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Increasing the Quality of Low-Rank Coal through The Upgrading Brown Coal (UBC) Process with Used Lubricant Oil and Waste Cooking Oil

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Abstract. The use of coal as the energy source for industry and steam power plants is dominated by high quality or hard coal. The Upgrading Brown Coal (UBC) process is carried out regarding the obligation to increase the added value of low-quality mining products as a substitute or reserve for hard coal supply. The use of UBC products can reduce hard coal consumption by up to 50% of the use of low-rank coal. Moreover, the UBC process is still being developed. In this study, a mixture of low-rank coal, waste lubricant oil, and waste cooking oil is used as a coating material to cover the coal pores after the dewatering process and enhance the characteristics of coal. The variation in the mixing ratio of low-rank coal, waste cooking oil, and used lubricant oil was 75:100:75 and 75:75:150, varying from the mixing time of 30, 60, and 90 minutes. The analysis showed that the highest calorific value obtained was 7614 cal/g at 75:75:150 mixture ratio with 90 minutes mixing time and 120 mesh particles sizing. Additionally, the lowest moisture content was found with a 75:100:125 mixture ratio, 90 minutes mixing time, and 120 mesh particles sizing at 2.79% air-dried basis inherent moisture.

INTRODUCTION

According to Government Regulation of The Republic of Indonesia No. 79 of 2014 concerning National Energy Policy, some achievement of national energy policy targets is required to meet the supply and utilization of energy to provide and utilize primary energy and final energy. This energy policy aims to achieve an optimal energy mix, which includes increasing the role of renewable energy and natural gas, followed by reducing oil and coal as an energy source. Based on the data, the position of coal is expected to increase to 25% by 2050, replacing oil as the primary energy source, expected to decrease to 20% [1]. The policy is based on the existing high coal production rate. It can be seen from the export demand for mining commodities, especially coal demand, from abroad is rising year after year. The volume of coal exports increased, from 287 million tons (2011) to 343.5 million tons (2016) [2]. Imported coal is also used to fulfill the demand, expected to grow from 4 million tons in 2016 to 11 million tons, or 2% in 2050 [3].

Indonesia's coal production is expected to increase as the country's coal demand and coal contracts increase. It is because coal is still a cheap and essential fossil fuel that can meet the needs of steam power plants and several industries, including cement, steel, and textiles. National coal production is targeted to increase to reach 648 million tons in 2050, which will undoubtedly deplete national coal reserves, especially the much-needed coal with calorie content above 5,100 kcal/kg [3]. Indonesia has the 5th largest coal reserves globally (39.9 billion tons) [4]. In

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contrast, the projected coal supply, including briquettes, will increase to 298 Million Tonne Oil Equivalent (MTOE) or its energy share of around 32% in 2050 [4]. Based on coal production data, as of 2020, the annual coal production reached 561.7 million tons or 102 % of the production target, which is 550 million tons [5].

Many power plants and industries require the use of a medium to high-quality coal (hard coal). Therefore, it is estimated that by 2038 and 2048, coal reserves and the total reserves of high-quality coal will be exhausted [2]. This condition needs attention from the government by supporting coal exploration, encouraging the use of low-quality coal (<5,100 kcal/kg) as fuel for coal power plants at the mouth of the mine, increasing the efficient use of technology, and encouraging the use of coal upgrading. The Upgrading Brown Coal (UBC) process is one of the applications for low-quality coal. Previous research mentioned that the net annual cash flow (ACF) has a positive value, and the UBC commercial plant is considered economically feasible [6].

Upgrading Brown Coal (UBC) technology development requires attention from the government by promoting brown coal exploration. The limitations of old coal energy sources in Indonesia encourage the use of low-quality coal (<5,100 kcal/kg) as an export resource and fuel for the coal power plant at the mouth of the mine, increasing efficient use of technology, and encouraging coal upgrading [7]. According to previous studies, it was found that the use of UBC can reduce coal consumption by 50% compared to using low-quality coal. The high humidity and low heating value of low-quality coal (brown coal) cause the amount of fuel needed by the boiler to be 3 to 4 times more than high-quality coal to generate the same amount of electricity [7].

Based on Government Regulation of The Republic of Indonesia No. 77 of 2014 concerning the Implementation of Mineral and Coal Mining Business Activities that require the process of adding value to low-quality coal (brown coal). This regulation requiring coal processing to add value includes quality improvement (upgrading), briquetting, coking, liquefaction, gasification, and coal slurry/coal-water mixtures [8].

The process of adding value with the Upgrading Brown Coal (UBC) method is a solution to enhance the quality of low-rank coal before it is used or converted into other types of energy, making the energy and heating values obtained more valuable and reducing emissions. Brown coal with low characteristics is difficult to compete with and harms the environmental aspect. Evaporation eliminates Moisture contents trapped between the pores in low-quality coal is eliminated through evaporation, allowing it to be further mixed with asphalt. After the evaporation process, asphalt fills the coal pores and prevents the re-absorption of water content. This study aims to learn the effect of the used cooking oil and waste lubricant oil as a replacement for asphalt, which is added as a mixture in the UBC process to fill coal pores after evaporation.

EXPERIMENTAL METHODS

The use of research methodology was experimental by taking low-rank coal samples at the mine site of PT Bukit Asam while waste cooking oil was from the seafood restaurant in South Sumatera and tested in the laboratory of the Universitas Sriwijaya Research Center. The following are the stages of the UBC process [8]:

a. Coal preparation: Low–rank coal was crushed and then sieved to size up to five different particle sizes, which are 40 mesh, 60 mesh, 80 mesh, 100 mesh, and 120 mesh particles size.
b. Slurry dewatering: low-rank coal was mixed with coal, waste cooking oil, and lubricant oil in different compositions 75:100:125 (Sample A) and 75:75:150 gr (Sample B), and the total of the mixed ingredients is 300 gr. The mixture was mixed and heated with the various temperatures 175 ^{o}C for about 1 hour in a magnetic stirrer. This stage is used to evaporate the water.
c. Coal-oil separation: The mixture was dried in the oven for about 1 hour. The slurry at every composition was filtered to separate coal and waste cooking oil.
d. Coal briquetting: The mixture was pressed at 7000-10.000 psi.

The inherent moisture and gross calorific value of UBC products were examined at the Mining Department Laboratory of South Sumatra. The next step is to examine the correlation between the inherent moisture content and the calorific value of the UBC product. This correlation is done to see whether the addition of waste cooking oil and used oil in the UBC process, which has the primary purpose of reducing water content, can increase the calorific value of the UBC product or not.

RESULTS AND DISCUSSION

Raw material from PT. Bukit Asam is coal that is not sold commercially because of the quality carried by the standards set by the company. Therefore, even though the heating value is above 5000 cal/gr, this coal is still categorized as low-rank coal because only used for the company's internal needs [9]. The proximate analysis of low-rank coal raw material has inherent moisture of 8,2%adb and a calorific value of 6242 cal/gr. In this research, the aim of the study is the effect of the composition of coal briquettes given different mixing times with different compositions.

Moisture Contents

The addition of lubricating oil to the briquette mixture impacts the product's qualities, including moisture content. The briquette composition with a more significant proportion of lubricating oil suggests a lower water content. The decrease in moisture content is the main target of this experiment, considering that the basis of the UBC process is the slurry dewatering process so that it can be a supporting factor in increasing the quality of low-rank coal [6]. The sample size and variations in the mixture between coal, waste cooking oil, and used lubricant oil affect the moisture content in UBC products. The differences in the composition of the coal give different results in moisture content.

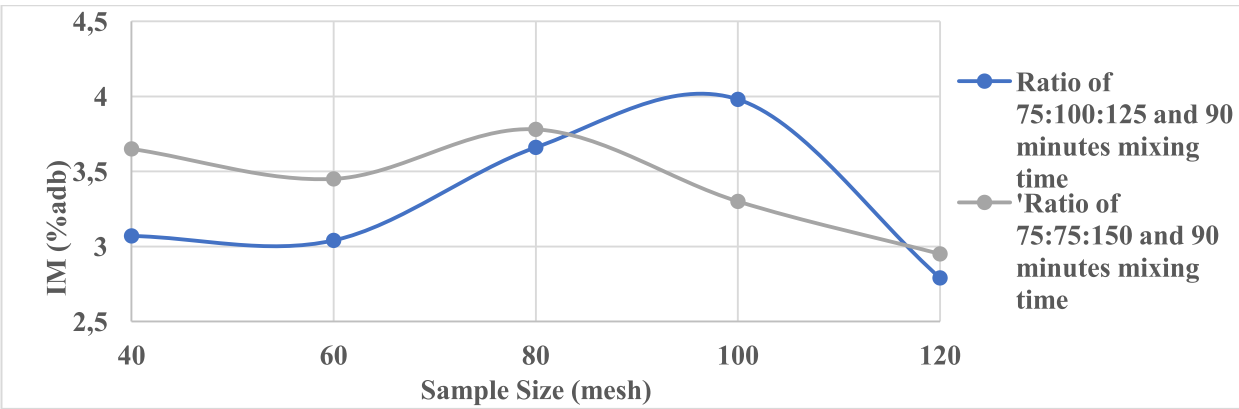

FIGURE 1. The Effect of Oil Addition at 90 Minutes Mixing Time to the Moisture Contents

Fig. 1 illustrates the effect of oil added to the coal mixture on the moisture contents. The addition of the oil shows the higher moisture content at 40 mesh with 3.65%, while sample A consists of 3.07%. Despite the fluctuated result, the addition of oil showed a downtrend starting at 80 mesh with 3.78% and finishing at 120 mesh with 2.95%. However, sample A fluctuated and showed the highest moisture content at 100 mesh with 4.05%, while the lowest moisture content obtained in this research was at 120 mesh with 2.79%.

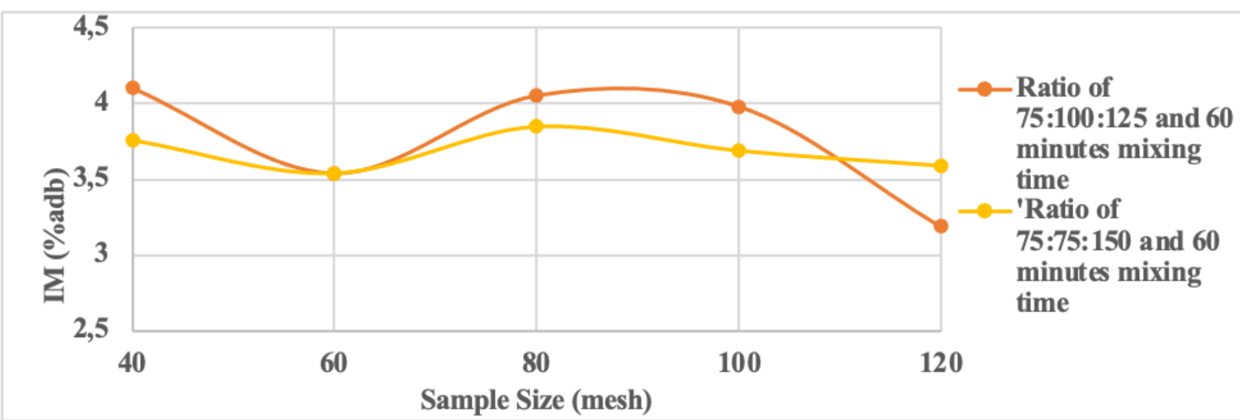

FIGURE 2. The Effect of Oil Addition at 60 Minutes Mixing Time to the Moisture Contents

Fig. 2 illustrates the effect of oil added to the coal mixture with a shorter mixing time (60 minutes) on the moisture contents. The addition of the oil resulted in the lower moisture content with 40 mesh at 3.76%, while sample A consisted of 4.01%. Despite the fluctuated result, the two samples indicate similar trends for all mesh sizing. Besides, the addition of oil shows a downtrend similar to Fig. 1, starting at 80 mesh with 3.85% and finishing at 120 mesh with 3.59%. Additionally, sample A gives the lowest moisture content with 120 mesh at 3.19%.

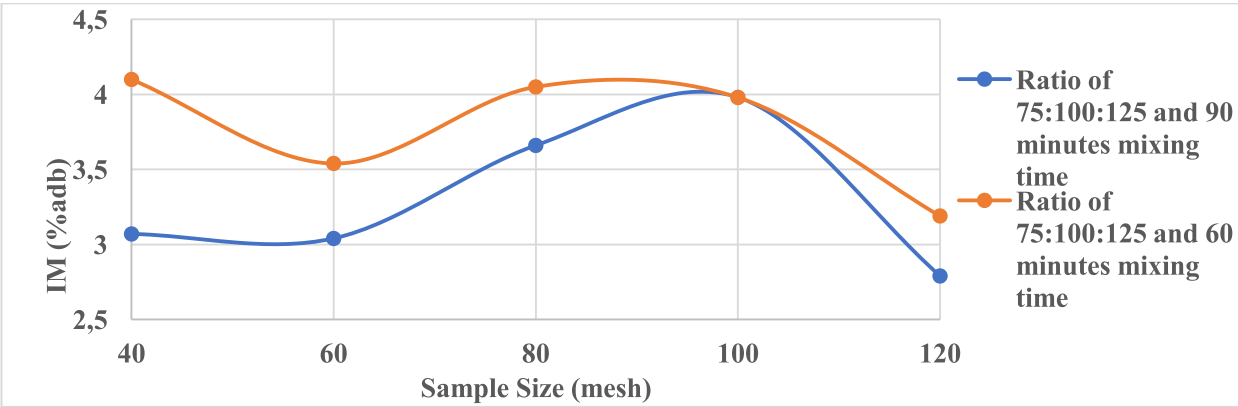

FIGURE 3. The Effect of Mixing Time at 75:100:125 ratio to the Moisture Contents

Fig. 3 shows the effect of coal mixing time for sample A on the moisture contents. The addition of mixing time (90 minutes) shows the lower moisture content with 40 mesh at 3.07%, while the 60 minutes mixing time consists of 4.1%. Despite the fluctuated result, two data resulted in similar trends. The longer mixing time shows a downtrend starting at 80 mesh with 3.66% and finishing at 120 mesh with 2/79%, while reaching the peak point at 100 mesh with 4.05%. However, sample A with 60 minutes mixing time results fluctuated and showed the lowest moisture content obtained in this research was at 120 mesh with 2.79%.

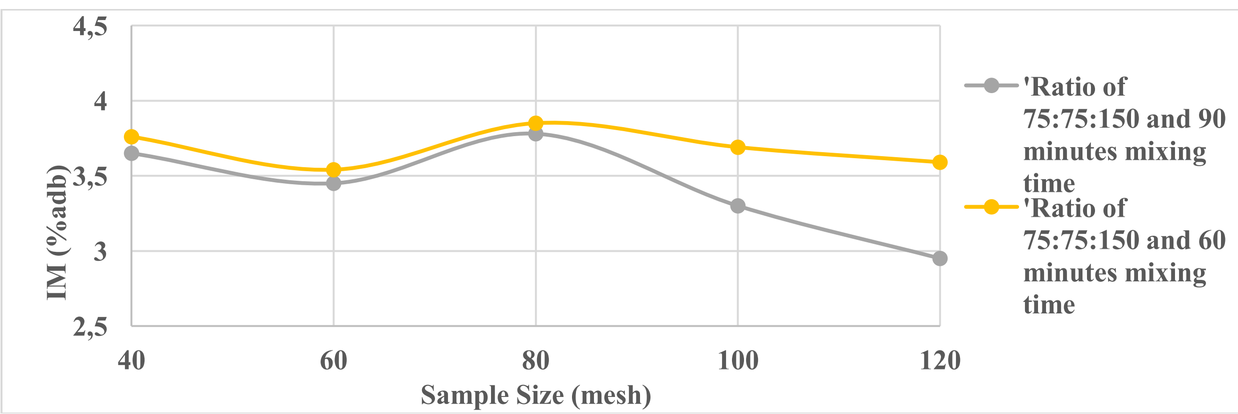

FIGURE 4. The Effect Mixing Time at 75:75:150 ratio to the Moisture Contents

Fig. 4 shows the effect of coal mixing time for sample B on the moisture contents. According to Fig.1, 90 minutes of mixing time resulted in lower moisture content in all mesh sizes than 60 minutes mixing time. The moisture content with 90 minutes mixing time and 40 mesh was at 3.65%, while the 60 minutes mixing time was lower at 3.75%. Despite the fluctuated result, two data resulted in similar trends. The longer mixing time showed a decrease in inherent moisture. In addition, the lowest inherent moisture in this category was obtained for 90 minutes mixing time with 120 mesh size at 2.95%

According to Fig. 1 to Fig. 4, the greater the lubricant oil composition from the mixture, the lower the moisture content. The composition of the oil content in the briquettes determines the quality of coal, especially the value of inherent moisture. The presence of oil in coal affects the attractiveness (cohesive force) between coal materials. Increasing the cohesive force will strengthen the pores and become smaller and prevent the entry of impurities. The cohesiveness of coal will increase if the moisture content in coal decreases. The presence of pores can cause a decrease in the quality of briquettes because many impurities can fill the pores. Empty Pores of water-bound that additives have not fully covered can absorb water vapor from the surrounding environment. The more oil that fills the pores, the fewer impurities that enter the pores of the briquettes. Furthermore, the used lubricant oil is better than waste cooking oil to decrease the moisture content in the UBC process [10].

Calorific Value

Since water inside the pores of brown coal will be pushed by C atoms of the additive and filled void fraction inside the pores of brown coal, heat regenerated in the UBC process will cut off the long chain of C atoms of the additive. Thus regeneration of heat evaporates water on the brown coal surface. The heating value of brown coal grew when the C atoms took up a vacancy proportion inside the pores. Calorific value is influenced by the mixture composition, mixing time, and mesh sizes. Water content also affects calorific value because the lower the water impurity, the higher the calorific value.

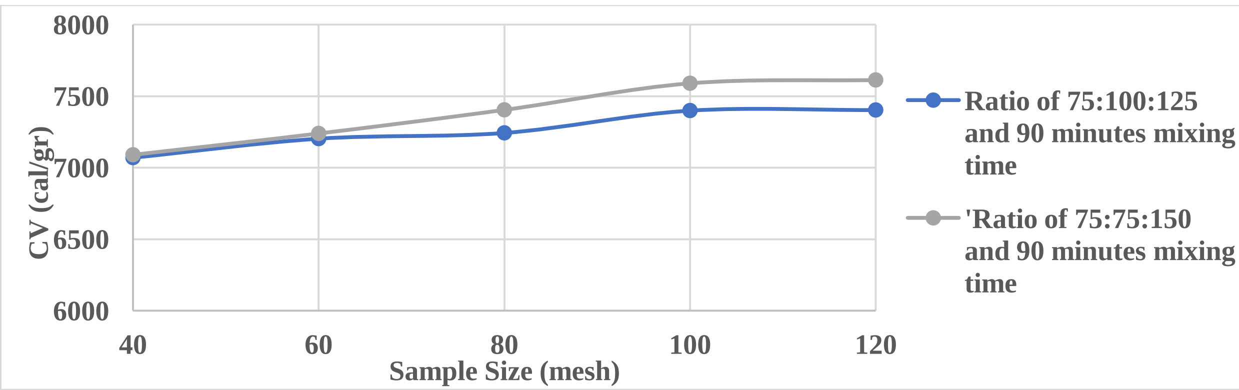

FIGURE 5. The Effect of Oil Addition at 90 Minutes Mixing Time to the Calorific Value

Fig. 5 represents the heating value of brown coal after the UBC process at a mixing time of 90 minutes for both mixture compositions. The highest calorific value was obtained by 75:75:150 mixture ratio and 120 mesh sizing at 7,614 cal/g, while the lowest point was the 75:100:125 mixture and 40 mesh sizing at 7071 cal/g. In addition, there was a similar upwards trend for both mixture variations. Moreover, a quite high disparity of 200 cal/g between both compositions started at 80 mesh to 120 mesh sizing. Furthermore, the rise of calorific value alongside the mesh sizing and mixture ratio showed the ability of waste lubricant oil to fill the void columns or pores and replace the moisture content. The result shown in Fig.5 was relevant to the study of Napitulu et al. The addition of used lubricant oil can improve the calorific value of briquette [11].

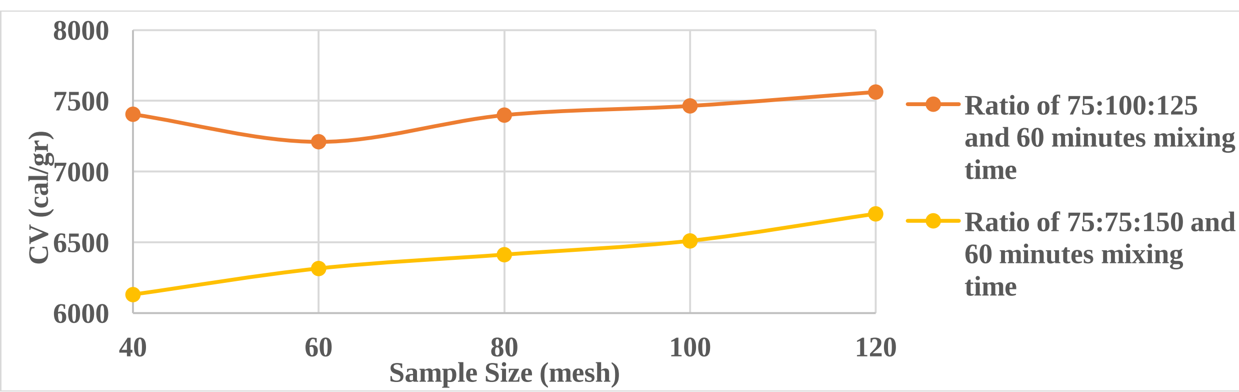

FIGURE 6. The Effect of Oil Addition at 60 Minutes Mixing Time to the Moisture Contents

Fig. 6 indicates the heating value of the briquette after the UBC process using waste cooking oil and lubricant as an additive. The results were obtained at a mixing time of 60 minutes and mixture ratio of 75:100:125 and

75:75:150. The highest calorific value was obtained for 120 mesh sizing and 75:100:125 mixture ratio at 7562 cal/g, while the lowest was acquired for 40 mesh and 75:75:150 mixture ratio at 6131 cal/g. Nonetheless, there was a fluctuation in 75:100:125 mixture composition while achieving an increasing trend from 60 mesh to 120 mesh. Meanwhile, there was a stable increase in the other mixture ratio with more used lubricant oil. However, there was an enormous discrepancy of 821 cal/g at 120 mesh between both compositions. Although the 75:75:150 mixture ratio still shows an upwards trend, the decrease of mixing time from 90 minutes to 60 minutes shows the different results compared to Fig.5. The calorific value for 75:75:125 was lower for the former, while it was higher than the 75:75:150 mixture in the latter. Furthermore, it shows that the 60 minutes mixing time is not enough for the used lubricant oil to fill the pores, while the results are better in a longer mixing time. In addition, the 75:75:125 composition is better to mix at 60 minutes since the used lubricant oil composition was lower than in another sample.

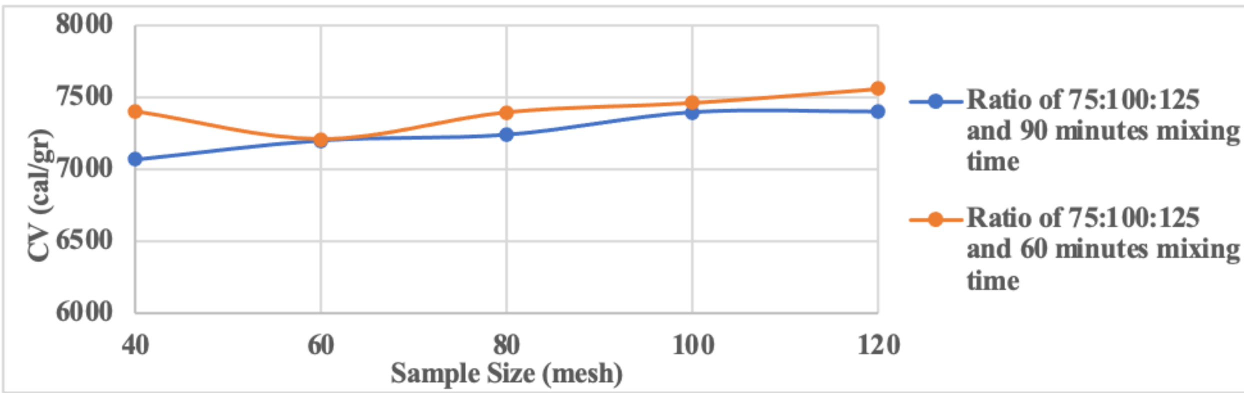

FIGURE 7. The Effect of Mixing Time at 75:100:125 Mixing Ratio to the Moisture Contents

Fig. 7 depicts the effect of mixing time and mesh size variation on calorific value results of the 75:100:125 mixture ratio. Nonetheless, there was a stable upward trend for the 90 minutes mixing time from the start, while there was a fluctuation in 60 minutes, although it kept increasing from 60 mesh to 120 mesh. Additionally, the highest calorific value obtained was 7562 cal/g at 60 minutes mixing time and 120 mesh size, while the lowest was 7071 cal/g at 90 minutes and 40 mesh. However, the increase of mixing time was not followed by the increase of calorific value for the longer time because the shorter time results were higher. Furthermore, based on these results, it can be taken that 60 minutes was a better mixing operation time since it shows a higher calorific value compared to 90 minutes. Besides that, it can be noticed that the waste cooking oil needs lower mixing time to fill the pores and increase the calorific value, while in a longer time, the oil could be already evaporated and released from the pores.

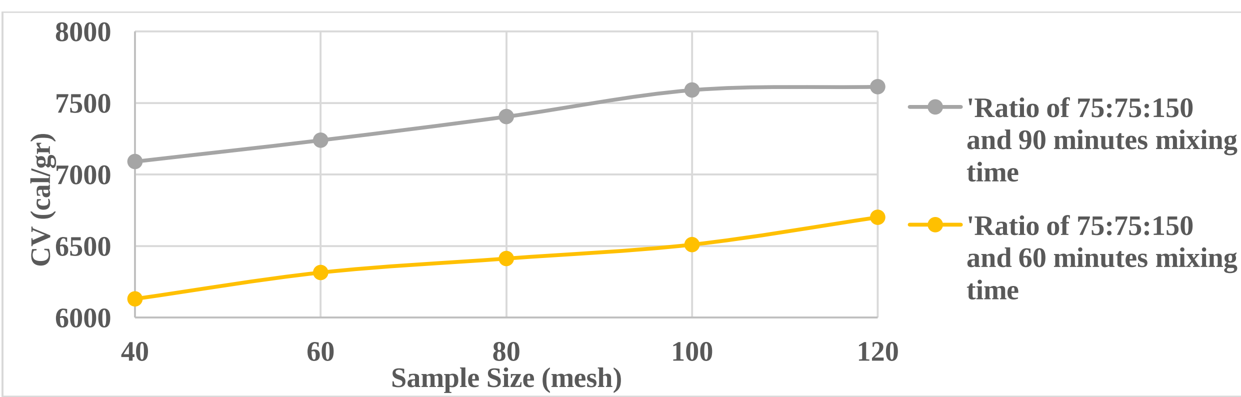

FIGURE 8. The Effect of Mixing Time at 75:75:150 Mixing Ratio to the Moisture Contents

Fig. 8 portrays the effect of various mixing times and mesh size on calorific value results of treated coal with a 75:100:125 mixture ratio. Additionally, there was a stable increase trend for the 90 and 60 minutes mixing time in all variations of the mesh size. Meanwhile, the highest calorific value obtained was 7614 cal/g at 90 minutes mixing time and 120 mesh size, while the lowest was 6131 cal/g at 60 minutes and 40 mesh. In addition, the increase of the mixing time expands the calorific value in every size from 40 mesh to 120 mesh for both mixing times. Although the 60 minutes mixing time results increased alongside the mesh size, the calorific value obtained for 90 minutes was higher. However, there was an immense disparity of 1081 cal/g at 100 mesh between both mixing times. Furthermore, it can be taken that 90 minutes was a better mixing operation time for 75:75:150 mixture ratio because it shows the higher calorific value compared to 60 minutes. Besides that, it can be noticed that the used lubricant oil needs a longer mixing time to fill the pores and increase the calorific value, while in the shorter time, the oil could not fill all the void fraction of the briquette.

CONCLUSION

The study showed that the highest calorific value obtained was 7614 cal/g at 75:75:150 mixture ratio with 90 minutes mixing time and 120 mesh sizing. Additionally, the lowest moisture content was found with a 75:100:125 mixture ratio, 90 minutes mixing time, and 120 mesh sizing at 2.79% adb. Furthermore, the 90 minutes mixing was better for the 75:75:150 mixture ratio, while the mixing time of 60 minutes was more suitable for a mixture of 75:100:125 mixture composition.

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