The Effect of Varying Adhesive Mixtures of POME Sludge (Palm Oil Mill Effluent) and Tapioca Flour on the Quality of Biobriquettes from Torrefacted Palm Oil Shells

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Abstract

The increase in the amount of palm oil waste produced by the palm oil industry is a major concern in efforts to reduce negative impacts on the environment. One alternative that is being developed is processing palm oil waste into biobriquettes through a torrefaction process. This research aims to analyze the effect of variations in the adhesive mixture of POME (Palm Oil Mill Effluent) sludge and tapioca flour on the quality of biobriquettes from refractionated palm oil shells This research uses the torrefaction method for palm oil shell at 300°C and torefaction that has been printed biobriquettes at 225°C with a time of 30 minutes each. The results showed that a good sample was found in samples with 90% palm shells 7.5% sludge POME and 2.5% tapioca with the test results for a moisture content of 2.33%, ash content of 4.09%, volatile matter content 49.43%, fixed carbon 44.13%, burning rate 3042 seconds, and calorific value 6724 cal/gr. This research makes an important contribution to the development of technology for making biobriquettes from palm oil waste through the torrefaction process. By using a mixture of POME sludge adhesive and tapioca flour, biobriquettes can be produced that are of better quality and environmentally friendly. Apart from that, the use of POME sludge waste in making biobriquettes can also help reduce the problem of processing palm oil industry waste in a sustainable manner.

Keywords: *palm, biobriquette, torrefaction, variety of adhesives*

1. introduction

Indonesia has quite extensive oil palm plantations in several regions. Based on data from the Directorate General of Plantations (2020), the area of oil palm plantations in Jambi City in 2019 was 1,070,723 hectares, increasing to 1,086,623 hectares. Production at palm oil mills will of course increase, which will be followed by an increase in PKS waste, especially palm oil shells and POME sludge which will be utilized in this research. Biobriquette research has high opportunities because it is considered a renewable energy that will help coal stocks, which are non-renewable natural products.

Currently, palm oil shells have begun to be exported for bioenergy-based power plans with an index price of 118 US dollars per ton free on board, which is equivalent to IDR 1,769,905/ton. However, if palm oil shells are processed into biobriquettes, the selling value will increase many times. Palm oil shell biobriquettes can be priced at up to IDR 32,000/kg which is equivalent to IDR 32,000,000/ton which is 1:18 the export index price of palm oil shells. Therefore, from an economic perspective, making biobriquettes has a great opportunity and is worthy of research and finding the best quality of biobriquettes.

The aim of this research is to determine the effect of adhesive variations on the quality of the solid fuel/biobriquette products produced as well as the length of burning time of these products..

2. method

The independent variable in this study is a variation of adhesive. The following is the composition of each variation:

Palm oil shells : Tapioca flour : POME sludge

a. 90% : 5% : 5% → 27 gr : 1,5 gr : 1,5 gr
b. 90% : 7,5% : 2,5% → 27 gr : 2,25 gr : 0,75 gr
c. 90% : 2,5% : 7,5% → 27 gr : 0,75 gr : 2,25 gr
d. 90% : 10% : 0% → 27 gr : 3 gr : 0 gr
e. 90% : 0% : 10% → 27 gr : 0 gr : 3 gr

In this study the dependent variables were testing for water content, ash content, volatile matter content, fixed carbon value, burning time and heating value. The dependent variable provides an overview of the quality of the product produced. The fixed variable in this research is the torrefaction temperature, namely 225oC to obtain the desired biobriquette product. The method used in this research is as follows:

2.1. Raw Material Preparation Stage

This stage starts with washing and drying the palm oil shells obtained from a local factory, then the palm oil shells are ground and then sieved with a 30 mesh size while the adhesive material, namely tapioca flour, is purchased from a local supplier and POME sludge is taken from a local factory. Images of palm shells and POME sludge can be seen below.

Figure 1. Palm Oil Shells

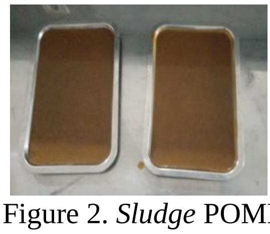

Figure 2. *Sludge* POME

2.2. Adhesive and Biobriquette Making Stage

The initial process for this stage is making the adhesive, to make the adhesive the distilled water and tapioca flour are weighed according to existing variations then dissolved in 100 ml of water for grams of tapioca which is multiplied by 6 samples (example: 5% tapioca from 30 grams is 1.5 gr which is for 6 samples then 1.5gr x 6 = 9 gr). Then heated until the solution thickens and the color changes from white to clear and thick. The adhesive that has formed a gel is then cooled.

The second process is that palm shells that have been ground using a 30 mesh filter are mixed with adhesive, the ratio of various adhesives has been determined. The starch adhesive that has been formed is then mixed with shells and POME (Palm Oil Mill Effluent) Sludge waste with the addition of adhesive according to the adhesive variation. With a total weight of 30 grams, then stir until homogeneous. After that, it is put into the mold with a pressure of 3 tons with a holding time of 30 minutes.

Figure 3. Flowchart for Preparation and Manufacturing of Adhesives and Biobriquettes.

2.3. Torrefaction Stage of Biobriquettes

In this research, the torrefaction process was carried out in a furnace, the briquettes were torrefacted at a temperature of 225ºC. Initially, the biobriquettes are put into the porcelain furnace and closed, then close the furnace tightly. Next, the briquettes are heated to temperature for 30 minutes. Once completed, the briquettes are removed from the furnace and stored at room temperature for a week to ensure stability and rigidity.

Figure 4. Biobriquette Torrefaction Flow Diagram

3. Results and Discussion

The research results were analyzed in accordance with SNI 06-3730-1995 such as water content, ash content, volatile matter content, bound carbon content, heating value and burning time. The results of testing the quality of the palm oil shell biobriquettes produced can be seen in Table 1. The research data obtained was then compared with the biobriquette quality standard data SNI 01-6235-2000 in table 2.

Table 1. Results of analysis of palm oil shell biobriquettes

No	Rasio bahan baku dan 2 jenis perekat (cangkang:POME:tapioka)	Analisa Kualitas Biobriket					
		Nilai Kalor (≥5000 kal/gr)	Kadar Air (≤8%)	Kadar Abu (≤8 %)	Zat Terbang (≤ 15%)	Karbon Terikat (≥77 %)	Laju Bakar (detik)
039	90%:0%:10%	6.506	3,77	4,03	48,14	44,04	2769
04	90%:7,5%:2,5%	6.724	2,33	4,09	49,43	44,13	3042

0							
041	90%:5%:5%	6.603	2,42	4,04	48,96	44,56	2836
042	90%:2,5%:7,5%	6.419	3,71	3,73	48,17	44,37	2902

Table 2. Biomass Briquette Quality Standards.

Sifat Briket	SNI 01-6235-2000
Kadar Air (%)	≤ 8
Kadar Abu(%)	≤ 8
Kadar Zat Terbang (%)	≤ 15
Kadar Karbon Terikat(%)	≥ 77
Nilai kalor (kal/gr)	≥ 5000

(Source: SNI 01-6235-2000)

Table 1. Information on Sample Numbers

No. Sampel	Keterangan
037	Serbuk Cangkang Sawit Sebelum Torefaksi 300ºC selama 30 menit
038	Serbuk Cangkang Sawit Setelah Torefaksi 300ºC selama 30 menit
039	90%:0%:10% (Biobriket Torefaksi 225ºC selama 30 menit)
040	90%:7,5%:2,5% (Biobriket Torefaksi 225ºC selama 30 menit)
041	90%:5%:5% (Biobriket Torefaksi 225ºC selama 30 menit)
042	90%:2,5%:7,5% (Biobriket Torefaksi 225ºC selama 30 menit)

3.1. The Effect of Varying Adhesive Mixtures of POME Sludge (Palm Oil Mill Effluent) and Tapioca Flour on the Moisture Content of Biobriquettes

Water content is an important property of briquettes that must be tested to determine the quality of biobriquettes. The water content must be as minimal as possible, so that the calorific value is high and flammable (Alfernando et al., 2022). From the results of the biobriquette analysis, it was found that the lowest water content was observed in samples with adhesive variations of 7.5% POME sludge and 2.5% tapioca, namely 2.42%, while the highest water content was observed in samples with adhesive variations of 0% POME sludge and 10% tapioca is 3.77%, it can be seen that all samples meet SNI standards, namely a maximum water content of 8%.

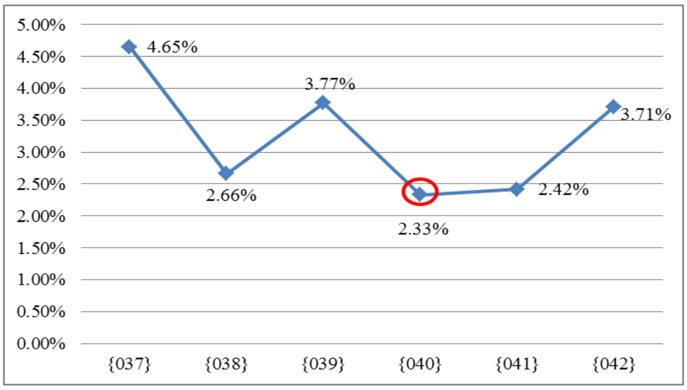

Figure 5. Graph of the Effect of Adhesive Variations on the Moisture Content of Biobriquettes.

In Figure 4 it can be seen that the biobriquettes resulting from torrefaction in samples 040 or 7.5% POME sludge have the lowest water content, this is because the water content in the adhesive is only found in the tapioca adhesive preparation, whereas the water content has been removed for the POME sludge adhesive. So the biobriquettes produced are dry and the water content is lower than samples 039, 041, and 042. It can be seen that the more or dominant POME sludge adhesive is used, the lower the water content and the more or dominant the tapioca, the higher the water content. This is because the pre-treatment of the POME sludge has had its water content removed using an oven, whereas for tapioca which has more water-holding properties, the water content is higher when an adhesive is added which is predominantly tapioca rather than POME sludge. It can be concluded that the adhesive concentration is considered good for the quality of SNI water content.

3.2. The Effect of Varying Adhesive Mixtures of POME Sludge (Palm Oil Mill Effluent) and Tapioca Flour on the Ash Content of Biobriquettes

Ash content is also an important parameter that must be tested to determine the quality of biobriquettes.

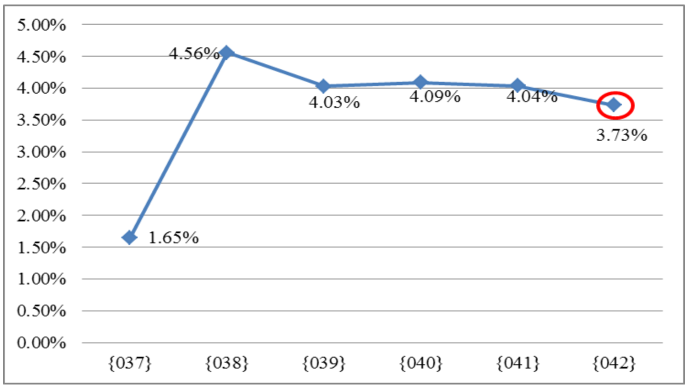

Figure 6. Graph of the Effect of Adhesive Variations on the Ash Content of Biobriquettes.

In the picture above, it is shown that the test results show results that are not too different from samples 039-042. All samples can be said to have successfully met SNI 01-6235-2000 standards. If you want to take a sample, the lowest ash content is in sample 042 with a variation of 90%:2.5%:7.5% (predominantly tapioca). This is supported by Norhikmah et al

(2021) that the high ash content is influenced by the impurities contained in the raw material so that the mineral content in charcoal is quite high and in the combustion process it leaves a lot of ash as combustion residue. The results of this research showed that the ash content was in accordance with SNI, which means that the impurities contained in the biobriquettes as a result of the research were quite small.

3.3. The Effect of Varying Adhesive Mixtures of POME Sludge (Palm Oil Mill Effluent) and Tapioca Flour on Biobriquette Volatile Matter Contents

The level of volatile matter is also an important parameter that must be tested to determine the quality of biobriquettes. In this study, the material used was palm oil shells which did have a fairly high volatile matter content, namely 92.56% and decreased when torrefacted and no adhesive had been added to 36.75%, but after being processed into biobriquettes using the torrefaction method the volatile matter content became fell to 48.14%-49.43%.

All samples did not meet the SNI standards for biomass briquettes, namely a maximum volatile matter content of 15%. The levels of volatile substances produced did not match expectations, where in this study it was expected that the levels of volatile substances were low. The high levels of volatile matter are due to the raw material in the form of palm oil shells having a volatile matter content of 92.56%.

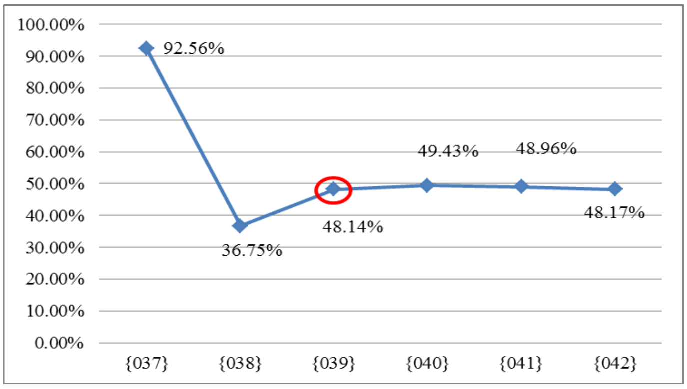

Figure 7. Graph of the Effect of Adhesive Variations on Volatile Matter Content in Biobriquettes.

It can be concluded that mixing adhesives has a very strong influence on volatile matter levels. This is supported by Norhikmah et al (2021) who stated that the higher the percentage of adhesive used in making briquettes, the more volatile/evaporating substances will also increase. The increase in volatile/evaporating substances is caused by the water content in the adhesive. The highest increase in volatile substances occurs when mixing dominant POME sludge of 7.5% and 5% so it can be concluded that mixing POME sludge has an effect on volatile substances but is quite low.

This research on making biobriquettes was also compared with the ASTM D 388-99 coal standard based on the properties of the volatile matter. The following is Table ASTM D 388-99

Table 4. Classification of Coal Based on Volatile Matter

Classification of Coal	Volatile Matter Limits (Dry, Mineral-matter-

	free basis), %	
	≥	≤
Meta-Antrhracite	0	2
Antrhracite	2	8
Semiantrhracite	8	14
Low Volatile Bituminious Coal	14	22
Medium Volatile Bituminious Coal	22	31
High Volatile A Bituminious Coal	31	…
High Volatile B Bituminious Coal	…	…
High Volatile C Bituminious Coal	…	…
Subbituminous A Coal	…	…
Subbituminous B Coal	…	…
Subbituminous C Coal	…	…
Lignite A	…	…
Lignite B	…	…

(Source: ASTM International D 388-99)

According to the Standard Classification of Coals by Rank (ASTM D 388-99) for Volatile Matter, this research produced values in the range of 48.14 – 48.96% which, if viewed based on ASTM D 388-99, falls into the High Volatile A coal type. Bituminous Coal down to Lignite B type in the range ≥ 31%.

3.4. The Effect of Varying Adhesive Mixtures of POME Sludge (Palm Oil Mill Effluent) and Tapioca Flour on the Fixed Carbon Content of Biobriquettes

The Fixed Carbon value is an important parameter that must be tested to determine the quality of biobriquettes. The fixed carbon content shows the amount of carbon element retained or contained in the briquette and influences the volatile components and torrefaction time.

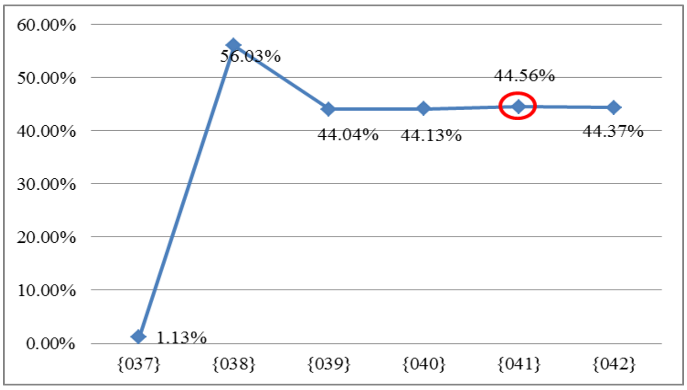

Figure 8. Graph of the Effect of Adhesive Variations on the Fixed Carbon Content of Biobriquettes.

The fixed carbon content in palm oil shells is very low at only 1.13%, so torrefaction was carried out to increase the carbon content even though the initial material was reduced very much after the first torrefaction produced a yield of 37.17% but succeeded in increasing the fixed carbon content to 56.03%. .

From the graphic data it can be concluded that the addition of adhesive cannot increase the fixed carbon content but reduces the fixed carbon content because fixed carbon is influenced by water content, ash content and also volatile matter content which is supported by Bema et al (2021), the bound carbon content is influenced by evaporated substance content, water content and briquette ash content. The addition of tapioca adhesive can increase the water content, so this can also affect the ash content which will decrease. Also, the higher the concentration of POME sludge adhesive used, the higher the evaporation content.

This research on making biobriquettes was also compared with the ASTM D 388-99 coal standard based on the nature of the bound carbon. The following is Table ASTM D 388-99

Table 5. Classification of Coal Based on Fixed Carbon

Classification of Coal	Fixed Carbon (Dry, Mineral-matter-free basis), %	
	≥	≤
Meta-Antrhracite	98	…
Antrhracite	92	98
Semiantrhracite	86	92
Low Volatile Bituminious Coal	78	86
Medium Volatile Bituminious Coal	69	78
High Volatile A Bituminious Coal	…	69
High Volatile B Bituminious Coal	…	…
High Volatile C Bituminious Coal	…	…
Subbituminous A Coal	…	…
Subbituminous B Coal	…	…
Subbituminous C Coal	…	…
Lignite A	…	…
Lignite B	…	…

(Source: ASTM International D 388-99)

According to the Standard Classification of Coals by Rank (ASTM D 388-99) for Fixed Carbon, this research resulted in a fixed carbon value in the range of 44.04 - 44.56% which, if viewed based on ASTM D 388-99, is included in the High coal type. Volatile A Bituminous Coal to Lignite B in the range ≤ 69%.

3.5. The Effect of Mixed Adhesive Variations of POME Sludge (Palm Oil Mill Effluent) and Tapioca Flour on the Calorific Value of Biobriquettes

The calorific value is the value tested to determine how much heat is contained in 1 gram of sample. The heating value really determines the quality of the biobriquettes produced, therefore the heating value needs to be known to determine the value of the combustion heat that can be produced.

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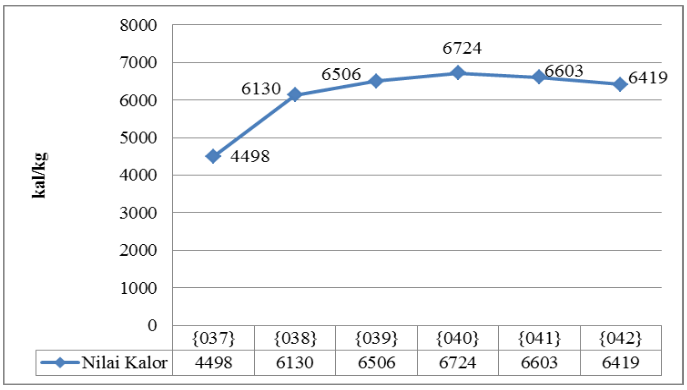

Figure 9. Effect of variations in solvents on the calorific value of biobriquettes.

Based on the results of the calorific value test, the results show that the results are not too different from samples 039-042. All samples can be said to have successfully met SNI 01-6235-2000 standards. However, if you take the highest sample, it is sample 040 with a variation of 90%:7.5%:2.5%, namely 6,724 cal/gr.

The addition of adhesive to the calorific value also increases the calorific value, where in sample 040 the variation is 90%:7.5%:2.5%, where this variation is more dominant in POME sludge adhesive which has the lowest water content after adding the adhesive. Supported by Norhikmah, et al (2021), said that the water content and ash content in charcoal briquettes can affect the calorific value, the increasing calorific value of the charcoal briquettes is obtained due to the lower water content and ash content in the charcoal briquettes.

If seen or compared with the classification based on SNI 13-6011-1999 of the coal produced, it can be seen in Table 4.11 as follows.

Table 6. SNI for Coal

SNI 13-6011-1999
Batu bara energi rendah (brown coal) < 7000 kalori/gram
Batu bara energi tinggi (hard coal) > 7000 kalori/gram

(Sumber : SNI 13-6011-1999)

(Source: SNI 13-6011-1999)

The calorific value obtained in this research sample has a calorific value like coal according to SNI 13-6011-1999, brown coal (low energy coal), which has a calorific value below 7000 cal/gr. Where the samples in this study had a range of 6,419- 6,724 cal/gr. Meanwhile, the type of hard coal (high energy coal) according to SNI 13-6011-1999 has a standard calorific value above 7000 cal/gr, of which sample 039-042 does not exceed the standard for high energy coal.

If you look at the classification based on ASTM D 388-99 of the coal produced, it can be seen in Table 4.12 as follows.

Table 7. Classification of Coal Based on Calorific Value

Jenis Batubara	Calorific Value (kal/gr)	
	≥	≤
High volatile A bituminious coal	7777	∞
High volatile B bituminious coal	7222	7777
High volatile C bituminious coal	6388	7222
Subbituminious A Coal	5833	6388
Subbituminious B Coal	5277	5833
Subbituminious C Coal	4611	5277
Lignite A	3500	4611
Lignite B	0	3500

(Sumber : ASTM Internasional D 388-99)

(Source: ASTM International D 388-99)

According to the Standard Classification of Coals by Rank (ASTM D 388-99) based on calories, the calorific value of biobriquettes in this study falls into the High Volatile C Bituminous Coal standard with a range of 11,500-13,000 Btu/lb or equivalent to 6388-7222 cal/gr where in The results of this research obtained 6,419- 6,724 cal/gr.

3.6. The Effect of Varying Adhesive Mixtures of POME Sludge (Palm Oil Mill Effluent) and Tapioca Flour on the Burning Rate of Biobriquettes

Burning time is also an important parameter that must be tested to determine the quality of biobriquettes. Below you can see the effect of variations in biobriquette burning adhesive.

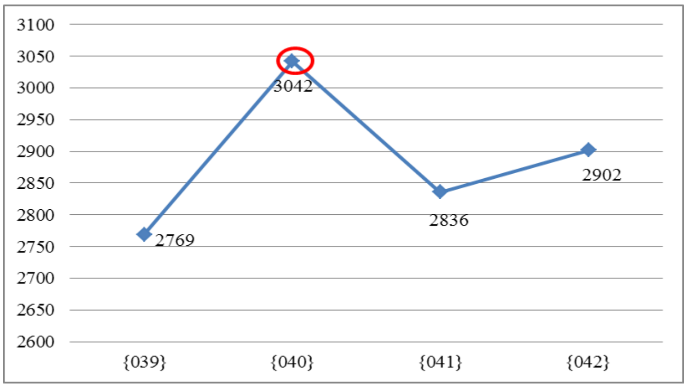

Figure 10. Effect of Adhesive Variations on Biobriquette Burn Time.

In Figure 8 above, the maximum burning time is 3042 seconds. The longer the burning time, the better the burning quality and efficiency. Burning time greatly affects the water content. The lower the water content, the higher the calorific value and combustion efficiency, and conversely, the higher the water content, the lower the calorific value and combustion efficiency.

Based on the graph above, it can be seen that sample 040 has the longest burning rate compared to the other samples. Supported by Machsalmina et al (2022) who stated that the more oil content in the briquettes, the more it affects the burning time. Because POME sludge comes from PKS waste which contains oil, therefore the adhesive variation with the best quality is the 90%:7.5%:2.5% variation where this variation has 7.5% POME sludge and 2.5% tapioca. . This variation also has the highest heat among the four samples. So it can be concluded that the combustion rate is directly proportional to the heating value, where the higher the heating value, the longer the burning rate of the biobriquette sample.

Conclusion

Based on the results of the biobriquette tests produced, it can be concluded that the adhesive variation of 90%:7.5%:2.5% where the variation of 7.5% POME sludge adhesive and 2.5% tapioca is considered the best. This is because the analysis test results obtained were for water content of 2.33%, ash content of 4.09%, volatile matter content of 49.43%, bound carbon content of 44.13%, combustion rate of 3042 seconds, and heating value of 6,724 cal/ gr. The quality results for water content, ash content and heating value have entered the SNI-01-6235-2000 charcoal briquette standard, however the results of the volatile matter content and bound carbon content tests do not meet the SNI-01-6235-2 charcoal briquette standard. 2000 due to the very high levels of volatile matter from the raw material itself, namely palm oil shells, which will affect the bound carbon content.

Because the initial aim of developing biobriquettes was as a renewable fuel, this research also compared it with coal standards from the Standard Classification of Coals by Rank (ASTM D 388-99). For the quality of volatile matter content, the biobriquettes resulting from this research fall into the High Volatile A Bituminous Coal type to the Lignite B type in the range ≥ 31%. For the quality of bound carbon content, the biobriquettes resulting from this research fall into the High Volatile A Bituminous Coal type to the Lignite B type in the range ≤ 69%. For the quality of calorific value, the biobriquettes resulting from this research are included in the High Volatile C Bituminous Coal type in the range of 6388-7222 cal/gr, whereas according to the SNI 13-6011-1999 standard the results of this research are included in the brown coal type (low energy coal) which has calorific value below 7000 cal/gr.

References

[1] Alfernando,O.,Muis,L.,Junaida,S.,Ginting,M,K.,Haviz,M.2022. Analisis Pengaruh Waktu Torefaksi Terhadap Kualitas Biobriket Dari Cangkang Kelapa Sawit (Palm Oil Shell).Jurnal Teknik Media Pengembangan Ilmu dan Aplikasi Teknik, Vol 21(2):181-190.

[2] ASTM D 388-99 : Standard Classification of Coals by Rank.

[3] Bema,E,S.,Hamzah,F.,Zalfiatri,Y. 2021. Karakteristik Briket Dari Arang Daun Kelapa Sawit Dan Arang Cangkang Biji Karet Dengan Perekat Tapioka. Sagu Journal, Vol 20(1):1-7.

[4] Machsalmina,Ismy,A,S.,Razi,M. 2022. Pengaruh Variasi Tekanan Terhadap Karakteristik Biobriket Cangkang Kelapa Sawit Dengan Menggunakan Mesin Pencetak Biobriket. Jurnal Mesin Sains Terapan, 6(2): 110-116.

[5] Norhikmah, Sari,N,M., Mahdie,M,F. 2021. Pengaruh Persentase Perekat Tapioka Terhadap Karakteristik Briket Arang Tempurung Kelapa. Jurnal Sylva Scienteae, Vol 4(2): 324-333.

[6] SNI 01-6235-2000 : Briket Arang Kayu.

[7] SNI SNI 13-6011-1999 : Klasifikasi sumber daya dan cadangan batu bara.