61% and the lowest calorific value is in sample V1 which is 69.59%. With linear regression data analysis using Microsoft Excel software, the R^2 value is 0.327, with a linear regression value of less than 1, it can be said that variations in the composition of char and coconut shell charcoal affect the fixed carbon value with a very small effect.

From the graph above, it can be seen that the more the composition of coconut shell charcoal, the higher the fixed carbon value, this is due to the high fixed carbon value of coconut shell charcoal.

Deviation occurs in sample V4, the same as the ash content in sample V4, this is very likely caused by impurities or external impurities originating from the handling process of sample V4 causing the ash content in sample V4 to become high and this affects the carbon content in the V4 sample to below.

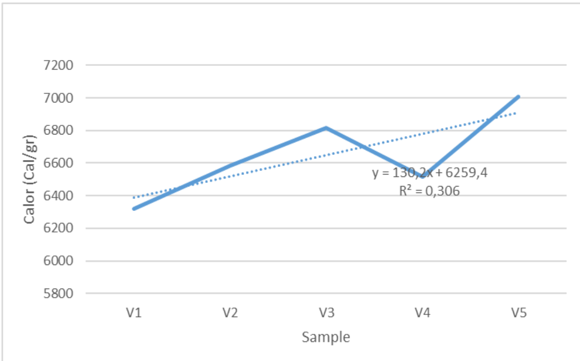


Figure 10. Calories and Variation in Composition

From the graph, it is known that the highest calorific value is in sample V5, which is 7007 cal/gr, and the lowest calorific value is in sample V1 which is 6321 cal/gr. With linear regression data analysis using Microsoft Excel software, the R^2 value is 0.306, with a linear regression value of less than 1, it can be said that variations in the composition of char and coconut shell charcoal affect the calorific value with a very small effect.

It can be said that the more the composition of coconut shell charcoal, the higher the caloric value, this is due to the high calorific value of coconut shell charcoal. This is in accordance with the results of research conducted by Anggoro where it was stated that the high and low calorific value was influenced by the composition of the briquettes themselves [32]. The calorific value is very influential on the quality of coal biobriquettes. The higher the coconut shell composition, the higher the calorific value, the better the quality of the biobriquettes. This is because the single calorific value for coconut shell is greater at 7274 cal/gr than the calorific value of char, which is 6183 cal/gr.

Deviation occurs in sample V4, the same as the ash content in sample V4, this is very likely caused by impurities or external impurities originating from the handling process of sample V4 causing the ash content in sample V4 to become high and this affects the carbon content in the V4 sample to be low and this affects the calorific value in the V4 sample to be lower. This deviation may also be caused by the effect of the adhesive used on the sample, this is because the adhesive material has a flammable nature and carries more water so that the heat generated is first used to evaporate the water in the briquettes [36].

CONCLUSION

From the results of the analysis of biobriquettes, using the reference of Ministerial Regulation 047 of 2006 regarding coal briquettes and qualifications of charcoal briquettes as referenced by Japan, England, America and Indonesia, namely SNI 01-6235-2000, it was found that the overall moisture content of all samples of briquettes met the standard of biobriquette coal briquettes in Permen 047 of 2006 which was a maximum of 15%, as well as the standard of charcoal briquettes in SNI 01-6235-2000 which was a maximum of 8%.

For volatile matter levels based on the qualification of SNI 01-6235-2000 it is determined that the minimum value is 15%, so it is found that the overall sample has met the standard, as well as the American, British and Japanese references, the value is in the range of 15 – 24%. Meanwhile, in Permen 047 of 2006, the level of volatile matter or volatile matter is not regulated.

Based on the qualification of SNI 01-6235-2000, the maximum ash content value is 8%, while in Permen 047 of 2006, the ash content is not regulated. Based on these qualifications, most of the biobriquette samples fall within that range, which is a maximum of 8%. For the total value of sulfur, the overall sample of briquettes has met the standards of Ministerial Regulation 047 of 2006 which is a maximum of 1%. Meanwhile, in SNI 01-6235-2000, the total sulfur value is not regulated.

Furthermore, for the fixed carbon value based on the SNI 01-6235-2000 qualification, the minimum value is 77%, while in Permen 047 of 2006, the fixed carbon value is not regulated. So based on the qualification of SNI 01-6235-2000, the overall sample did not meet the standard, where the highest fixed carbon value was in sample V5, which was 73.61%. However, if based on qualifications from Japan and America, the value of the fixed carbon sample has met the standard because the qualification value for fixed carbon is a minimum of 60%, as well as qualifications based on the Indian BEE Standard, for the tethered carbon standard is a minimum of 46.79% [37].

For the calorific value, based on Ministerial Regulation 047 of 2006, the desired calorific value is at least 4000 kcal/kg and based on SNI 01-623-2000 qualification the calorific value is at least 5,000 kcal/kg, so that all samples of briquettes have met the quality standard values.

ACKNOWLEDGMENT

The authors would like to thank the Head of the Renewable Energy Masters Study Program, the Head of the Chemical Laboratory and the Sriwijaya State Polytechnic Staff, the General Manager of the Tanjung Enim Mining Unit (UPTE) and the Manager of PT Bukit Asam who have supported this research.

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