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Preparation of Biocoke from Rubberwood Sawdust by Using Used Coffee Ground as a Binder

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Abstract

Biocoke is a solid fuel produced from bio-residues such as agricultural residues, woodchips, sawdust. Biocoke is expected to use as a replacement for coal coke to reduce CO_2 and pollution gases emission. Properties of biocoke depend on various factors such as forming conditions, type of raw material and binder, moisture content of raw material. Recently, Thailand has become one of the world leader for natural rubber production. Apart from natural rubber, rubber tree produces a large quantity of biomass. In addition, rubberwood has been widely used as a raw material for furniture industry. Therefore, rubberwood sawdust is one of the main waste generated from furniture industry. In this study, biocoke was prepared from rubberwood sawdust by using used coffee ground as a binder. The effect of binder and forming conditions on properties of the prepared biocokes such as bulk density and calorific value were investigated and reported.

Keywords: Biomass, Solid Fuel, Biocoke, Rubberwood Sawdust, Alternative Energy.

1. Introduction

Nowadays, global warming has become more serious problem. One of the main causes of the global warming problem is the emission of greenhouse gasses from human activities, for example, the emission of CO_2 from the combustion of fossil fuel such as coal coke in industry and power generation. The development of clean and renewable energy sources such as the fuel from biomass resources is necessary to reduce the use of fossil fuel in the future.

Biocoke is a solid fuel produced from biomass resources, municipal solid waste and bio-residues such as agricultural residues, woodchips, sawdust, green tea ground and coffee ground [1-4]. Biocoke has been developed by Kinki University, Japan. Biocoke can be produced by hot-pressing process using high pressure to change the physical properties of the biomass without the carbonization process [5]. Biocoke is expected to use as a replacement for coal coke in iron smelting industry to reduce CO_2 and pollution gases emission [6]. To utilize biocoke in the iron smelting industry, the calorific value and bulk density of the prepared biocoke should be relative high compared to coal coke [4, 6]. Properties of biocoke depend on various factors such as forming conditions, type of raw material and binder, moisture content of raw material [1-5].

In this study, new raw materials which are available in Thailand was considered for production of biocoke. Recently, Thailand has the second largest area of rubber trees plantation in the world [7]. The total area for plantation of rubber trees in Thailand was approximately 22 million hectares in 2013 [8]. Thus, Thailand has become one of the world leader for natural rubber production. Apart from natural rubber, rubber tree produces a large quantity of biomass. In addition, rubberwood has been widely used as a raw material for furniture industry. Therefore, rubberwood sawdust is one of the main waste generated from furniture industry. Moreover, coffee is one of the popular plants in recent year [9]. The residues from using coffee was also increased year by year. It has been reported that used coffee ground has a potential for the production of biocoke [1, 4, 5]. Cherdkeattikul et al. reported that the used coffee ground was a lignocellulosic material which consists of 39.97% of lignin, 18.38 % of cellulose, 22.95% of hemicellulose and 11-20% of oil content [4]. Used coffee ground was considered to be used as a binder because it consists of large amount of lignin which will be decomposed in the range of 130-190 ºC.

Therefore, in this study, biocoke was prepared from rubberwood sawdust by using used coffee ground as a binder. The objective of this study is to investigate the effect of binder and forming conditions on properties of the prepared biocokes such as bulk density and calorific value.

2. Experimental

2.1 Preparation of raw materials

In this study, biocoke was prepared from rubberwood sawdust by using used coffee ground as a binder. Fig. 1 shows photos of rubberwood sawdust and used coffee ground which were used for preparation of biocoke in this study. The rubberwood sawdust used in this study consists of 26.69% of lignin, 41.54 % of cellulose and 34.15% of hemicellulose. The calorific value of rubberwood sawdust and used coffee ground were respectively 3,000 kcal/kg and 3,500 kcal/kg. The particle size of rubberwood sawdust and used coffee ground was separated by sieve shaker. Rubberwood sawdust and used coffee ground with the particle size smaller than 600 μm were chosen as raw materials for preparation of biocoke. The raw materials were dried in oven at 100 °C to control the moisture content to approximately 10 %wt. 50 g (± 0.01) of mixtures of rubberwood sawdust and used coffee ground were prepared by varied the amount of used coffee ground (binder content) at 0, 5, 10, 15, 20 and 25 %wt.

2.2 Forming process

Fig. 2 shows the schematic diagram of the cylindrical reactor for preparation of biocoke which consists of a vertical cylinder with inner diameter 5 cm covered with electrical heater, compression piston and mold. The procedure of forming process is shown in Fig. 3. The prepared raw materials were fed in to the reactor. Then the raw materials were pressed at 16 MPa using 160 °C. The forming pressure was controlled by pressure controller. The forming times were varied at 10, 15 and 20 min. After cooling at room temperature, the biocoke were obtained and discharged from the reactor.

2.3 Determination of biocoke properties

To utilize biocoke in the iron smelting industry by replacing the use of coal coke, the calorific value and bulk density of the prepared biocoke should be relative high compared to coal coke. Therefore, the calorific value and bulk density of was determined to investigate the quality of biocoke.

2.2.1 Bulk density

As mention earlier, the biocoke with high bulk density is expected for more convenient in a transportation process and inventory management. In this study the expected bulk density of the prepared biocoke is higher than 1.2 g/cm^3. The bulk density of prepared biocoke was calculated by using Eq.1. The prepared biocoke was weighted after discharging from reactor. The height and diameter of the prepared biocoke were measured for calculating the volume.

$$D_{bulk} = m/V_{bulk} \quad (1)$$

where D_{bulk} is the bulk density (g/cm^3), m is mass of prepared biocoke (g), V_{bulk} is bulk volume of prepared biocoke (cm^3).

2.2.2 Calorific Value

To use biocoke instead of coal coke, the prepared of the high calorific value to compare with coal coke and other biomass. In this study the expected calorific value of the prepared biocoke is higher than 4000 kcal/kg. The calorific value of prepared biocoke was investigated by using Bomb Calorimeter (Parr, Model 1341-Plain Jacket). The temperature difference of the water in the tank after the bombing process was measured using RTD sensor to control the accuracy of the measurement at 0.23 °C.

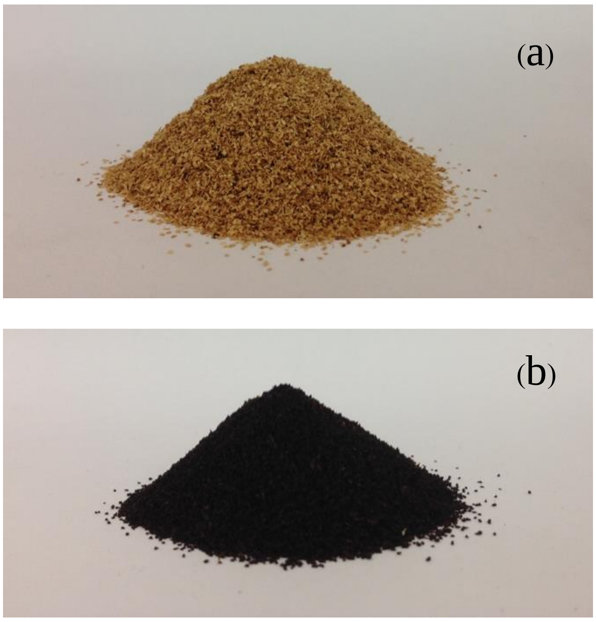

Fig. 1 Photos of raw materials for preparation of biocoke: (a) rubberwood sawdust and (b) used coffee ground (binder)

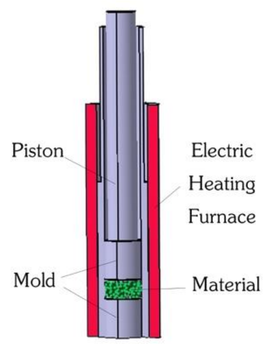

Fig. 2 schematic diagram of the cylindrical reactor for preparation of biocoke

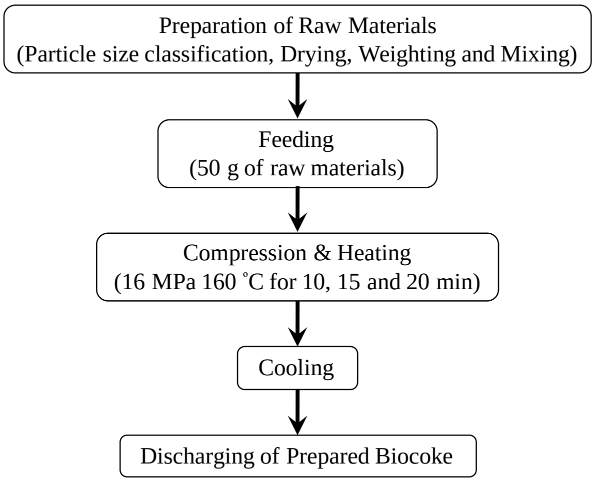

Fig. 3 Procedure of forming process for preparation of biocoke

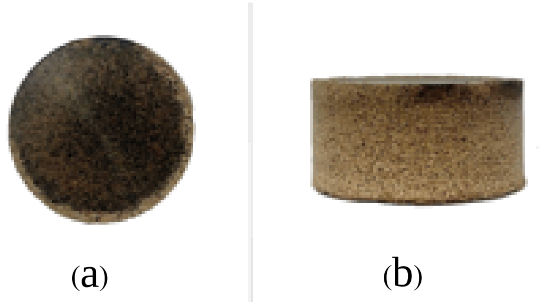

Fig. 4 Photos of the example biocoke prepared from rubberwood sawdust by using used coffee ground as a binder: (a) top view and (b) side view

3. Results and Discussion

Photos of the top and side view of example of biocoke prepared from rubberwood sawdust by using used coffee ground as a binder is shown in Fig. 4. However, the prepared biocokes under different binder content and forming time temperature possess a different diameter and height. The diameters of the prepared biocokes were approximately 4.8 cm in diameter and 2.1 cm in height.

3.1 Effect of binder content

Fig. 5 and Fig. 6 show the effect of binder content on calorific value and bulk density of biocoke prepared from rubberwood sawdust by using used coffee ground as a binder. The calorific value and bulk density of most prepared biocoke gradually increased with increasing the binder content. This is because the increase amount of coffee ground (as a binder) which possesses higher calorific value than rubberwood sawdust. In addition, the thermal decomposition of hemicellulose and pegtin which content in coffee ground during forming process is considered as the key factor on the increase of bulk density [10]. The maximum calorific value was 1.37 g/cm^3 which was obtained by using used coffee as a binder was using the binder content at 15% and forming time at 20 min. However, the maximum bulk density was 1.37 g/cm^3 which was obtained by using the binder content at 25%wt.

3.2 Effect of forming time

Effect of forming time on calorific value of biocoke prepared from rubberwood sawdust by using used coffee ground as a binder is shown in Fig. 7. It is found that, when using the binder content at 0 %wt. and 15 %wt., the calorific value of produced biocoke significantly increased with increasing the forming time. However, a clear relationship between calorific value of produced biocokes at other binder contents and forming time was not observed. Fig. 8 shows the effect of forming time on bulk density of the prepared biocoke. It can be concluded that the forming time did not show significant effect on the preparation of biocoke from rubberwood sawdust by using used coffee ground as a binder.

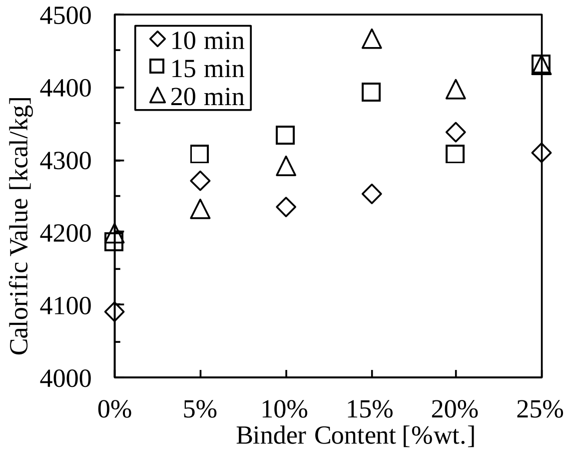

Fig. 5 Effect of binder content on calorific value of biocoke prepared from rubberwood sawdust by using used coffee ground as a binder

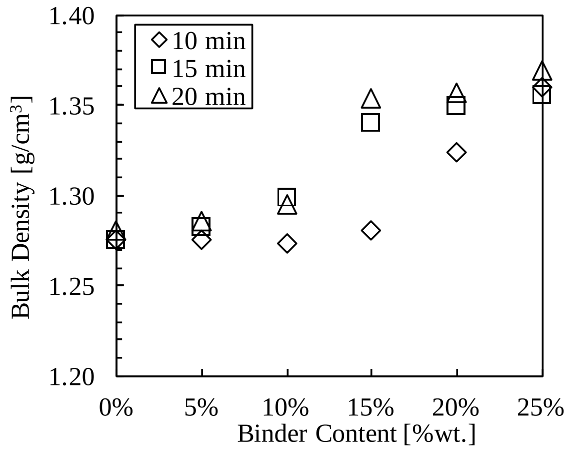

Fig. 6 Effect of binder content on bulk density of biocoke prepared from rubberwood sawdust by using used coffee ground as a binder

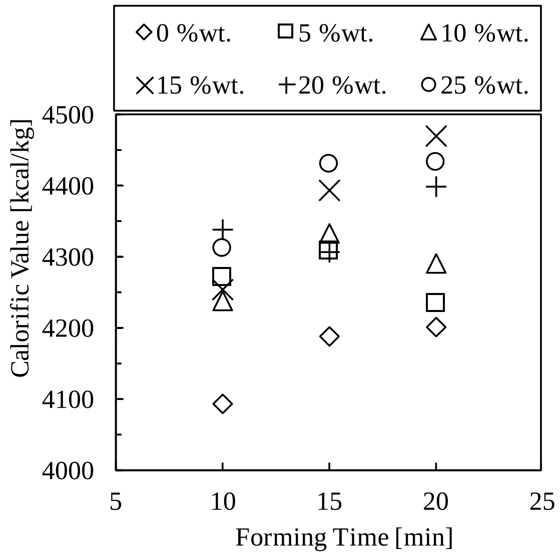

Fig. 7 Effect of forming time on calorific value of biocoke prepared from rubberwood sawdust by using used coffee ground as a binder

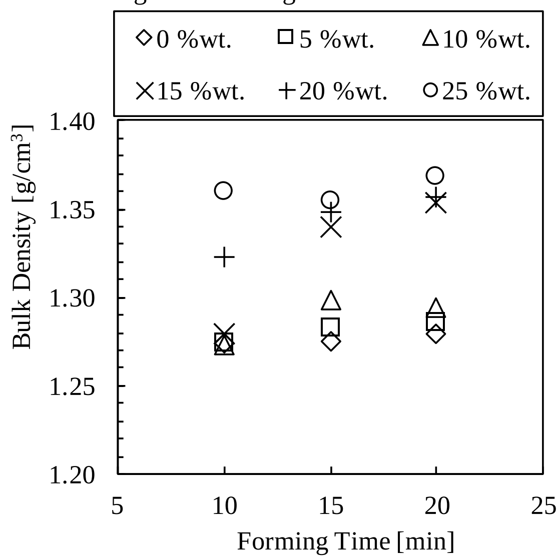

Fig. 8 Effect of forming time on bulk density of biocoke prepared from rubberwood sawdust by using used coffee ground as a binder

4. Conclusion

Biocoke was produced from rubberwood sawdust by using used coffee ground as a binder under forming temperature at 160 °C and forming pressure at 16 MPa. The effects of binder content and forming time on properties of prepared biocoke were investigated. The binder content was varied in the range of 0 – 25 %wt. The forming time was varied in the range of 10 - 20 min. It is found that the bulk density and calorific value of produced biocoke increased with increasing the binder content, whereas a clear relationship between calorific value of produced biocokes and forming time was not observed. Based on the calorific value and bulk density of prepared biocoke, the recommended condition for preparation of biocoke from rubberwood sawdust by using used coffee as a binder was using the binder content at 15% and forming time at 20 min.

5. Acknowledgement

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6. References

[1] Chaichanawong, J., Supachutikul, P., Cherdkeattikul, S., and Supachutikul, P. (2015). reparation of Biocoke from Coffee Grounds, paper presented in *International Conference on Advanced Technology in Experimental Mechanics 2015(ATEM'15)*, Toyohashi, Japan. □

[2] Sawai, T.; Ohmasa, M.; Kajimoto T., and Ida, T. (2010). Compressive strength properties of bio-solid fuel made form pruned branch, *Journal of High Temperature Society*, 2010, vol.36, pp. 36 – 40.

[3] Fuchihada, M.; Shakuto, Y.; Mizuno, S.; Ida, T. and Adachi, Y. (2013). Influence of production condition of high hardness solid fuel made from coffee residues on the combustion property, *Journal of Smart Processing*, 2013, vol. 2(2), pp. 88- 93.

[4] Cherdkeattikul, S; Saisermsak, P.; Nantasaksiri, K.; Chaichanawong, J. (2015). Effects of Forming Temperature on Biocoke Properties from Used Coffee Ground, paper presented in *the 6th TSME International Conference on Mechanical Engineering*, Petchaburi, Thailand.

[5] Cherdkeattikul, S., Supachutikul, P. and Chaichanawong, J. (2015). Effect of particle size on properties of biocoke from used coffee ground, *Journal of Engineering and Technology*, vol. 3(2), July-December 2015, pp. 44-47 (in Thai).

[6] Kazuyoshi, I., Murata, H., Kuwana, K., Mizuno, S., Morita, A., and Ida,T. (2009). Combustion simulation and quick-freeze observation of a cupola-furnace process using a bio-coke fuel based on tea scum, *Journal of High Temperature Society*, vol. 35 (2), May 2009, pp. 91-96.

[7] Cheewakate, K., and.Wongchai, A. (2016). *A Comparative Analysis of Natural Rubber's Exports among Thailand, Indonesia, and Malaysia*, URL: http://www.econ.cmu.ac.th, accessed on 20/08/2016.

[8] Rubber Statistics (2014), *Plantation Area of Rubber Trees in Thailand*, URL:

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http://www.rubberthai.com/statistic/stat_index.htm, accessed on 20/08/2016.

[9] Statistics on Coffee, International Coffee Organization (2014). *Annual Report 2014*.

[10] Mobarak, F., Fahmy, Y. and Augustin, H. (1982). Binderless lignocellulose composite from bagasse and mechanism of self-bonding", *Holzforschung*, vol. 36, pp.160- 168.