**AEC005**

# Effects of Forming Temperature on Biocoke Properties from Used Coffee Ground

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***Abstract***

According to National Oceanic and Atmospheric Administration (NOAA) report, atmospheric carbon dioxide concentration has reached 400 ppm in March 2015, which increased 24 percent from the beginning of the record in 1958. Human activities such as deforestation and burning fossil fuels have direct effect on the increase of atmospheric carbon dioxide concentration. Biocoke is a promising solid fuel made from various types of biomass resources such as woodchips, sawdust, agricultural residues and used tea leaves, which is expected to utilize as an alternative energy source to reduce $CO_2$. Recently, coffee ground residues from beverage industry have gradually increased year by year without an effective utilization. In this study, biocoke was successfully prepared from used coffee grounds under conditions of 150 °C to 190 °C at 16 MPa. The effect of forming temperature on properties of biocoke such as maximum compressive strength, bulk density and calorific value were investigated.

***Keywords:*** Biomass, Solid fuel, Biocoke, Coffee Ground, Alternative energy

## 1. Introduction

To support the world economic expansion, the world primary energy consumption (traditional and renewable energy) is continued growth according to British Petroleum predictions [1]. Since the industrial revolution, traditional energy from fossil fuels was used as fuels for electricity, heating and transportation. On the other hand, fossil fuels burning activities release Green House Gas (GHG) which included carbon dioxide, methane and nitrous oxide into the air [2]. Renewable energy such as biomass, solar energy, wind power, fuel cells, etc., becomes an option which aims to reduce the use of fossil fuels in human activities. Since Thailand is considered as one of agricultural countries, agricultural residues are high as well. Therefore, increasing value of the agricultural residues is becoming the interesting topic. Among the various alternative energy, biomass is one of the captivating alternative energy since it was generated form residues obtained from agriculture, food and beverage industry. There are three types of biomass conduction technology, which are physical conversion, biochemical conversion and thermochemical conversion.

Recently, there are many publications related to the development of biocoke. Different kind of agricultural residues such as pruned branch (plum and persimmon), herby biomass, Japan knotweed, broccoli, leaves of the dead cherry tree, seed of mango, mixture of bamboo with carbonized Japanese cedar and green tea were used as raw materials for the production of biocoke. The quality of the biocoke can be identified by many factors such as physical property, mechanical property, calorific value, thermal behavior and ignition behavior in high-temperature air flows were reported [3-8].

Nowadays, coffee is one of the popular plants all over the world. More than 8.6 million tons of coffee were produced in 2013. Hence, the residues from using coffee was becoming a higher amount as well [9]. However, the residue obtained from coffee still not applicable. There are a few researches studying on the production of biocoke from the coffee residues. Fuchihada et al. [10] has studied combustion property of biocoke made from mixture of coffee outer skin, coffee inner skin (Arabica and Robusta) and coffee ground. The used coffee ground was known as lignocellulosic material (39.97% of lignin, 18.38 % of cellulose, 22.95% of hemicellulose) with 11-20% of oil content [11]. The lignin is one of the important of the composition of biomass which will be decomposed in the range of 130-190 °C. However, the water in the raw material can cause the decreasing of the decomposing range of the lignin lower than 100 °C [12]. Therefore, the raw materials need to be dried before the compressing process since the lignin is the composition which help forming biomass.

In this study, biocoke was produced from the used coffee ground, which was planted in the north of Thailand. The objective of this work was aimed to investigate the effect of different forming temperature under the constant pressure and operating time.

## 2. Experimental

Used coffee ground was dried at 100 °C overnight in the oven (Redline, model RF115) to control the moisture to 0.05 - 0.1 kg/kg-wet. Then, the particle size of used coffee ground was classified by sieving method. In this work, the used coffee ground with the particle size smaller than 1000 microns was used.

### 2.1 Preparation of Biocoke Sample

Dried used coffee ground, approximately 50 g, was fed into the cylinder and covered by top and bottom mold. The production machine used in this work was developed by Kinki University, Japan which is the vertical pressing machine. The schematic of biocoke producing machine is shown in Fig. 1. To control operating temperature, a thermocouple linked with a temperature controller was connected into a top mold. A Pressure of 16 MPa used for the forming was generated via a hydraulic system. The forming temperature of biocoke was heated up by using electric tube furnace with the power of 2.6 kW and measured by type-k thermocouple. In this work, the forming temperature was varied from 150 ºC to 190 ºC. During the heating up process, the hydraulic started pressing. After the forming temperature reached the required temperature, the time was counted for 20 minutes.

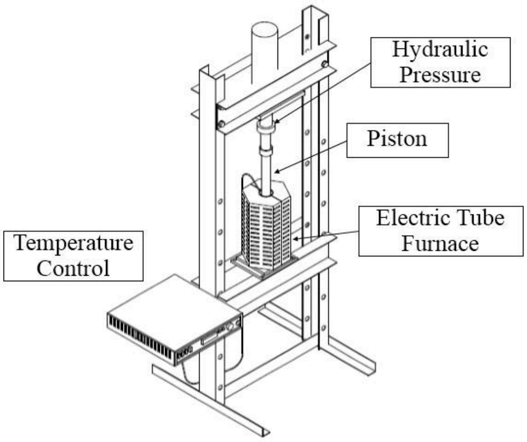


Fig. 1 The schematic of the vertical type of biocoke producing machine

### 2.2 Analytical Method

Biocoke is expected to be an application of coal coke in the iron smelting industry. Therefore, to utilize biocoke instead of coal coke, the biocoke should be hardness and high heating value. The three properties which are physical property, mechanical property and thermal property was conducted to investigate the quality of biocoke.

#### 2.2.1 Physical Property

As mentioned earlier, biocoke was aimed to use in iron smelting industry and others option. To be more convenient in a transportation process, the smaller size of biocoke would provide an advantage for transportation process. Therefore, the smaller size of biocoke will give a higher bulk density which would save a space and the shipping cost. Thus, physical property which was determined in term of bulk density was calculated by using Eq.1. The height and diameter will be measured afterward for calculating the volume.

$$D_B = \frac{m}{V} \quad (1)$$

where $D_B$ is the bulk density (g/cm$^3$), $m$ is mass of each biocoke (g), $V$ is volume of each biocoke (cm$^3$).

#### 2.2.2 Thermal Property

Since the biocoke was aimed to use instead of coal coke, it needs to have the result of the high heating value to compare with coal coke and other biomass used in Thailand. Therefore, this property need to be carefully checked. For this research, the Calorific value (gross heat of combustions), which was defined as thermal property, was investigated by using Bomb Calorimeter, Parr Model 1341 Plain Jacket as shown in Fig.2.

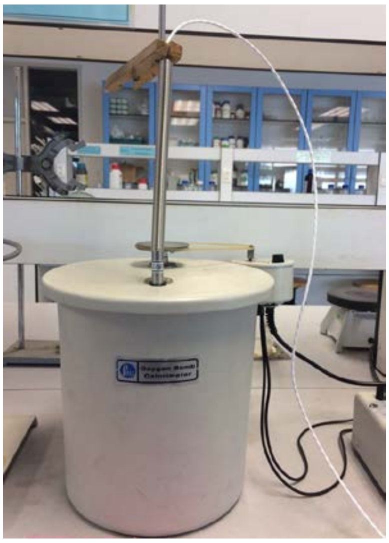

Fig. 2 Bomb Calorimeter, Parr Model 1341

The procedure of this measurement tool is to investigate the difference temperature of the water in the tank after the bombing process. Therefore, the temperature difference is very sensitive because the calorific value can be changed easily. To give an accuracy in the measurement process, the RTD sensor was chosen to measure the temperature since the accuracy class of this sensor was only 0.23 ºC.

#### 2.2.3 Mechanical Property

The biocoke was investigated the maximum compressive strength by the compressive testing machine. The biocoke will be pressing until it broke. In this study, maximum compressive strength, which was defined as mechanical property, was conducted by ADR-Auto V2.0 300 BS EN Compression Machine. The compressive strength estimated from Eq.2.

$$\sigma_{\max} = \frac{F}{A} \quad (2)$$

where $\sigma_{\max}$ is maximum compressive strength (MPa), $F$ is compressive force (kgf) and $A$ is cross section area (m$^2$)

### 3. Result and Discussion

Fig. 3 shows the top and side view of the example of the biocoke from used coffee ground. However, the biocokes which produced under the different forming temperature possess a different diameter, height and mass of product as summarized in Table 1.

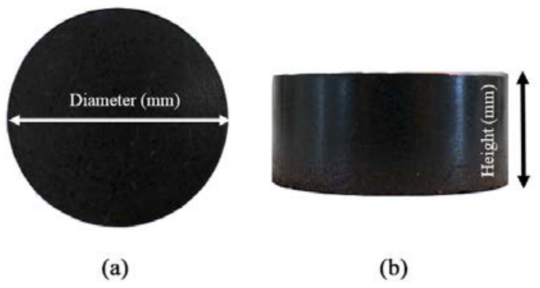


Fig. 3 The biocoke obtained from used coffee ground which is shown in (a) top view and (b) side view

As seen in Table 1, under the different condition of forming temperature, the height of the biocoke was quite different. The higher forming temperature gives a smaller product. However, the difference between each condition was insignificant. The reducing of the mass of biocoke may cause by the oil of the raw material. Since after the pressing process, the used coffee ground has released oil itself.

Table 1 The size and mass of the biocoke in the difference forming temperature

| Forming Temperature (°C) | Diameter (cm) | Height (cm) | Mass (g) |
|---|---|---|---|
| 150 | 4.78 | 1.99 | 47.66 |
| 160 | 4.78 | 1.97 | 47.54 |
| 170 | 4.78 | 1.96 | 47.45 |
| 180 | 4.77 | 1.95 | 47.30 |
| 190 | 4.78 | 1.94 | 47.05 |

The relationship between bulk density, calorific value and forming temperature are shown in Fig. 4 – 5 respectively. Bulk densities of biocokes which were produced at different forming temperature (150 – 190 °C) are 1.33, 1.34, 1.34, 1.34 and 1.34 g/cm$^3$. The bulk density of biocoke result was similar to the related works, approximately 1.30-1.39 g/cm$^3$ [3-8]. Calorific values of biocokes which were produced at different forming temperature are 4,885, 4,912, 5,045, 5,001 and 5,130 kcal/kg. It can be concluded that under forming temperature between 150 – 190 °C, the difference between bulk density and calorific value at each condition was very small.

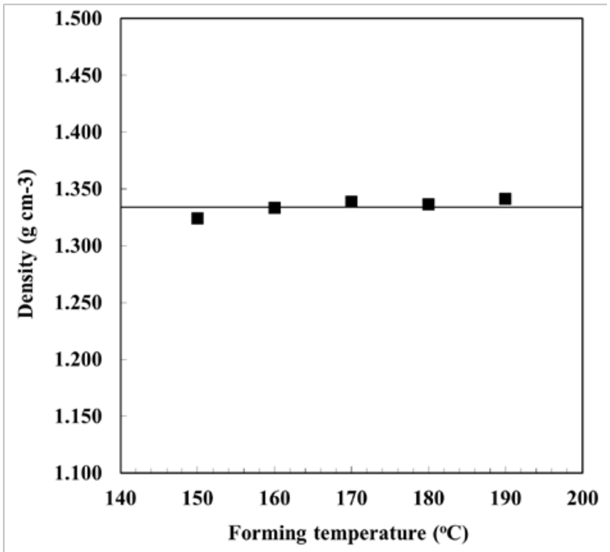


Fig. 4 The relationship between forming and Bulk Density

The result in a calorific value was obviously seen that the higher forming temperature would give a higher calorific value. However, the difference between the highest (190°C) and lowest (150 °C) of forming temperature was only 250 kcal/kg which is very small since it has to be noted that the error can be occurred by the measurement tool.

For the reason that there is no report on the calorific value of biocoke, thus the calorific of biocoke in this study was compared with the other biomass used in Thailand. The biocoke from used coffee ground, has greater result of calorific value, nearly 5,000 kal/kg, than most of the biomass used in Thailand which around 3,000 kcal/kg.

Maximum compressive strength at different conditions are 62.90, 63.80, 70.44, 57.12 and 67.49 MPa. Fig. 6 shows the relationship between forming temperature and maximum compressive strength. As a result of the relationship, at 150 – 170 °C forming temperature has greatly affected on maximum compressive strength. This is because when the temperature was increased, gap between molecules would be smaller which led to the lesser amount of porous [3, 13]. However, at higher forming temperature, hemicellulose is decomposed, let to the decrease of maximum compressive strength [4].

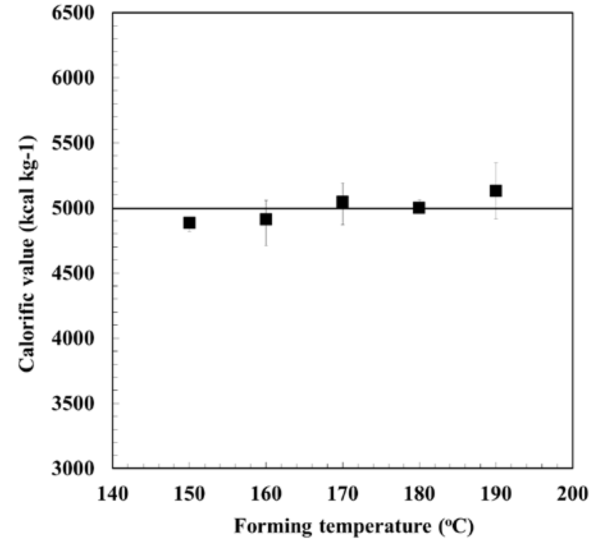


Fig. 5 The relationship between forming temperature and calorific value

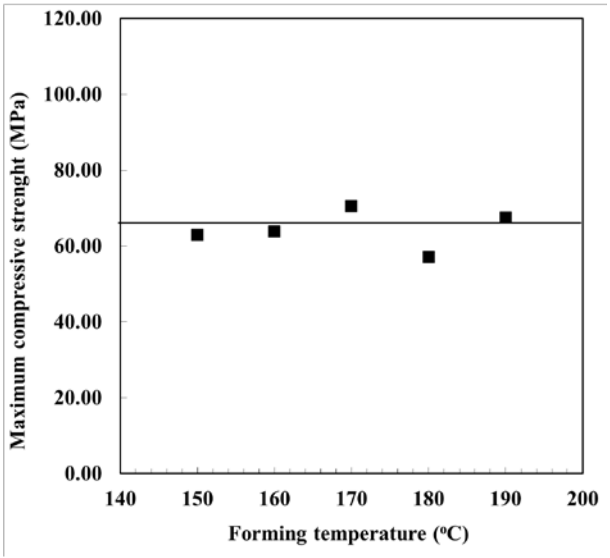


Fig. 6 The relationship between forming temperature and maximum compressive strength

The results of properties analysis in term of physical, thermal and mechanical property of biocoke under different forming temperature were found insignificantly. Thus, the processing time of each condition was calculated to compare. The heating time which was counted from 50 °C to the required temperature. Fig. 7 reveals the relationship between operating time, which was included the heating up time, plus 20 minutes of operating time, and forming temperature. There was the difference between the processing time of the forming temperature of 150 °C and 190 °C, which would be a direct impact to biocoke processing cost in term of mass production.

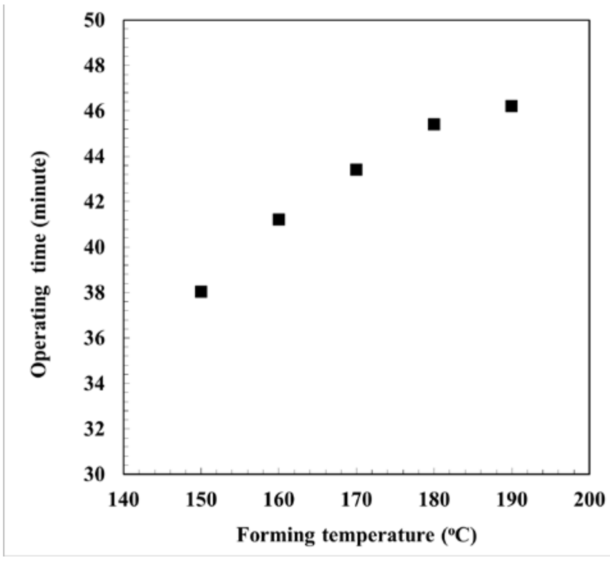


Fig. 7 The relationship between forming temperature and operating time

## 4. Conclusion

Biocoke was successfully developed from used coffee ground under 16 MPa at 10 minutes of operating time. The different forming temperature had few effects on the bulk density and calorific value. Nevertheless, the forming temperature had influenced on maximum compressive strength at high forming temperature (180 – 190 °C). On the other hand, when forming temperature and operating time was compared, the effect of forming temperature was clearly seen. The lowest forming temperature (150 °C) would be the best condition for biocoke production at 16 MPa, 20 minutes operating time.

## 5. Acknowledgement

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