INDONESIAN JOURNAL OF MULTIDISCIPLINARY SCIENCE

P-ISSN: 2808-5957
E-ISSN: 2808-6724
ijoms.internationaljournallabs.com

Potential Use of Waste Biodrying Products as Cofiring Steam Power Plants (PLTU Labuhan Angin)

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Keywords:
Biodrying, waste, cofiring, coal-fired power plants, renewable energy, carbon value, wind farms, emission reduction.

ABSTRACT

Sustainable waste management is an important challenge in facing the energy and environmental crisis. One of the solutions that has begun to be developed is the use of biodrying technology, which is the process of drying organic waste using biological activity and aeration to reduce moisture content and increase the calorific value. This study aims to examine the potential of waste biodrying products as an alternative fuel in the cofiring process at the Labuhan Angin Steam Power Plant (PLTU). The methodology used includes the analysis of biodrying product characteristics, measurement of calorific values, as well as technical and environmental feasibility studies in cofiring applications. The results show that biodrying products have a calorific value that is competitive enough to be used as a partial substitute for coal, and can reduce carbon emissions and environmental burden. The implementation of cofiring with waste biodrying has the potential to contribute to the clean energy transition and reduce the volume of waste disposed of in landfills.

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INTRODUCTION

Waste is an item or object in the form of residual material that is no longer used, then thrown into nature (Susanto, 2017). In Law No. 18 of 2008 concerning Waste Management, it is stated that waste is the residue of human activities or natural processes in solid or semi-solid form in the form of organic or inorganic substances that are easily decomposed or not easily decomposed and are considered useless and then disposed of into the environment. In general, households do not have a system for sorting organic, inorganic and recycled waste (Chazanah & Nandiyanto, 2022; Czajkowski et al., 2014; Pedersen & Manhice, 2020). In his research, Rojak et al., (2021) stated that door-to-door garbage collection is rarely done or has not been handled properly which will eventually lead to household waste usually ending up in an open dump or roadside landfill.

The rapid increase in the number of people in Central Tapanuli Regency has changed people's consumptive habits and lifestyles (Fahmi et al., 2019). In addition, people's purchasing power for various types of staples, electronic equipment and development activities is also the cause of the increase in the amount of waste (Manomaivibool & Vassanadumrongdee, 2011; Mihai et al., 2019). The increase in the amount of waste causes an increase in the type and characteristics of waste in landfills. In line with this, there will be an increase in the volume of generation. Waste generation that is not processed or utilized will have a negative impact on health and the surrounding environment (Alabi et al., 2019; Gaur et al., 2020; Z. Zhang et al., 2022).

With a population of 365,177 people, the waste produced in Central Tapanuli Regency until 2022 reached ±182,588.5 kg/day or ±182,588 tons/day. With a composition percentage of 60% organic waste and 40% inorganic waste. Most of the waste comes from households. According to data from the National Waste Management Information System (SIPSN, 2022), the volume of national waste in 2023 is 40.74%. For Central Tapanuli Regency, the percentage of waste

generation recorded in SIPSN is as much as 6.7% which comes from various human activities such as industrial activities, markets, community settlements, and office activities. Currently, waste generation in Central Tapanuli Regency is a problem faced by the community and the Central Tapanuli Regency Government (Eriza et al., 2024; Sitorus et al., 2024).

In the last two years, the amount of waste generated in Central Tapanuli Regency was 66,644.80 tons in 2021 and 67,397.25 tons in 2022. Currently, waste management in Central Tapanuli Regency is carried out by the Environment Agency (DLH) of Central Tapanuli Regency which is followed by community participation in managing waste. Waste management is carried out by carrying out mutual cooperation and community service, paying waste levies and carrying out the 3R principle (reuse, recycle and reduce). Waste that cannot be managed or reprocessed will be taken to the Final Disposal Site (TPA). According to the conditions in the field, there are several obstacles encountered such as the Final Disposal Site (TPA) in Central Tapanuli Regency, namely the Aek Nabobar Landfill located in Pinangsori is still an open dumping system, so better management is needed.

The limited waste facilities and infrastructure in Central Tapanuli Regency also greatly affect the condition of waste management, the limited service area in only two sub-districts and the limited human resources in the Government area in carrying out waste management. The author made observations in the field and saw firsthand the situation and found several obstacles, therefore the researcher intends to carry out waste management. Management is carried out by utilizing waste at the Aek Nabobar landfill into alternative energy using biodrying. Biodrying is a technology used to convert solid waste into energy (waste to energy) which can produce refuse derived fuel (RDF) (Zaman & others, 2021). In the research of Andani et al., (2002) it was stated that the biodrying process is a process of degradation of organic matter that is easily biodegradable in the waste so that it produces heat coupled with sufficient air circulation so that it allows the process of rapid evaporation of water content in the waste. This is in line with the research of Zhang et al., (2008) who said that the largest proportion of waste is food waste because it has a high moisture content, which can accelerate the evaporation process.

Biodrying is an aerobic process in solid waste where solid waste will undergo biological processes and produce rejected derived fuel (RDF). RDF is used as an alternative energy in steam power plants (PLTU). Co-firing is the main combustion of fuel accompanied by other fuels. The purpose of the implementation of co-firing is to reduce carbon emissions in a sustainable manner by replacing some coal with biomass which is generally sourced from wood. This study will analyze the potential to reduce the volume of waste at the Aek Nabobar Landfill after being used as co-firing biomass at the Labuhan Angin PLTU located in Tapian Nauli I, Central Tapanuli Regency. The composition of waste at the Aek Nabobar Landfill is in line with the characteristics of biomass that will be used for co-firing, where waste is dominated by combustible waste (flammable) such as leaf litter, paper, plastic, food waste and inorganic waste such as metal and glass that cannot be decomposed but can be recycled.

Based on research by Sembiring et al., (2018) it is said that combustible waste in the Jatibarang Landfill has the potential as a raw material for RDF which is one of the alternative fuels

This research was conducted at PLTU Labuhan Angin, a coal-fired steam power plant located in the Central Tapanuli Regency area. The Labuhan Angin PLTU is located in the Tapian Nauli I sub-district which is not too far from the Aek Nabobar Landfill. With a distance of 1 hour and 44 minutes as far as 48.2km from the Aek Nabobar Landfill to the Labuhan Angin PLTU. The Labuhan Angin coal-fired power plant has a capacity of 2 x 115 MW installed using fossil fuels

as the main fuel. Until 2021, the Labuhan Angin coal-fired power plant uses 406,953.67 tons of fossil fuels. In 2022, the Labuhan Angin co-firing power plant has conducted a biomass co-firing experiment using palm shells. In line with the experiments that have been carried out, this research aims to utilize waste at the Aek Nabobar Landfill as biomass co-firing as an alternative energy at the Labuhan Angin coal-fired power plant.

METHOD

The data that will be used in this study are primary data and secondary data. Primary data were obtained from direct observation in the field, conducting biodrying research and conducting test analysis in the laboratory. Meanwhile, secondary data was obtained from journals, books and other appropriate data to support the data in this study.

This research was conducted at the Labuhan Angin-Tapanuli Tengah Organic TPTU. During the study, four rectangular reactors were used as containers for the biodrying process. The design of the reactor used for the biodrying process can be seen in Figure 2. The 80 L plywood reactor is equipped with sampling pits, gas emission pits, and temperature monitoring pits. Furthermore, the reactor is also equipped with a blower that functions as an air supply and the rate of air flow is measured using an anemometer. Figure 4 Biodrying Reactor Design: 1) gas emission hole, 2) upper sampling hole, 3) middle sampling hole, 4) lower sampling hole, 5) leachate outlet, 6) airflow rate pump.

Solid waste comes from the Aek Nabobar landfill in Pinangsori, Central Tapanuli. The waste is dominated by plastic waste, fabric, food waste, paper, leaf litter, wood branches, metal and glass. Next, the waste is sorted to find out the percentage of each component (%). The composition of solid waste used is 64% (v/v) leaf litter, 2% (v/v) food waste, 15% (v/v) paper waste, and 19% (v/v) plastic waste.

Furthermore, the waste is chopped and then stirred with mature compost (bulking agent) with a ratio of 70% (v/v) of compost and 30% (v/v) of waste composition. The height of the waste will reach three-quarters of the total reactor height (50 L). The arrangement of the height of the types of waste put into the reactor is: 27cm leaf litter, 1cm of food waste, 6cm of paper waste, and 8cm of plastic waste.

This research uses a reactor made of plywood material measuring 40 x 40 x 60. The choice of plywood reactors was made because of its ability to avoid direct sunlight, increase the temperature and affect the microbial activity in the reactor. The temperature is monitored using a thermometer. Next, the air flow pipe is placed behind the reactor connected to the blower.

The biodrying reactor uses four reactors, namely control reactor (R0), reactor 1 (R1), reactor 2 (R2) and reactor 3 (R3). The reactor is equipped with temperature picking holes and airflow pipes. The airflow rate used during this study was as follows: 0 L/minute/kg (control), 4L/minute/kg, 5L/minute/kg, 6L/minute/kg. The measurement of the airflow rate is carried out at the end of the exit hose using an anemometer. RDF sample testing was carried out by analyzing moisture content, temperature, organic C content, total N and calorific value on day -0, day -15 and day -30. This study was conducted for 30 days.

This study uses three variables, namely independent variables, control variables, and bound variables. The variables used in this study are::

Variabel Bebas : Laju Aliran Udara
Variabel Terikat : RDF
Variabel Kontrol : Suhu dan Kadar Air

Data Presentation Methods

This research will present the data described in the form of graphs and tables. The data in the form of a graph will present data on temperature, moisture content, organic c, total n and calorific value during the biodrying process within 30 days of the study. Data in the form of a table will be presented with data on the development of the biodrying process for 30 days.

RESULT AND DISCUSSION

Biodrying Process

Biodrying in this study was carried out using aerobic methods using aeration (air circulation), biodrying reactors, addition of bulking agents and waste shredding. The study was conducted for 30 days on 4 sample reactors. The parameters to be analyzed in this study are based on the explanation contained in sub-chapter 3.7. After analyzing these parameters, it will be known that the calorific value of solid waste at the Aek Nabobar Landfill can meet the caloric standards that will be needed for fuel at the Labuhan Angin PLTU. The following are the parameters that will be identified in the biodrying process:

Temperature

The purpose of temperature measurement is to find out the extent of the success of the waste conversion process of the Aek Nabobar Landfill converting waste into waste-derived fuel (RDF) by the biodrying method. Based on Dofour's research, (2006) that the principle of biodrying operation is to reduce the moisture content of materials through the evaporation process using heat from exothermic waste decomposition, so as to produce dry products according to the desired characteristics.

In this study, temperature measurements were taken from 3 measurement points, namely the bottom, middle and upper part. Temperature measurements are carried out daily during the 30-day biodrying process to determine the temperature change pattern of each reactor. Based on the Picture .. Above, the initial temperature in each reactor is: R0 (control) 31.50C, R1 290C, R2 350C, R3 31.50C. In the biodrying process, the temperature is divided into three phases, namely the heating, cooling and stable phases. The heating stage occurred on the 2nd day which was marked by the occurrence of peak temperatures in the R2 reactor where the temperature reached 390C, while the R0 control reactor was 32.70C. The results show that the rate of air flow can increase the temperature of solid waste that reaches 390C. In the research of Ab Jalil et al., 2016 it was stated that the increase in temperature in the reactor until it reaches the peak temperature occurs between the first to the third day of the biodrying process. In this study, the peak temperature reached on day 2 was due to the addition of mature compost (bulking agent) which can increase the number of microorganisms so that the biodrying process can take place quickly. Based on the research of Sugni et al., 2005 that the aerobic process in biodrying aims to remove water, especially water vapor by using aeration and high temperatures. The highest temperature achieved in this biodrying study was a moderate thermophilic temperature. Based on the research of Ab Jalil et al., 2016 that biodrying is effective at mesophilic temperatures of 35-400C or moderate thermophilic temperatures of 40-450C compared to thermophilic temperatures of 55-700C. This happens because the temperature of >600C will kill the microbes, and the only thing that survives is thermophilic microbes. The temperature pattern on day 2 to day 30 in each reactor tends to

decrease slowly until it enters the mesophilic temperature. The temperature of R1 on the last day was lower than that of other reactors. This is because a higher airflow rate will accelerate the cooling of the material and stop microbial activity.

Moisture content

Moisture content is one of the important parameters in determining the efficiency of the biodrying process. This process relies heavily on microbial activity that decomposes organic matter in the waste, generating heat and lowering moisture content. A decrease in moisture content during biodrying occurs through two main mechanisms: evaporation and microbial activity (Chaerul & Wardhani, 2020).

During this process, the temperature rises due to the biodegradation process which causes evaporation and heating. As microbes decompose organic matter, the heat energy released increases the temperature inside the garbage pile. This increase in temperature accelerates water evaporation, so that the overall moisture content in the garbage will be reduced.

Microbes that play a role in the biodegradation process of organic matter require a balanced water content to function optimally. The results of the measurement of the moisture content of each reactor for 30 days.

The initial moisture content was 49.78-67.91%. The moisture content began to decline slowly on day 1, with a decrease of 15.27% in R0, 12.56% in R1, 7.8% in R2 and 17.01% in R3. At R0, no treatment is carried out on the airflow rate.

In this study, the results of the analysis of moisture content for 30 days showed fluctuating properties in the control R0 reactor (0 L/m) and the R3 reactor (6 L/m). Changes in the water content level that occur during the biodrying process tend to decrease. The moisture content in the R0 (control) reactor ranges from 35.76-67.91 while the R2 ranges from 37.06-67.81. A good water content for the beginning of the aerobic process is 50-70% for the growth of microorganisms (Tchobanoglous &Kreith, 2002). If the water content is less than 40%, it will cause low microbial activity because it requires water in the metabolic process. If the water content is too high, it will cause water to fill the pores of the garbage so that the condition becomes anaerobic (Sadaka et al., 2010). The moisture content contained in the organic matter will be reduced due to the activity of microorganisms in the biodrying process which will naturally increase the temperature during the decomposition process (Velis et al., 2009). When the biodrying process takes place, it will generate heat due to the activity of microorganisms, so that the heat will be used in the process of evaporating water contained in organic waste (Aminah et al., 2017). The cause of the increase in water content is due to the presence of water vapor that is retained at the bottom and causes an increase in air humidity (Andani & others, 2002). In this study, water that seeps out to the bottom of the pile as leachate cannot flow perfectly so it is trapped in the garbage pile (Santosa & Soemarno, 2014).

The moisture content in the R0 reactor before the processing process was 67.91% which then changed to 35.76% on the 30th day. So that the percentage decrease in the sample moisture content in the R0 reactor is 47% of the initial moisture content value. The waste moisture content in the R2 reactor before treatment was 67.81% and then dropped to 37.06 on the 30th day. The water content value of biodrying product waste in the R2 reactor decreased by 45%. The decrease in water content starts from day 1 to day 15. The percentage decrease in moisture content in the R2 reactor is greater when compared to the R0 reactor because the provision of air discharge in the waste pile effectively realizes an aerobic process that can reduce the moisture content of organic

matter (Velis et al., 2009). In this biodrying process, plastic and paper waste acts as a bulking agent (additional material) that can provide porosity between the piles of waste where it will help oxygen to enter and microorganisms will be more active and effective in reducing water content. During the biodrying process, the activity of microorganisms can reduce the moisture content from 60% to less than 20% in less than a month (Velis et al., 2009). The lowest moisture content value was achieved in the biodrying reactor (aeration 6 L/min) on the 30th day, which was 41.09%, this value has not reached the supposed moisture content value of less than 20%. This happens because the moisture trapped in the garbage pile during the biodrying process is not evenly distributed in the garbage pile. According to Johari et.al 2011, if the waste biodrying product to be used as a fuel element has a moisture content greater than 20%, the temperature will rise to 6000C so that the combustion process will not be successful.



Gambar 11 Kadar air hari ke 0
Gambar 13. kadar air hari ke 15
Gambar 12. kadar air hari ke 1
Gambar 14. kadar air hari ke 30

Figure 1. Water Content

Organic C and total N analysis

The relationship between carbon and nitrogen (C/N) is an important indicator that determines how effectively microbes play a role in the biodrying process, as well as their effect on the balance between the decomposition of organic matter and nitrogen use. The ideal C/N relationship is essential to achieve maximum biodrying, this is to ensure that microorganisms get sufficient amounts of carbon for energy and nitrogen for growth (Sadaka, S.2017). Microorganisms utilize carbon as a source of energy and nitrogen to build proteins. The right balance ensures that both processes take place effectively, leading to good heat production and moisture removal (Ingram E & Keshwani. 2020). The study proposes a C/N ratio of between 20-30 for optimal composting and biodrying (Sadaka, S.2017).

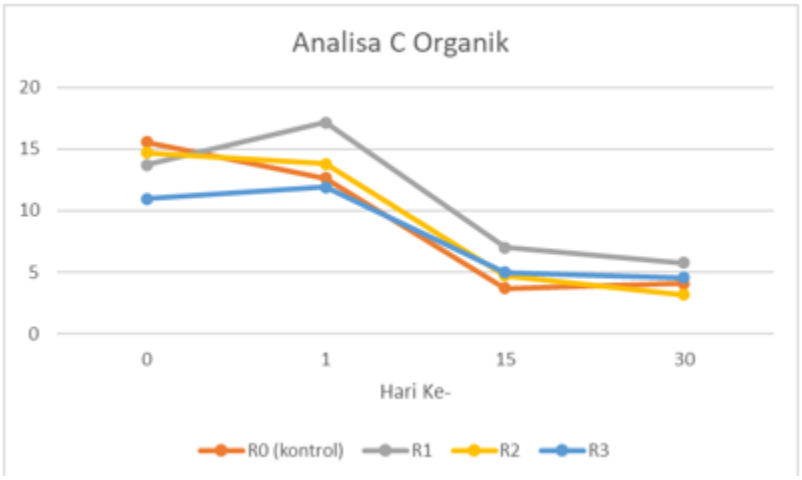


Figure 2. Graph of organic C analysis results

Based on Figure 2. The initial organic C graph on each reactor is 14.55% for R1 12.7%, R2 13.69% and R3 9.97%. Based on the results of the analysis, there has been a significant decrease in organic C levels. This happens because the organic carbon contained in waste is the basic material used by microorganisms as a source of energy and food to develop and carry out metabolism (Sadaka, S. 2017). The rapidly degrading organic carbon content will accelerate the activity of microorganisms so that peak temperatures can be reached on the first day (Velis, et.al., 2009). The organic C content decreases due to the decomposition of carbon materials into CO2 and energy.

On day 15, the decrease in organic C is not very large, because the activity of microorganisms on day 15 is not as high as day 1 and the reactor enters the cooling phase on day 15. On the 30th day, organic C increases due to a decrease in the activity of microorganisms, so that the degradation process of organic C slows down and the dead microorganisms will become biomass measured as organic c (Simanungkalit, R.D.M, et.al., 2006).

The lowest organic C levels (9.97%) were in the R2 reactor with an air flow of 6L/min, while the lowest decrease was (14.55%) in the R0 reactor with an air flow of 0L/min. The results of this study are in accordance with the results of a study with Rada, 2012 it is said that a good biodrying process occurs with a slow degradation process. The slow degradation process will increase the calorific value at the end of the biodrying process (Tom AP, Pawels R, et.al., 2016).

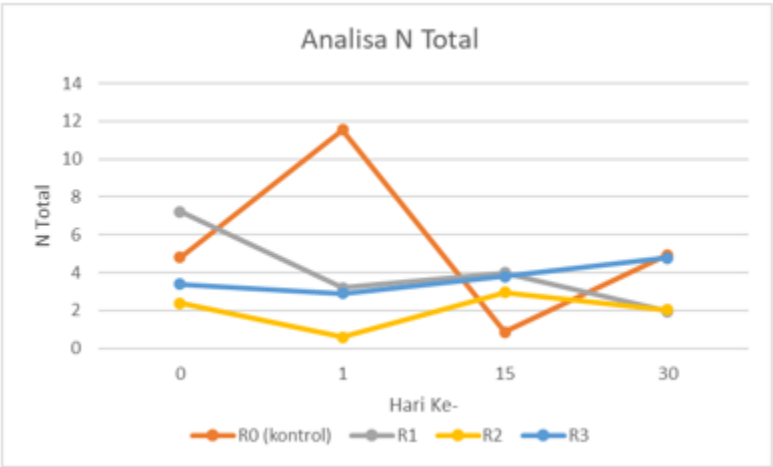


Figure 3. Graph of total N Analysis Results

Based on the figure, the initial total N content in each reactor was R0 3.81%, R1 6.23%, R2 1.38% and R3 2.4%. The lowest decrease (1.38%) occurred in the R2 reactor with an air flow of 5 L/min, while the highest decrease (3.81%) occurred in the control reactor. Total N decreases because most of the nitrogen present in the waste composition has been converted to NH3, and this process occurs after the thermophilic phase (Yuan J, et.al., 2018). On day 30, there was an increase in all reactors caused by a nitrification process that converted nitrogen into NH4+. The results of this study are in line with the research on urban waste with high water content by (Tom PA, et.al., 2016) it was conveyed that the total N content will increase due to the formation of NH4 in 15 to 30 days of biodrying.

Caloric Value

Several studies have examined the energy value of solid waste after going through the biodrying process, and the results generally show a large improvement when compared to unprocessed waste. This increase occurs mainly due to reduced moisture levels, which efficiently increases the amount of flammable materials in the waste (Ab Jalil, N. A., et a 2016).

Based on previous research, generally the initial calorific value of waste ranges from 8-11 MJ/kg. After going through the biodrying process, this calorific value can increase drastically, reaching 15-20 MJ/kg or more (Gajewska, T., Malinowski, M., & Szkoda, M., 2019). The increase in calorific value that occurs after going through the biodrying process will allow the material to meet or exceed the quality criteria for the manufacture of Refused Derrived Fuel (RDF) (Gajewska, T., Malinowski, M., & Szkoda, M., 2019). By converting waste that has a low energy value into high-quality fuel, biodrying provides a good outlet to reduce dependence on landfills and can also harness the energy potential contained in waste (Tambone, F., Scaglia, B., Scotti, S., & Adani, F., 2011).

Hasil penelitian dari pengukuran nilai kalor ditunjukkan pada Gambar 17. dibawah ini

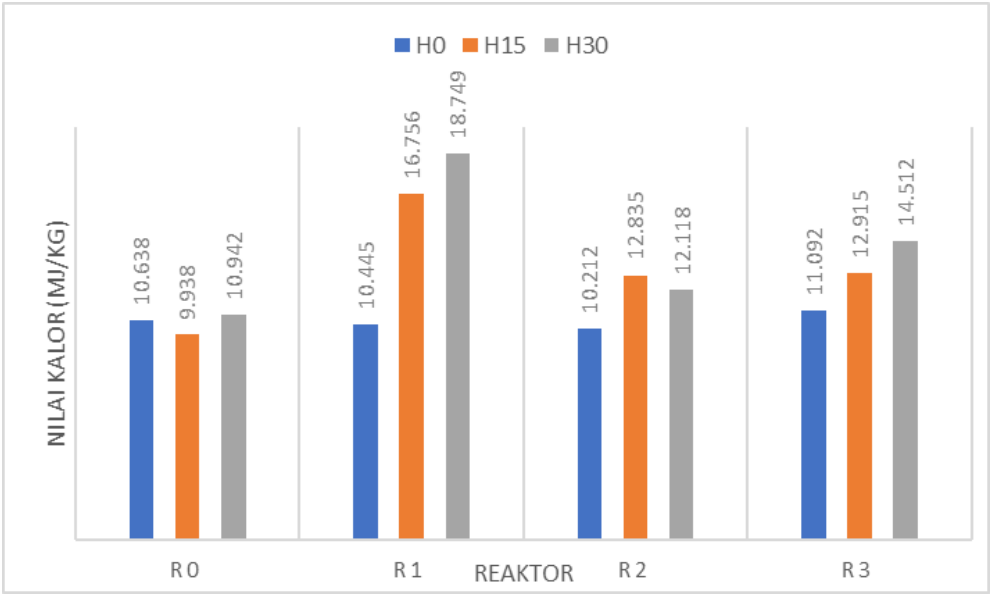


Figure 4. Graph of the results of the calorific value analysis

The caloric value in R1 has the highest calorific value of 18.74 MJ/kg, which is 71% higher than the calorific value of unprocessed waste. For R2 and R3, the calorific value increased by 10.69% and 32.63% compared to unprocessed waste.

The biodrying product in R2 has a lower calorific value of 10.21 MJ/kg. The calorific value is influenced by the carbon remains in the sample. According to Qu, T, et.al., 2011 that the calorific values of lignocellulose and lignin are 13.4 and 20.6 MJ/kg, respectively. According to Nasrullah, M, et.al., 2014 it is said that the presence of plastic in the sample can also increase the calorific value.

Based on this study, reclaimed fuel (SRF) has a calorific value of 18.74 MJ/kg which can be classified into class 3 (i.e. >15MJ/kg), while class 2 SRF has a calorific value of 20 MJ/kg (Hilda, L, et.al., 2023). For SRF with a calorific value of 18.74 MJ/kg, it can be used in hard coal, cement, fluidized bed combustion, and brown coal (Purnomo, 2021).

CONCLUSION

The main purpose of this study is to determine the calorific value of waste from the waste of the Aek Nabobar Landfill, Central Tapanuli, Indonesia. The results showed that the calorific value of treated waste in the biodrying reactor and control reactor was 71% and 10.69% higher than the calorific value of untreated waste, respectively. The rate of air flow also affects the calorific value. The highest calorific value is 18.74MJ/kg, at an air flow rate of 5L/min. The highest temperature in the biodrying process is 35.50C and the moisture content is 47%. The biodrying process is the right method to increase the calorific value, because it can increase the calorific value and reduce the moisture content of waste, thereby triggering the realization of waste into energy. The final product, which has a calorific value of 18.74 MJ/kg, is a good substitute for brown coal that can be used in hard coal, cement, hard coal and fluidized bed combustion. Biodrying encourages the way of thinking that solid waste can be a source of energy and not just waste.

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