# Characteristics of Biobriquette Mixture of Char Gasified Coal and Torreffed Coconut Shell as Fuel Co-firing

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**Abstract.** Energy derived from biomass plays a strategic role and ranks third in the national primary energy supply, which is 20.06% or 307,346,838 BOE. The first and second orders are still supplied by oil and coal which are non-renewable fossil energy. Meanwhile, coal production is quite large but has not been matched by domestic utilization which is only 20% of its production capacity. Industry globally as a large energy consumer has begun to utilize coal and biomass through a co-firing combustion system as an effort to utilize a sustainable and environmentally friendly energy system. Utilization of biomass together with coal often requires improving the quality of the biomass, including through a torrefaction system. In order to optimize the utilization of the coal–biomass combination for the national industry, the composition and type of biomass in the form of torrefied coal–biomass briquettes have been identified that meet the criteria for industrial fuel. In this research on the conversion of solid fuels using the Co firing method of Coal and Biomass torrefaction, the researchers will examine the effect of the torrefaction process and the composition of raw materials and grain size on the quality of solid fuel biobriquettes with SNI briquette quality analysis standards. The test parameters are the Biomass Torrefaction temperature of 200, 250 and 300 °C, the composition of 100,75,50,25 and 0%, as well as the grain size of the sample 20, 60 and 100 #. From the results of the study, it was found that the biobriquettes produced were included in the standard category of SNI biobriquettes and material size and material composition affect the calorific value of biobriquettes.

**Keywords:** Coal · Char · Biobriquettes · Coconut Shell Charcoal · Fuel Co-firing

## 1 Introduction

Coal is the most potential energy source which is expected to replace the role of petroleum as a fuel and raw material for the chemical industry [1]. Based on data from the 2013 BP Statistical Review of World Energy, Indonesia's proven coal reserves for anthracite and bituminous types are 1,520 million tons and for subbituminous and lignite types are 4,009 million tons, while at the world level, coal reserves are 404,762 million tons for anthracite and bituminous types. Subbituminous and lignite species amounted to 456,176 million tons [2].


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CO2, NO2, NOx, SOx, and H2 are among the gases released by coal that contribute to the current global issue of global warming. Additionally, coal has the highest carbon concentration and impurities (sulfur, nitrogen, and others). Due to this, using clean and efficient coal is still a challenge that needs active research in the context of decarbonization as well as extending its usable life (coal conversion). One method to increase the usage of clean coal while also lessening the impact on the environment is coal gasification [2]. Thermochemical gasification is a method used to turn solid coal into flammable gas. What's left over after coal is converted to gas is called syngas (synthetic gas). Char is a byproduct of the gasification of coal that can still store energy. It is first possible to hypothesize that char still has energy potential and that there has been a significant decrease in sulfur concentration based on the results of the characterization. Char, the study's original waste product, has the potential to be used as a raw material for the manufacture of briquettes [3]. When attempting to increase the added value of coal by converting it into solid fuel through briquettes, concentrating exclusively on increasing calorific value is insufficient due to the fact that coal also has a low volatile matter content in addition to its large proportion of solid carbon. These conditions lead to high ignition temperatures [4]. To help solve this problem, biomass (agricultural/plantation waste) will be added to coal briquettes. This is because the biomass has a high concentration of volatile stuff, which permits. This is because the biomass has a high concentration of volatile materials, allowing for ignition at low temperatures and so requiring less time and energy [5].

The creation of biobriquettes, which combine coal with biomass, is an attempt to produce briquettes. Calories being the same. Due to its calorific value being on par with or even higher than coal, coconut shell was chosen as an additional material to increase the fuel value of biobriquettes [6]. Coconut shell will be used as a supporting material in this experiment since it has the ability to diffuse heat, which is a property of this biomass. Exceptional and capable of producing heat at a rate of 6500–7600 kcal/kg [7]. Co-firing is the name of the process that combines the use of coal and biomass fuels. Co-firing, often referred to as co-combustion, is the practice of utilizing two distinct fuels in a single combustion unit. Co-Firing Fuel and Torreffed Biomass in the Form of Gandhi K. Hudaya 33, which is frequently used in a steam boiler. Co-firing combustion of coal and biomass can be seen as an addition to a system that works with coal-fired boilers [8].

### 1.1 Co-firing

Co-firing is, in general, defined as the process of simultaneously burning two different fuel types. The reduction of CO2, SOx, and NOx emissions from fossil fuels is a benefit of using the co-firing combustion system. This increases demand for the co-firing technology in coal-fired steam power facilities (Winaya, Susila and Agung, 2010). According to the combustion process, there are at least two different cofiring methods: direct cofiring and indirect cofiring. Direct cofiring, which concurrently burns biomass and coal, is the less expensive of the two combustion techniques. Biomass gasification comes before indirect co-firing. In the combustion chamber, the resultant gas is fed coal. Cofiring of biomass does not increase the greenhouse effect because it emits the same amount of CO2 during combustion as it absorbs.. The majority of biomass fuels contain

**Table 1.** Coal Briquette Quality Standards

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

Sumber [18]

less sulfur and nitrogen than coal, hence co-firing the biomass can frequently reduce NOx and SOx emissions. Co-firing of biomass with coal has therefore attracted a lot of research in recent years (Mehmood, Reddy and Rosen, 2012). In general, biomass has high volatile matter and moisture content, solid carbon content, and a relatively low calorific value, but very little ash content—less than 5%. (Surono, 2010; Rismayani and Sjaifudin, 2011; Sui et al., 2013). Elephant grass has a calorific value of 4,191 kcal/kg, but cassava stems have a greater calorific value at 4,400 kcal/kg. Kiara umbrella leaf biomass has a calorific value of roughly 4,000 kcal/kg (Prakobboon and Vahdati, 2013; dos Santos et al., 2015). Typically, biomass material has a lower heating value than coal. As an illustration, the South Sumatra coal Air Laya has a calorific value of 5,300 kcal/kg [18] (Table 1).

Focusing solely on boosting calorific value is insufficient when trying to raise the added value of coal by converting it into solid fuel through briquettes because, in addition to its high proportion of solid carbon, coal also has a low volatile matter content. High ignition temperatures are a result of these circumstances [9, 10]. Therefore, to anticipate this problem, coal briquettes will be added with biomass (agricultural/plantation waste). This is due to the biomass's high volatile matter concentration, which enables ignition at low temperatures and reduces the time and energy needed for ignition [11, 12]. Bio-briquettes are attempts to create briquettes by combining coal with biomass. Coconut shell was chosen as an additive to boost the fuel value of biobriquettes because it has a calorific value that is equal to or even exceeds that of coal [13]. 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

**Table 2.** Ultimate Analysis Biomass Materials

| 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 |

Sumber: [13]

6500–7600 kcal/kg [14]. The following is the ultimate analysis table for various types of biomass (Table 2).

## 2 Material and Methods

This research was conducted at the Energy Engineering Laboratory of the Sriwijaya State of Polytechnic, Palembang and the PT. Bukit Asam, Tanjung Enim. The tools used in this research are portable furnace, infrared thermometer, charcoal pounder, mesh sieve, digital scale, briquette mold, press machine, heating oven, desiccator, beaker, and stirring rod. Coconut shell charcoal.

In this study, the fixed variables were the type of adhesive and the concentration of the adhesive used, namely 10% w/v tapioca adhesive, while the variable variables were variations in the size and composition of each raw material used and the shape of the briquettes. For size variations, the sizes used are (+20 mesh), (−20 + 60 mesh), and (−60 + 170 mesh) coded X–Z. used is the ratio (100:0; 75:25; 50:50; 25:75; 0:100) %w/w of the total weight of the mixture of 300 g for each composition variation, each coded V1–V5.

## 3 Results and Discussion

### 3.1 Characterization of Gasified Char Coal and Coconut Shell Torrification

Char is combined with the primary raw material used to make biobriquettes. The coal used in coal gasification and the production of torreffed coconut shell comes from a mine in the Muara Tiga Besar (MTB) region. Coal and char were characterized to see how the gasification process affected changes in the quality of the two. The characterization of these two raw materials can be seen from Tables 3 and 4.

**Table 3.** Char Gasification Analysis

| **Proximate Analysis** | **Char** |
|---|---|
| Inheren Moisture (%,) | 13.00 |
| Ash Content (%,) | 0.70 |
| Volatile Matter (%,) | 41.00 |
| Fixed Carbon (%,) | 47.30 |
| Total Sulphur (%,) | 0.28 |
| Calorific Value (Cal/gr) | 6,7830 |

**Table 4.** Analysis of Carcoal Shell

| **Proximate Analysis** | **Shell Charcoal** |
|---|---|
| Moisture (%) | 6.9 |
| Volatile Matter (%) | 18.2 |
| Ash Content (%) | 2.1 |
| Total Sulfur (% adb) | 0.40 |
| Fixed Karbon (% adb) | 74.85 |
| Calorific Value (cal/gr) | 6,275 |

The coal from the Muara Tiga Besar Mine will then go through a gasification process using the Underground Coal Gasification prototype [15]. The Char from this gasification will then be used as the main raw material for making biobriquettes.

As an extra biomass material for the production of biobriquettes, coconut shell charcoal will first undergo proximate and ultimate analysis to identify its chemical composition. Includes water content, ash content, volatile matter, carbon value and calorific value, as well as elements of carbon, hydrogen, nitrogen, sulfur and oxygen. The results of the proximate and ultimate analysis of coconut shell charcoal are as follows:

From the results of previous studies [18], it is known that char has a very good potential as a raw material for biobriquettes, it can be seen from the decrease in water content and total sulfur as well as a significant increase in the calorific value of coal and char gasification samples. After proximate analysis was used to characterize the char, it was discovered that the calorific value had increased from 5,804 to 6,7830 cal per gram, the sulfur level had significantly decreased from 1.18 to 0.28, and the water content had significantly decreased from 16.10 to 13%.. This improvement in quality is also due to the coal (of the lignite variety) utilized, which is suited for use as a raw material because low thermal maturity coal performs better during gasification than high rank coal with higher coalification [19].

**Table 5.** Proximate Analysis Biobriquete

| | Variasi Sample | Parameter Karakterisasi | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Moisture (%)* | *Volatile Matter (%)* | *Ash Content (%)* | *Total Sulfur (%)* | *Fixed Carbon (%)* | *Kalori (Cal/gr)* |
| 1 | XV1 | 6,61 | 16,6 | 7,2 | 0,81 | 69,59 | 6.321 |
| 2 | XV2 | 6,62 | 17,7 | 5 | 0,47 | 70,68 | 6.587 |
| 3 | XV3 | 4,92 | 17,5 | 4,3 | 0,38 | 73,28 | 6.818 |
| 4 | XV4 | 4,90 | 17,9 | 6,1 | 0,48 | 71,10 | 6.517 |
| 5 | XV5 | 5,09 | 19,3 | 2 | 0,19 | 73,61 | 7.007 |
| 6 | YV1 | 5,92 | 23,8 | 10 | 0,69 | 60,28 | 5.830 |
| 7 | YV2 | 6,86 | 21,3 | 5,1 | 0,61 | 66,74 | 6.288 |
| 8 | YV3 | 6,18 | 18,6 | 4,8 | 0,53 | 70,42 | 6.630 |
| 9 | YV4 | 4,26 | 19,6 | 2,8 | 0,27 | 73,34 | 6.878 |
| 10 | YV5 | 4,85 | 20,1 | 1,4 | 0,19 | 73,65 | 7.076 |
| 11 | ZV1 | 7,35 | 24,5 | 7,1 | 0,77 | 61,05 | 5.896 |
| 12 | ZV2 | 6,14 | 22,3 | 8,3 | 0,69 | 63,26 | 6.016 |
| 13 | ZV3 | 6,26 | 20,8 | 7,7 | 0,53 | 65,24 | 6.244 |
| 14 | ZV4 | 5,32 | 22,4 | 5,9 | 0,38 | 66,38 | 6.457 |
| 15 | ZV5 | 3,58 | 22 | 4,1 | 0,24 | 70,32 | 6.710 |

### 3.2 Biobriquette Characteristics

The results of the biobriquettes obtained were carried out with characteristic analysis, namely proximate analysis, the results of the analysis can be seen in the Table 5.

Based on the findings of earlier studies [20], and referring to Ministerial Regulation 047 of 2006 regarding coal briquettes and the qualifications of Japanese, British, American, and Indonesian charcoal briquettes, namely SNI 01-6235-2000, it was discovered that the overall water content value of all briquette samples had been in compliance with the maximum 15% standard for biobriquette coal briquettes in referring to Ministerial Regulation 047 of 2006 which is no more than 15%, as well as the charcoal briquette standard in SNI 01-6235-2000, which is no more than 8% so that it was found that the overall sample had met the standard, as well as the American, British and Japanese references, the value was in the range of 15–24%. Meanwhile Ministerial Regulation 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 to Ministerial Regulation 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%. The whole sample of briquettes has complied with Permen 047 of 2006's requirements for a maximum of 1% in the total sulfur value. In contrast, SNI01-6235-2000 does not regulate the total sulfur value. Additionally, the minimum value is determined to be 77%

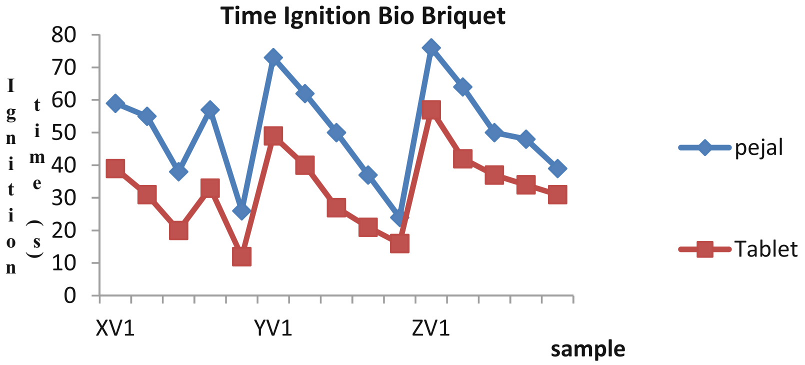


**Fig. 1.** Graph of Ignition temperature

for the fixed carbon value based on the qualification of SNI 01-6235-2000, while on Ministerial Regulation 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 74.61%. However, if based on qualifications from Japan and America, the fixed carbon samples all meet the standard as the qualification value for fixed carbon is at least 60%, and the qualifications based on the Indian BEE Criterion Standard, the tethered carbon standard is a minimum of 46.79% [21]. According to SNI 01-623-2000 qualification and Ministerial Regulation 047 of 2006, the calorific value must be at least 5000 kcal/kg and at least 4000 kcal/kg, respectively, for all samples of briquettes to meet the quality standard values.

### 3.3 Ignition Time

A good biobriquette is one that burns quickly or has a short ignition time. In the biobriquettes produced, the calculation of the time required for ignition is relatively short with the fastest time being 24 s on the BV5 sample or 60 mesh size with 100% coconut shell charcoal, while the longest ignition time is 76 s or 1 min more on the ZV1 sample or size 100 mesh with 100% char, as can be seen in Fig. 1.

From the graph it can be seen that in the same grain size group, the more coconut charcoal composites are added, the faster the biobriquettes will ignite, this is very likely related to the volatile content contained in coconut charcoal [22] and also the decreasing water content along with the increasing addition of coconut shell charcoal [17, 23]. The combustion characteristics of biobriquettes are significantly influenced by their moisture and volatile matter contents. The amount of volatile matter in coal briquettes determines how easily they burn and ignite, which in turn affects how quickly they ignite. The amount of volatile coal biobriquettes produced depends on the type of coal used, its raw materials, and the mass density of the biobriquettes at the time of printing [17, 24]. Meanwhile, when compared in grain size, it can be seen that the 60 mesh size is the faster burning grain size, followed by the 20 mesh size and finally the 100 mesh size, this may be due to the use of adhesives, small particle size, low porosity and bond strength of the briquettes high [25]. Where the use of flour as an adhesive will show a higher water content [24], in this study the use of adhesives was not taken into account in detail. Meanwhile, the higher the water content value, the more difficult it is for ignition to occur, because the high water content will cause the calorific value produced by the briquettes to decrease, this is because the energy produced will be absorbed a lot to evaporate water [26, 27]. This makes the briquettes more difficult to burn. In addition, the presence of inorganic content in the adhesive can increase the ash content so that it can become an impurity and slow down the combustion flame [28].

## 4 Conclusions

Based on the results of the study, it was found that the addition of coconut shell charcoal has a good impact on the ignition properties of biobriquettes made from coal char gasification, this can be seen in the nature of the ignition time in the combustion of biobriquettes, it was found that the ignition time with the fastest time was 24 seconds in the sample BV5 or the size of 60 mesh with 100% coconut shell charcoal, while the longest ignition time is 76 seconds or 1 minute more on the CV1 sample or the size of 100 mesh with 100% char. Meanwhile, the longest burning time was in the BV5 sample or biobriquette with a grain size of 60 mesh and 100% coconut shell charcoal, which was 1894 seconds or equivalent to 31.5 minutes, while the fastest was in the AV4 sample or grain size of 20 mesh and 75% shell charcoal coconut is 1440 seconds or 24 minutes. And for the maximum temperature of all samples obtained in the second 4 minutes, then decreased, for the highest maximum temperature was found in the sample BV5 or size 60 mesh with 100% coconut shell charcoal, which was 532.80C, but in general the initial temperature of combustion was up to After the completion of the briquette burning, all samples followed a pattern that was not much different, the deviation occurred at CV3 or 100 mesh with a variation of 50% char and coconut shell charcoal. The best grain size variation is in the grain size of 60 mesh and 100 mesh, this is because the smaller the grain size will increase the ignition time and bind oxygen to maintain a more efficient combustion time.

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