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# Synthesis of Rice Straw and Coconut Shell-Based Bio Briquettes as an Alternative Energy

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**ABSTRACT**

*This comparison of composition and particle size of bio briquettes from the raw material of the rice straw-coconut shell mixture can produce solid fuels with high calorific value and minimum pollutants. This study aims to synthesize bio briquettes based on a mixture of rice straw and coconut shells, to find the best composition to obtain high-calorie bio briquettes. In the first stage, analyzing bio briquettes with a composition ratio of rice straw-coconut shells are 90:10; 80:20: 70:30; 60:40; 50:50; 40:60; 30:70; 20:80 and the particle size (mesh) are 20, 60, 100, 140 and 170. Determine the characteristics of the bio briquette, it consists of inherent matter (IM), volatile matter (VM), ash content (AC), fixed carbon (FC), and calorific value (CV). From the analysis results obtained data that accordance to SNI 01-6235-2000, namely the ratio of rice straw and coconut shell mixture of 55:45 with a particle size of 98 mesh obtained CV of 5005 cal/g, IM of 7.0985%, VM of 26,3971%, AC of 22,2198%, FC of 44,2421%.*

***Keywords:*** *Characteristic Bio-briquettes, Particle Size, Composition Ratio.*

## 1. INTRODUCTION

Indonesia is an agricultural country with a geographical location on the equator, causing Indonesia to become a country rich in natural resources, including agriculture. The Indonesian government has directed agricultural land into three parts based on crop commodities, namely annual crops covering an area of 15.1 million ha, dry land annual crops covering an area of 8.3 million ha, and rice fields covering an area of 10 million ha [1].

As for the availability of swamp land throughout Indonesia covering an area of 33.4 million ha, consisting of 20.1 ha of tidal swamp land (60.2%) and non-tidal swamp land or lebak swamp area of 13.3 ha (39.8%) which is one of the natural resources with great potential to be developed into agricultural land [2]. The rice harvest in Muara Telang village, Banyuasin district, produced 114 tons of straw per harvest [3]. Straw was piled on the farm for 2-3 weeks and then burned.

The treatment of some farmers who burn the staw will create a new problem, namely the emergence of carbon dioxide gas which will contribute to global warming. In addition, the straw that is burned directly will produce a lot smoke and burn quickly and the rest of the combustion is easy to fly and produces low energy which is less than 400 cal/g [4],[12].

Utilization of rice straw as fuel has been carried out by burning a mixture of rice straw and coal (50:50) which produces nitrogen dioxide gas emissions of 127 mg/m and sulfur dioxide of 204 mg/m³ [5]. Burning bio briquettes with a mixture of rice straw and coconut shells (50:50) with constant air velocity in the kitchen by producing $CO_2$ emissions of 2.74 mg/m, $NO_2$ of 2.38 mg/m' and $SO_2$ of 2.07 mg/m [6].

The previous research found that rice straw can be used as an alternative fuel but produces gas emissions of nitrogen monoxide, carbon monoxide, and sulfur dioxide [11]. To utilize rice straw as fuel that has a high calorific value and minimum gas emissions, it is necessary to add other biomass which can increase calorific value and reduce gas emissions. The material is a coconut shell, which is obtained from plantation waste around the life of farmers.

Bio briquettes which are the result of processing straw and shells will certainly be used by farmers and the community as a household fuel [13]. This not only avoids the direct burning of straw and coconut shells which will produce carbon dioxide gas but can also use straw and coconut shells to become useful materials for farmers.The burning by most farmers of the solid waste of straw and coconut shells has the potential to produce polluting gases. Therefore, solid waste originating from rice straw and coconut shells are used as valuable material, namely bio briquettes to reduce and control gas pollution resulting from the combustion as well as the temperature profile during the combustion process in the furnace.

## 2. MATERIAL AND METHODS

### 2.1 Materials

The materials used in this study were rice straw, coconut shell, magnesium oxide (MgO), crystalline sodium carbonate ($Na_2CO_3.10H_2O$), crystal barium chloride ($BaCl_2.2H_2O$), hydrochloric acid (HCI), aquadest, methyl orange, sodium hydroxide (NaOH), oxygen (purity >95%), certified standard benzoic acid with calorific value 6.318 cal/g, starch, hydrogen peroxide ($H_2O_2$), sulfuric acid ($H_2SO_4$), crystalline zincum sulfate ($ZnSO_4.7H_2O$), ammonium sulfate (($NH_4$)2$SO_4$)), potassium iodide (KI), $I_2O_5$ solution, ethanol solution.

### 2.2 Method

The raw materials in the form of rice straw and coconut shells are dried in the sun to reduce the water content. The carbonization process was carried out in a furnace at a temperature of 298°C for 24 minutes for rice straw while for coconut shells it was carried out at a temperature of 485°C for 15 minutes. Furthermore, the size of the raw material is reduced, and both rice straw and coconut shells pass at 20, 60, 100, 140, 170 mesh. Then, the raw materials of rice straw and coconut shell were mixed and the adhesive material in the form of starch-water was mixed thoroughly with each composition of rice straw : coconut shell with the composition 90:10, 80:20, 70:30, 60: 40, 50:50, 40:60, 30:70, 20:80. Furthermore, the briquettes were molded into a cylindrical mold with a diameter of 2.54 cm and a height of 7.9 cm. Then press with a pressure of 3-5 psi and allowed to stand for 10 minutes. After that, the bio briquettes were removed from the mold and dried for 3 days at 1 atm and a temperature of 25°C during the combustion process in the furnace.

## 3. RESULTS AND DISCUSSIONS

The analytical method used for each bio briquette characteristic is as follows:

- Water content analysis (inherent moisture) using ASTM D 3173-2003 method.
- Ash content analysis using the ASTM D 3174-04 method.
- Volatile matter analysis using ISO 562-1998 method.
- Calorific value determination using the isoperibol technique using ASTM D 5865-07 method.
- Fixed carbon analysis using ASTM D 3172-89 method.

The results of laboratory analysis of raw materials for bio briquettes in the form of rice straw and coconut shells can be seen in Table 1. The calorific value of straw is 1525.5 cal/g lower than the calorific value of coconut shell is 7283.5 cal/g. This is due to the volatile matter and water content in rice straw more than the volatile matter and water content in the coconut shell. Therefore, the more volatile matter and inherent matter, the smaller the calorific value of the material, which of course will also produce more ash.

**Table 1.** Analysis of Bio Briquette Raw Materials

| Parameter | Raw Materials | |
|---|---|---|
| | Rice Straw | Coconut Shells |
| Proximate Analysis | | |
| Inherent Moisture (%) | 11,58 | 6,17 |
| Ash (%) | 25,61 | 13,22 |
| Volatile Matter (%) | 34,35 | 10,85 |
| Fixed Carbon (%) | 28,64 | 69,79 |
| Calorific Value (cal/g) | 1525,5 | 7283,5 |
| Ultimate Analysis | | |
| Carbon (%) | 35,45 | 68,29 |
| Hydrogen (%) | 2,32 | 3,32 |
| Nitrogen (%) | 0,46 | 0,22 |
| Sulfur (%) | 0,45 | 0,08 |

Table 1 shows that the raw material that has high volatile matter and inherent matter is rice straw, which is 11.58% of inherent matter and 34.35% of volatile matter compared to coconut shell which is 6.17% of inherent matter and 10,85% of volatile matter. Meanwhile, the calorific value obtained indicates that rice straw cannot be used as fuel for bio briquettes because the calorific value does not accordance the Indonesian National Standard (SNI 01-6235-2000). According to SNI, biomass that can be considered as fuel is biomass that meets a maximum moisture content of 8%, a maximum ash content of 8%, and a minimum calorific value of 5000 kale, while coconut shell meets SNI 01-6235-2000. Therefore, to meet the SNI for bio briquettes, these two materials, namely rice straw and coconut shell, were mixed by varying the particle size in the mesh and the composition ratio in percent by weight (%w).

### 3.2 Characteristic of Bio Briquettes

3.2.1 Inherent Moisture

Analysis result of the characteristics of inherent matter of bio briquettes with various compositions of raw materials can be seen in Figure 1. The water content contained in bio briquettes shows a downward trend with increasing coconut shell composition because the water content in a coconut shell is lower than in rice straw.

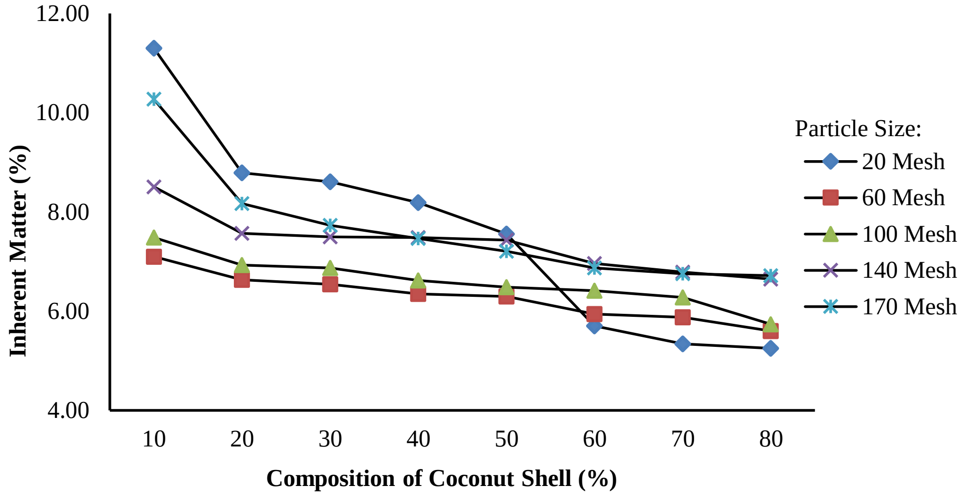


**Figure 1.** The Influence of Coconut Shell Composition and Particle Size of Bio Briquettes on Inherent Matter

Biobriquettes that have different particle sizes can affect the water content. Particles that have a smaller size for the same amount of composition, make the surface area of the material large, as a result, more water is absorbed on average except at a particle size of 20 mesh. At the size of 20 mesh, there is a composition ratio that has more rice straw particles or the same as coconut shell particles, namely the ratio of rice straw and coconut shells are 50:50, 60:40, 70:30, 80:20, and 90:10. Rice straw has a large fibre compared to coconut shell, so the pores of rice straw become large. Large pores will absorb a lot of water. Therefore, the ability of rice straws to absorb water is greater than the ability of coconut shells to absorb water. The high and low water content in rice straw-coconut shell bio briquettes is caused by the raw materials used, surface area, and pore size.

The large inherent matter of 11.22% in the bio briquette will cover the pore surface with a particle size of 20 mesh, making it difficult for the bio briquette to burn. In this condition, all the inherent matter on the surface and in the pores must be evaporated because it prevents the burning of the carbon compounds present. So bio briquettes that have a large water content are certainly difficult to burn.

**Table 2.** Anova of Composition Ratio and Particle Size on Inherent Matter

| Model | df | Sum of Square | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regresi | 2 | 29,688 | 14,844 | 19,222 | 0,00 |
| Residual | 37 | 28,573 | 772 | | |
| Total | 39 | 58,261 | | | |

The influence of composition ratio and particle size on inherent matter can be seen in Table 2 using ANOVA. It can be stated that there is a linear regression between the composition ratio and particle size. Analysis of the mixture of bio briquettes using ANOVA obtained the results of water content of 7.0985%. This value accordance to SNI 01-6235-2000 which is less than 8%. The bio briquette composition ratio of rice straw and coconut shells was also obtained, namely 55: 45, and the particle size of 98 mesh. The research results states that bio briquettes derived from powdered charcoal with small particle sizes have a high water content compared to powdered charcoal with larger particle sizes [7]. Charcoal can absorb large amounts of water which is influenced by the surface area and pores of the charcoal [8].

3.2.2 Volatile Matter

From Figure 2 it is found that the average volatile matter of the mixture of rice straw-coconut shell composition decreased for each particle size. The highest volatile matter occurred in the composition of rice straw-coconut shell 90: 10, which was 32.92%, while the lowest volatile content was found in the composition of rice straw and coconut shell 20:80, which was 7.44%. This is because the more coconut shell composition in the bio briquette mixture, the lower the volatile matter. For the particle size of 20 mesh, the downward trend is very large, this is due to the heating time factor for the bio briquettes in the combustion chamber for less than 7 minutes, as a result, the volatile matter in the bio briquettes does not burn completely. This also causes the weight of bio briquettes after heating to be large. Besides that, the composition of bio briquettes containing rice straw which causes a large amount of volatile matter content, because rice straw has large fibers and pores compared to coconut shell.The particles present in the bio briquettes are also determined by the materials that make up the bio briquettes. The formation of bio briquettes that have high levels of volatile matter, of course, will produce bio briquettes that contain large amounts of volatile matter.

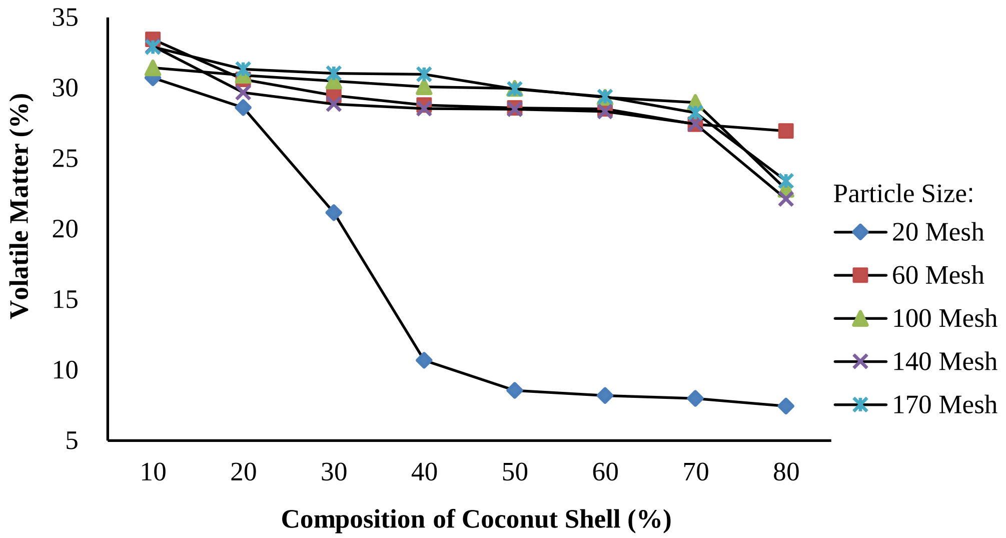


**Figure 2.** The Influence of Coconut Shell Composition and Particle Size of Bio Briquettes on Volatile Matter

The particle size of 170 mesh gives a bio briquette composition of 90:10 which means that rice straw has a larger composition compared to coconut shell. In this composition, the value of the volatile matter is 32.92%. As for the particle size of 20 mesh where rice straw is less than coconut shell, it has a volatile matter of 7.44%. The heating time of bio briquettes in the furnace is not long, causing the mass of bio briquettes before and after heating to have a small difference so that a large particle size of 20 mesh has a low value of volatile matter.

**Table 3.** Anova of Composition Ratio and Particle Size on Volatile Matter

| Model | df | Sum of Square | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regresi | 2 | 1090,428 | 545,214 | 20,198 | 0,00 |
| Residual | 37 | 998,777 | 26,994 | | |
| Total | 39 | 2089,205 | | | |

The influence of composition ratio and particle size on volatile matter can be seen in table 3 using ANOVA. It can be stated that there is a linear regression between the composition ratio and particle size. Analysis of the bio briquette mixture carbonization process and are also influenced by the time and temperature of the cooking process. The using ANOVA obtained the results of the volatile matter of 26.3671 with a composition of rice straw-coconut shell of 55:45 and a particle size of 98 mesh. In addition, the high and low levels of volatile matter in bio briquettes are caused by the perfection of the greater the temperature and time of writing, the more volatile substances are wasted so that when testing the volatile substance level, a low volatile substance will be obtained [10].

3.2.3 Ash Content

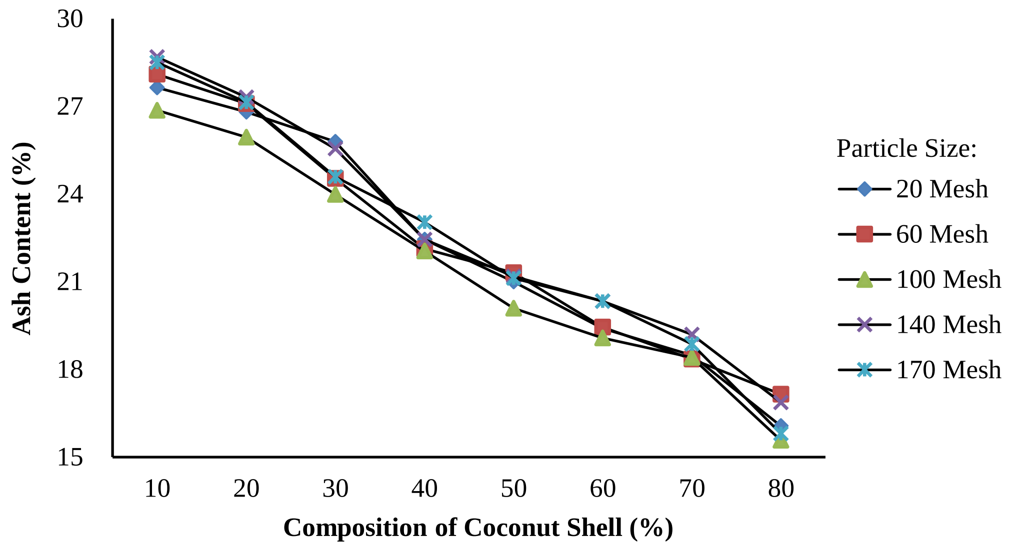


**Figure 3.** The Influence of Coconut Shell Composition and Particle Size of Bio Briquettes on Ash Content

The analysis results show that the highest ash content of 28.69% is at a composition ratio of 90:10, while the minimum ash content of 15.57 % is at a composition ratio of 20:80. It turns out that the composition which has rice straw as raw material has high ash content. Because the raw material for straw has a greater ash content than coconut shell.

The particle size of 140 mesh has the largest ash content of 28.69% with a mixture composition of rice straw-coconut shell of 90:10, while the smallest ash content is found in the particle size 100 mesh with a composition of rice straw-coconut shell of 20:80 of 15.57%. The value obtained does not meet the standard of SNI 01-6235-2000, which is a maximum of 8%, because the composition of bio briquettes, namely rice straw and coconut shell, has a fairly large ash content.

**Table 4.** Anova of Composition Ratio and Particle Size on Ash Content

| Model | df | Sum of Square | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regresi | 2 | 581,238 | 290,619 | 652,193 | 0,00 |
| Residual | 37 | 16,487 | 0,446 | | |
| Total | 39 | 597,725 | | | |

The influence of composition ratio and particle size on ash content can be seen in Table 4 using ANOVA. It can be stated that there is a linear regression between the composition ratio and particle size. Analysis of the bio briquette mixture using ANOVA obtained the results of the ash content of 22,2198% with a composition of rice straw-coconut shell of 55:45 and a particle size of 98 mesh.

3.2.4 Fixed Carbon

The presence of fixed carbon in the bio briquette is influenced by the amount of ash content and the content of volatile matter. The fixed carbon content will be of high value if the value of ash content and volatile matter in the bio briquette is low. The results show that the lowest fixed carbon content is at the composition ratio of rice straw-coconut shell 90: 10, which is 25.88%, while the highest fixed carbon content is 71.24% at a composition ratio of 20: 80. The less the composition of rice straw in the bio briquette mixture, the greater the fixed carbon content produced, due to the decreasing water content and volatile matter in the bio briquette mixture, namely rice straw and coconut shell.

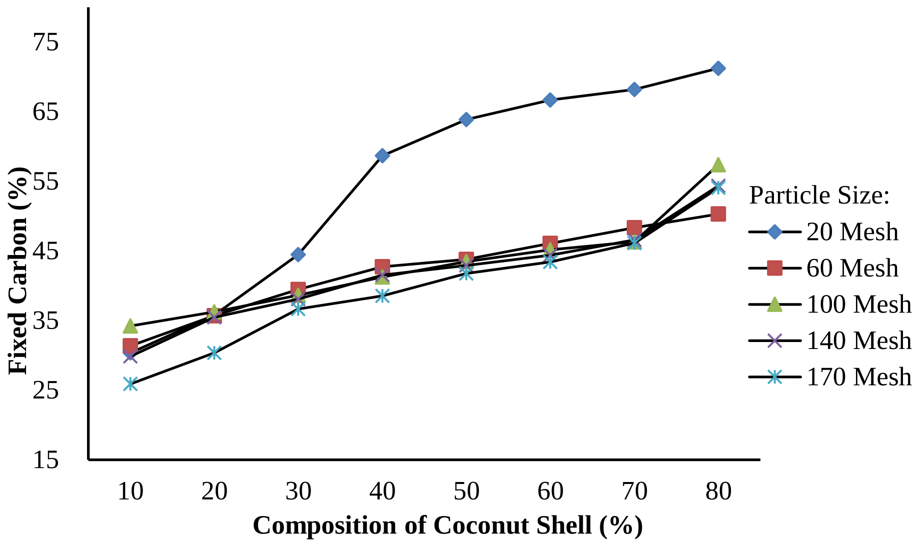


**Figure 4.** The Influence of Coconut Shell Composition and Particle Size of Bio Briquettes on Fixed Carbon

The particle size of 20 mesh shows that the largest fixed carbon content is 71.24% with a tendency to decrease to 170 mesh particle size, which is 25.88%. The lower the ash content and the volatile matter content, the higher the fixed carbon content will be or otherwise [9].

**Table 5.** Anova of Composition Ratio and Particle Size on Fixed Carbon

| Model | df | Sum of Square | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regresi | 2 | 3542,411 | 1771,205 | 65,957 | 0,00 |
| Residual | 37 | 993,592 | 26,854 | | |
| Total | 39 | 4536,003 | | | |

The influence of composition ratio and particle size on fixed carbon can be seen in Table 5 using ANOVA. It can be stated that there is a linear regression between the composition ratio and particle size. Analysis of the bio briquette mixture using ANOVA obtained the results of the fixed carbon of 44,2421% with a composition of rice straw-coconut shell of 55:45 and a particle size of 98 mesh.

3.2.5. Calorific Value

The composition of fuel which has high inherent matter and volatile matter content will cause a small calorific value, while the ash content resulting from the combustion of volatile matter and fixed carbon causes the resulting calorific value to be small. Therefore, the composition of rice straw-coconut shell in the bio briquettes certainly affects the calorific value produced by the bio briquettes.

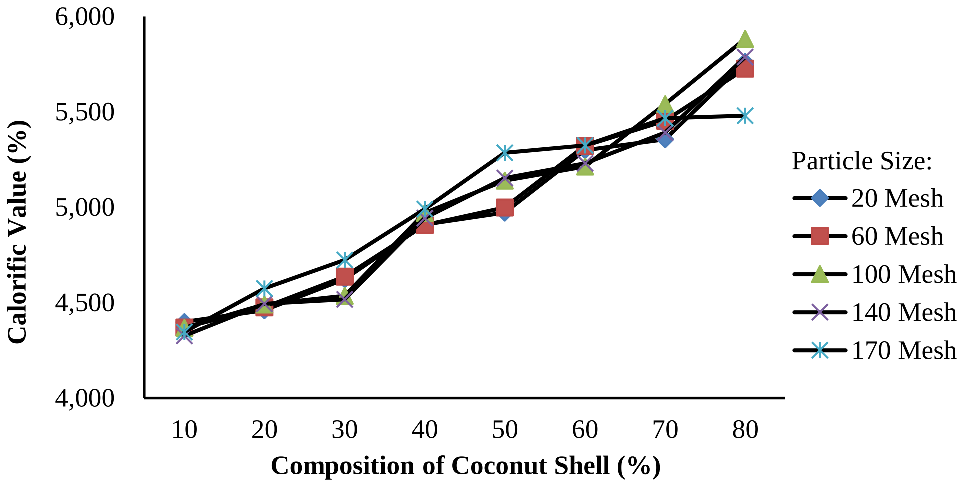


**Figure 4.** The Influence of Coconut Shell Composition and Particle Size of Bio Briquettes on Calorific Value

The calorific value of bio briquette fuel tends not to increase too much due to changes in particle size because the density that occurs in the formation of bio briquettes through pressing/pressure is not large. After all, it will damage the structure of the bio briquettes. The density of bio briquettes is greater than the density of rice straw and less than the density of coconut shells, which means that the pressure applied when pressing the bio briquettes is not high [14].

**Table 6.** Anova of Composition Ratio and Particle Size on Calorific Value

| Model | df | Sum of Square | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regresi | 2 | 8582340,797 | 4291170,399 | 589,855 | 0,00 |
| Residual | 37 | 270089,103 | 7299,705 | | |
| Total | 39 | 8852429,900 | | | |

The influence of composition ratio and particle size on calorific value can be seen in Table 6 using ANOVA. It can be stated that there is a linear regression between the composition ratio and particle size. Analysis of the bio briquette mixture using ANOVA obtained the results of the calorific value of 5005 cal/g with a composition of rice straw-coconut shell of 55:45 and a particle size of 98 mesh.

## 4. CONCLUSION

From the experimental results that rice straw as the main raw material can be used as bio briquette mixed with coconut shell as an additional material to increase its calorific value. Bio briquettes with a mixture ratio of rice straw and coconut shell of 55:45 and a particle size of 98 mesh obtained a calorific value of 5005 cal/g, inherent moisture of 7.0985%, volatile matter of 26.3971%, ash content of 22.2198% and fixed carbon of 44.2421%.

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