# Utilization of Bottom Ash and Biogas Sludge into Carbon Briquette as an Alternative Fuel

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Abstract: Bottom ash is by-product of coal power plant that gain less attention to be utilized compared to fly ash whereas the production of bottom ash will continue to increase due to increasing of energy demand particularly in Indonesia where most of its power plant use coal as combustion material. Former researches commonly proposed bottom ash as fertilizer or soil amendment and although the idea of utilization of bottom ash as fuel had been identified years ago, study of bottom ash as fuel seems to be still limited. This research aims to investigate potential utilization of bottom ash as fuel by mixing it with carbonized biogas sludge prior to briquetting process to produce carbon briquette. The quality of briquette determined using parameters such as moisture content, ash content, and calorific value. Result shows that adding biogas sludge carbon significantly increase calorific value of bottom ash from 270.9141 Cal/g to as high as 2180.7976 Cal/g.

## 1 INTRODUCTION

Bottom ash and fly ash, two major by-product of coal power plant, considered to be increased in years ahead especially in Indonesia where most power plant are still using coal as its fuel. It has made known that electricity supply in this country is still constantly in struggle to meet the domestic's needs to this day while on the other hand, the domestic energy demand continuously increasing. This condition will cause unavoidable increasing use of coal and aligned to that, the increasing production of bottom ash and fly ash. There are differences of properties of bottom and fly ash, that results different potential utilization of both. Many research concluded that utilization of fly ash are preferable than bottom ash due to its properties i.e. mineral content, important trace element (James et al., 2012), and heavy metal contaminants (Khan, A.; Jong, W.; Jansens, P.; Spliethoff, 2009). Other issue is that research on utilization of fly ash are more in number than of bottom ash that effective management and potential utilization of bottom ash still little known (James et al., 2012). Former studies which have been conducted on bottom ash commonly proposed its utilization as fertilizer and soil amendment, in addition to that, papers and studies in this field of research are still limited (James et al., 2012).

It is also known from former researches that bottom ash contains unburnt carbon due to inefficient fuel use during combustion process. This unburnt carbon content, however, can be a potential energy resource to harvest. Unburnt carbon content act as combustible matter which can be convert to heat through combustion process. This fact strengthens idea of utilization bottom ash as fuel, which had been proposed by Batra et al. (Batra, V.; Urbonaite, S.; Svensson, 2008). He stated that bottom ash can be utilized as household fuel or gasifier feed after briquetting or pelletizing, but according to James et al. (James et al., 2012), there is no research of bottom ash as fuel can be found to this day, that more investigation still needed to conduct to have better understanding of capturing this energy as fuel.

Biogas sludge, a left-over solid after anaerobic digestion of organic substance to produce biogas, is mixed with bottom ash to complement the properties of briquette as fuel. Biogas or biofuel has been widely known as promising future energy source due to its economical, renewable, and clean energy

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characteristics whilst also has high calorific value. Biogas global production in 2015 according to Scarlat (Scarlat, N., Dallemand, J.F., Fahl, 2018) already reach approximately 36 billion $m^3$. Study on biogas is still enchanting many researchers to this day in the search of more effective and efficient method to produce biogas as well as the higher purity one, yet utilization of biogas residue somehow gains less attention. Optimizing potential utilization of biogas residue is worth to conduct considering its increasing amount due to increasing biogas production. According to Campo (del Campo et al., 2010), biogas residue is common to be applied directly by spreading it onto soil as soil fertilizer because it has undergone maturation or composting process to form valuable organic matter.

Former researches also had proposed several methods of utilizing anaerobic digestion sludge. Fish farm sludge can be used as agricultural fertilizer, input factor in microalgae production, source of combustion, and fish feed ingredients (del Campo et al., 2010). Nusong and Puajindanetr proposed utilization of beer industry wastewater sludge mixed with biodiesel production waste as briquette fuel (Nusong & Puajindanetr, 2018) and many other researches has been conduct on utilization wastewater treatment plant sludge as alternative energy source such as industrial fuel or combustion feed for incineration, some of them are represented by Chiou et al. (Chiou, I.-J., & Wu, 2014), Werle S. (Werle, 2015), and Jiang et al. (Jiang, L., Yuan, X., Xiao, Z., Liang, J., Li, H., Cao, L., ... Zeng, 2016). These researches concluded the undoubtedly potential utilization of organic substance sludge as alternative energy.

This study proposed briquetted bottom ash mixed with carbonized biogas sludge as an alternative fuel. The sludge taken after anaerobic digestion of organic mixture consist of cow manure, fish waste, and water hyacinth. Cow manure has been proven of producing high calorific value biogas and fish waste are also considered to have high organic content that is potential to produce high calorific value biogas, fish waste can be found easily in coastal area of Cilacap, Central Java since it has many fishing industries, while water hyacinth added in order to increase C/N ratio or carbon content in biogas sludge which will increase calorific value of fuel briquette. Carbonization conducted to convert organic substance of biogas sludge into combustible matter ready for energy capturing in the form of heat by combustion. According to Kurniawan et al. (Kurniawan et al., 2018), combustion is one among many technologies to convert sludge into energy source. Briquetting method is selected for practical purpose of usage considering suggestion proposed by Batra et al. (Batra, V.; Urbonaite, S.; Svensson, 2008). This research aims particularly to utilize the potential of bottom ash as fuel by mixing it with carbonized biogas sludge using briquetting method as part of larger purpose of finding effective and efficient method to optimally utilize bottom ash.

# 2 EXPERIMENTAL METHOD

## 2.1 Material

Bottom ash taken from Bunton Coal Power Plant, Adipala, Cilacap, Central Java. Feed material for anaerobic digestion is mixture of cow manure, fish waste, and water hyacinth with ratio of weight 5:1:1. Cow manure, fish waste, and water hyacinth originally taken from around coastal area of Cilacap, Central Java. Molasses used as mixture binder in briquetting process are commercial molasses.

## 2.2 Testing Procedures

Biogas sludge collected after 28 days of anaerobic digestion process. Sludge then dried under sunlight for 5 days prior to carbonization process at 200-300 $^{o}$ C for 2 hours in the furnace. Carbon from carbonization process of sludge then mixed with bottom ash (weight ratio of biogas sludge carbon, BSC and bottom ash, BA presented in table 4) and sieving with 200 mesh prior to pressing to form briquette with molasses as binder with weight ratio of solid and molasses 1 : 1.25. Briquette then dried up and hardened by exposing under sunlight for 5 hours. Parameters used in this research are calorific value, moisture content and ash content , based on Indonesian Standard Quality (SNI) 01-6235-2000 for fuel briquette. Calorific analysis conducted in PT. Solusi Bangun Indonesia's alternative fuel and raw material laboratory using Bomb Calorimeter to determine calorific value, ash content and moisture content by thermogravimetric analysis in Chemistry Laboratorium, Environmental Pollution Control Engineering Department, Politeknik Negeri Cilacap.

# 3 RESULT AND ANALYSIS

## 3.1 Characteristics of Raw Material

Chemical composition/properties of coal combustion bottom ash derived from literatures concised by Priyadharshini et al. (Priyadharshini P, Dr. Santhi A S, 2011) are presented in Table 1.

Table 1: Chemical Composition of Combustion Coal Bottom Ash.

| **Major Element** | **% Weight** |
|---|---|
| SiO2 | 38.2-54.5 |
| Al2 O3 | 15.1-21.3 |
| C | 6.52-10.10 |
| Fe2O3 | 5.50-32.8 |
| CaO | 2.04-17.9 |
| K2O | 1.10-2.1 |
| LOI | 1.40-11.0 |
| MgO | 0.79-4.26 |
| TiO2 | 0.70-1.3 |
| Na2O | 0.27-1.0 |
| SO3 | 0.21-2.5 |

Properties of biogas sludge examined at 28$^{th}$ day of anaerobic digestion process are presented in Table 2.

Table 2: Properties of Biogas Sludge.

| Parameters | Value |
|---|---|
| Moisture content (% w) | 94.27 |
| Volatile solid concentration (ppm) | 10,400 |
| Total solid concentration (ppm) | 28,000 |

## 3.2 Briquette Experimental Result

Parameters examined in this study are moisture content, ash content, and calorific value. These parameters based on Indonesian Standard Quality (SNI) 01-6235-2000 for fuel briquette (Table 3) and the result provided in Table 4.

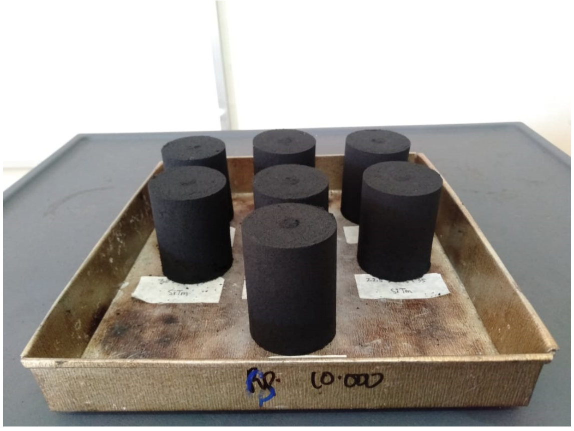

Figure 1: Bottom ash and biogas sludge briquette.

Table 3: Indonesian National Quality Standard for Quality Briquette.

| **Parameters** | **Value** |
|---|---|
| Moisture content (%) | <8 |
| Ash content (%) | <8 |
| Carbon content (%) | > 77 |
| Calorific value (cal/g) | > 5000 |

Badan Penelitian dan Pengembangan Kehutanan (1994) , Putri (2017) (Putri, 2017)

Variable of experiment is ratio of biogas sludge carbon (BSC) and bottom ash (BA) which composed fuel briquette. Experiment aims to find out ratio with the best quality briquette in parameters of moisture content, ash content, and calorific value. Result of experiment provided in Table 4.

Table 4: Briquette Experimental Result.

| **Sample (%w)** | **Moisture Content (%)** | **Ash Content (%)** | **Calorific Value (Cal/g)** |
|---|---|---|---|
| BSC : *BA*= 0%:100% | 1.55 | 83.96 | 270.9141 |
| BSC : BA= 20%:80% | 2.21 | 80.81 | 919.3231 |
| BSC : BA= 40%:60% | 3.00 | 71.41 | 1180.657 |
| BSC : BA= 60%:40% | 3.98 | 59.64 | 1497.1601 |
| BSC : BA= 80%:20% | 5.70 | 48.79 | 2180.7976 |
| BSC : BA= 100%:0% | 7.05 | 29.52 | 3226.7651 |

## 3.3 Moisture Content

Moisture content for each sample of briquette are presented in Figure 2. It shows that moisture content of briquette increase along with the increasing ratio of biogas sludge to bottom ash increase. This is due to hygroscopic nature of biogas sludge. The ability to absorb water comes from carbon's high surface area and pores. Moisture content is a disadvantage in capturing energy of fuel briquette because it inhibits conversion of chemical potential energy into heat by oxidation process (combustion) which is unwanted in accordance with the purpose of research and the higher the moisture content, the lower its ability of burning and heating and briquette's quality. However, moisture content in all variants of briquettes are below limit value of standard (< 8 %). This also conclude that briquette of carbonized biogas sludge and bottom ash typically has low moisture content. This low moisture content is derived as result of carbonization process of biogas sludge where most of water vaporized during the process.

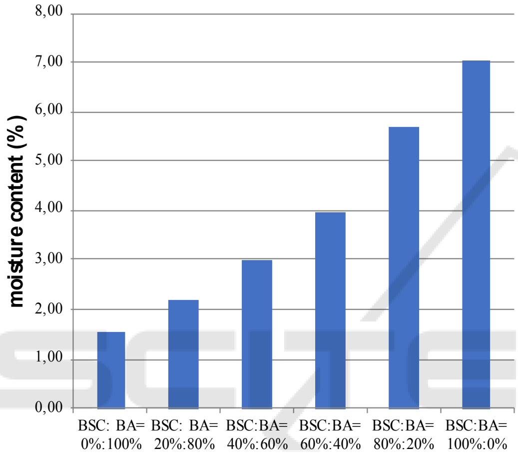


Figure 2: Moisture content of briquette.

## 3.4 Ash Content

Results of ash content are presented Figure 3. It shows that increasing ratio of biogas sludge to bottom ash on the contrary decrease ash content of briquette. It is due to amount of bottom ash composed the briquette. Ash is inorganic incombustible matter left after combustion process of fuel and bottom ash is an incombustible left over solid of coal combustion. Ash content in a briquette prevent combustion gas free movement to the core of briquette (James et al., 2012) and inhibit energy conversion which is unwanted. The higher the ash content, the lower the quality of briquette. Ash content of all variant briquette are above standard value (< 8%) which shows that the use of bottom ash as fuel might be at cross purposes.

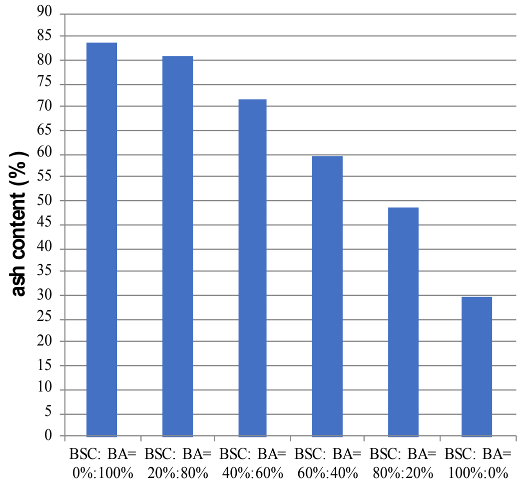


Figure 3: Ash content of briquette.

## 3.5 Calorific Value

Calorific value is the most important parameter of fuel's quality (Isa, 2012). The higher the calorific value, the higher the quality of briquette as fuel. From Figure 4. we may know that 100 % bottom ash briquette has calorific value even though far below SNI standard. Calorific value of 100% bottom ash briquette shows that bottom ash still contain combustible matter that is unburnt carbon (James et al., 2012). Calorific value increase with the increasing ratio of biogas sludge carbon. It extent from only 270.9141 Cal/g (100% bottom ash) to as high as 2180.7976 Cal/g (20% bottom ash).

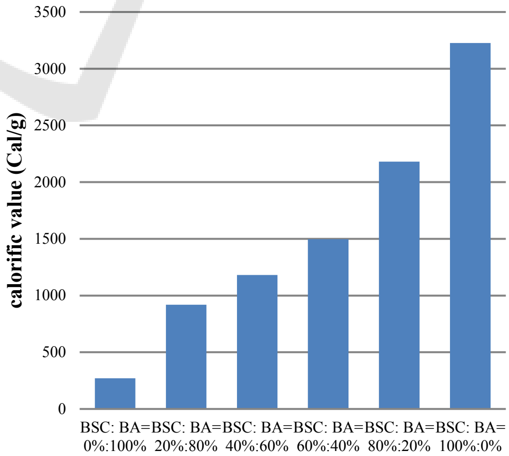


Figure 4: Calorific value of briquette.

According to (Erikson, 2011), moisture content and ash content influence calorific value of carbon briquette. The higher moisture content and ash content, the lower calorific value however results of this research show that highest calorific value possess by briquette with highest moisture content (20 % bottom ash). This is due to drying process applied prior to usage that removed moisture and increase heating efficiency in briquette.

# 4 CONCLUSIONS

Result of experiments conducted in this research draws conclusion that biogas sludge carbon added to bottom ash proven to be successfully increased calorific value of briquette from only 270.9141 Cal/g (100% bottom ash) to as high as 2180.7976 Cal/g (20% bottom ash) with low moisture content (below 8%) even though ash content is above standard value of SNI 01-6235-2000, that it might open ways for bottom ash not just ended at landfill, yet it still needs further research to be optimally utilized as fuel. Other organic substance to increase calorific value of bottom ash might considerably conduct for the next research.

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