Calorific value analysis, reduction of period weight, reaction rate, activation energy of old coconut, young coconut waste briquette burning, cocoa

W Nuriana¹, A Suryanto² and M Kamal ¹

¹ Faculty of Engineering, University of Merdeka Madiun
² Faculty of Agriculture, University of Merdeka Ponorogo

nuriana@unmer-madiun.ac.id

Abstract. Indonesia was a country with considerable biomass energy potential. Biomass energy could be explored from agricultural waste, abundant and easily obtained biomass, for example: old coconut waste, young coconut waste and cocoa waste. This study aims to obtain the heating value of charcoal briquettes from biomass of old coconut waste, young coconut waste and cocoa waste. The study was conducted on a laboratory scale, and used a complete randomized design with 3 repetitions. The procedure of this study begins with sorting raw materials, cutting and drying. Next carbonize, grind, filter, add tapioca glue, then print, and press at 115 kg/cm². Carbonize at 400°C, for 30, 60, 90 and 120 minutes. The briquettes produced would be analyzed for density analysis, calorific value, and highest calorific value. Then analyzed for reducing the mass and rate of the combustion reaction. The test results of the old coconut briquette density were 0.937 g/l, the highest calorific value was 6.927 kcal/g with a 90 minute carbonization time. Old coconut briquettes had the lowest or lowest combustion reaction rate compared to the level of combustion reaction rate of young coconut briquettes and cocoa briquettes. The effect of a higher density value, the higher the briquette heat value and the slower or lower the combustion rate. In the Thermogravimetry test using The Thermal Gravimetry Analyzer (TGA), the highest decrease in mass of old coconut waste briquettes compared to young coconut waste briquettes and cacao waste briquettes was 55.34% from 590.5°C to 599.2°C. In Thermal Gravimetric Differentials. (DTG) shows the rate of combustion reaction in old coconut waste briquettes is 0.10%/minute with an air speed of 5 ml/minute.

1. Introduction
Energy was a basic need for human life, the need for fuel was increasing. As an example of increasing energy consumption in all sectors, among others in the fields of transportation, electricity, industry and domestic. Total energy consumption in 2013 amounted to 1.1 billion BOE (Barel of Equivalent), the use of conventional fuel was quite dominating such as petroleum and coal (ESDM , 2014) The potential of biomass in Indonesia, especially agricultural waste biomass (old coconut skin waste, young coconut and cocoa) was available in large quantities and cheaply, the utilization was not maximized. Beside from being a fuel, these wastes could be used as raw materials for activated charcoal, carbon paper, battery stones and others. In general, agricultural waste was only used as fuel that was directly burned, so that it could cause environmental pollution (Jati, et al., 2005; Nuriana, 2013). Conversion of young coconut skin waste, old coconut and cocoa into briquettes will increase
the density, thus increasing economic value. Fuel in the form of briquettes in addition to having high heat values could ignite for a long time (Lusia, 2008).

This research was to obtain the characteristics of the combustion reaction and its application, it was necessary to reduce the mass weight, reaction rate and its relationship with density, heating value in young coconut skin waste briquettes, old coconut and cocoa.

2. Research Method
The research was carried out and analyzed in a laboratory manner, the treatment was repeated three times. The design of the experiment using a completely randomized design with the variable effect of carbonization time and response variable was density, heating value. Weight reduction period and rate when the combustion reaction process.

2.1. Materials and tools
The materials used in this study were: old coconut waste (skin, coir, shell), young coconut (skin, coir, shell), cocoa, starch, water, aluminum foil as a wrap when oven. The equipment used in this study were ovens, knives, trays, mortars, desiccators, printing devices, briquette presses, measuring cups, picnometers, erlenmeyers, volume flasks, electric scales, 80mesh sieves, bomb calorimetry, Thermo Gravimetry Analayzer (TGA) units, Differential Themo Analayzer (DTA).

2.2. Making Briquettes
Old coconut waste, young coconut waste and cocoa waste were sorted, dried in the sun for 3 days to reduce water content. Continued carbonization at 400°C for 30, 60, 90, 120 minutes using an oven. Then pounded, sieved with 80 mesh sieve, followed by mixing with starch glue/stirred until homogeneous, printed and pressed with a pressure of 115 kg / cm². The printed briquettes were then dried to reduce the water content contained in the glue, dried in the sun for 2 days. Briquettes were analyzed for water content, density, heating value, combustion reaction rate, reduction in mass weight in the combustion process. From carbonization with a variation of time 30, 60, 90, 120 minutes the highest heating value of each briquette was selected and then analyzed the reaction rate and reduction in mass weight in the combustion reaction process.

3. Result and Discussion
The research was carried out and analyzed in a laboratory manner, the treatment was repeated three times. The design of the experiment using a completely randomized design with the variable effect of carbonization time and response variable was density, heating value. Weight reduction period and rate when the combustion reaction process.

3.1. Old Coconut Waste Briquette Density Test, Young Coconut waste and Cocoa waste
In figure 4.1 shows the graph of the effect of carbonization time at 400°C on the density of old coconut waste, young coconut and cocoa. The manufacture of carbonized briquettes was basically to increase the density of a raw material and obtain a greater heat value than the material before making a charcoal. Increased carbonization time increases density.

In the graph below the price of density increases significantly with the length of carbonization time (Tirono, 2011; Nuriana, 2013).
Figure 1. Effect of carbonization times 30, 60, 90, 120 minutes at 400°C on the density of old coconut waste, young coconut waste and cocoa waste.

3.2. Calorific Value Test for Old Coconut Waste Briquettes, Young Coconut Waste and Cocoa Waste

After the carbonization process was carried out at a temperature of 400°C with a time variation of 30, 60, 90, 120 minutes and briquette was made and then pounded and sifted to a size of 100 mesh, to facilitate the heat value test in combustion with oxygen in bomb calorimetry (Syamsiro, 2007). The smaller the particle size will increase the surface so that the material burns faster (Subroto, 2006; Nuriana, 2013). Calorific value was the main parameter in the assessment of a fuel or energy (Scroder E., 2006; Tirono, 2011; Table 1. The calorific value of old coconut, young coconut and cocoa waste briquettes at a carbonization temperature of 400°C with variations of carbonization time of 30, 60, 90, 120 minutes.

| No. | Waste   | Time (minutes) | Heating value (cal / g) |
|-----|---------|----------------|-------------------------|
| 1   | old coconut | 30             | 6.635                   |
|     |          | 60             | 6.882                   |
|     |          | 90             | 6.927                   |
|     |          | 120            | 6.879                   |
| 2   | old coconut | 30             | 5.457                   |
|     |          | 60             | 5.846                   |
|     |          | 90             | 5.328                   |
|     |          | 120            | 5.740                   |
| 3   | cocoa    | 30             | 4.925                   |
|     |          | 60             | 5.059                   |
|     |          | 90             | 4.967                   |
|     |          | 120            | 4.787                   |

Source: Nuriana, 2018

The results were tested by TG, DTG in reducing the weight and rate of combustion reaction at the highest calorific value, also in testing the activation energy with Differential Scan Calorimetry (DSC). Of the three old coconut waste briquettes, young coconut, cocoa each had a value of 6,927 cal/g with
90 minutes carbonization time, 5,846 cal/g with 60 minutes carbonization time, 5,059 cal/g 60 minutes long.

![Calorific Value](image.png)

**Figure 2.** Calorific value of old coconut waste briquettes 6,927 cal/g with carbonization time 90 minutes, young coconut calorific value, 5,846 cal/g with 60 minutes carbonization time, cocoa 5,059 cal/g with 60 minutes long.

3.2.1. The results of the reduction in briquette weight and the reaction rate of burning old coconut waste briquettes were tested by TG and DTG. Changes in the weight of briquettes when starting burning 40°C to 100°C reduced weight was 1.1%, at a temperature of 100 °C to 262°C reduced weight 6.04 and at a temperature of 262°C to 590.5°C reduced weight 37.51% and temperature 590.5°C to 599.2 °C 55.34%. The DTG was shown as an endothermic process, and at the end of the combustion there was a faster reduction of the charcoal period. The rate of combustion reaction in Figure 4.1 was 0.10% / minute, with an air rate of 5 ml/minute.

![TG and DTG Curves](image.png)

**Figure 3.** TG and DTG curves for old coconut waste briquettes with heating value of 6,927 cal/g, weight of 13.75 mg briquette sample, temperature of 40-600°C, air rate of 5ml/minute and heating rate of 10°C.

3.2.2. The results of reduction of briquette weight and reaction rate of burning young coconut waste briquettes with testing with TG and DTG. Changes in the weight of briquettes at the start of combustion temperature of 40°C to 79.5°C reduction in weight of 6.04%, at a temperature of 79.5°C to...
188°C weight reduction of 6.50%, at a temperature of 258°C to 590°C and a reduction in weight of 42.10%. at a temperature of 590°C to 599.2°C weight reduction drastically 50.09%. The rate of combustion reaction in young coconut waste briquettes was 0.22% / minute.

![TGA curve and DTA for young coconut waste briquettes](image1.png)

**Figure 4.** TGA curve and DTA for young coconut waste briquettes with heating value of 5.846 cal/g, weight of briquette samples of 13.54 mg, temperature of 40-600°C, air rate of 5ml/minute and heating rate of 10°C.

3.2.3. The results of the reduction of briquette weight and reaction rate of combustion of cocoa waste briquettes testing with TGA. Changes in the weight of briquette when starting burning temperature of 40°C to 50.5°C reduction in mass weight 0.84%, at a temperature of 50.5°C to 188°C weight reduction of 8.15%, at a temperature of 188°C to 590°C there was a reduction in weight 55.46%. At a temperature of 590°C to 599.2°C there was a reduction in weight of 35.53%. The rate of combustion reaction in young coconut waste briquettes was 0.24% / minute.

![TGA curve and DTA for cocoa waste briquette](image2.png)

**Figure 5.** TGA curve and DTA for cocoa waste briquette with heating value of 5,059 cal/g, weight of briquette sample 13.22 mg, temperature 40-600°C, air rate of 5ml / minute and heating rate of 10°C.
The results of this study, the calorific value of old coconut briquettes has a slow or low combustion reaction rate compared to the rate of burning of young coconut briquettes and cocoa. The effect of the higher density value, the higher the briquette heating value and the slower or lower combustion rate according to the study of Afif, et al., 2014; Kurniawan, et al., 2012).

The highest mass weight reduction in old coconut waste briquettes compared to young coconut waste and cocoa briquettes was 55.34% from $590.5^\circ$C to $599.2^\circ$C in the analysis by Thermogravimetry (Himawanto, DA, et al., 2011; Aries D. Himawanto, 2013).

### 3.2.4. Activation Energy Results

Activation energy results by testing using DSC (Differential Scanning Calorimetry) tools on old coconut briquettes, young coconut and cocoa each of different weights performed with a variation of air flow rate of 20.30.40 ml / min was stated in table 4.1 below.

#### Table 2. Results of activation energy in old coconut briquettes, young coconut and cocoa with variations in air flow rates of 20,30,40 ml / minute.

| Air flow. (ml/minutes) | Activation of briquettes ( j/ g) |
|------------------------|----------------------------------|
|                       | Old Coconut | Young Coconut | Cocoa    |
| 20                     | 163,80      | 195,40        | 216,60  |
| 30                     | 150,50      | 182,4        | 207,10  |
| 40                     | 133,20      | 138,4        | 185,60  |

The results of comparison of the activation energy of old coconut briquettes, young coconut and cocoa with variations in airflow rate of 20.30.40 ml / min and the weight of each sample in the DSC test were different, could be seen in the graph below.

**Figure 6.** Energy Chart of activation of old coconut briquettes, young coconut and cocoa on variations in air flow rates of 20,30,40 ml / minute.

The higher the air flow rate was 20,30,40 ml / minute, the activation energy in old coconut briquettes, young coconut and cocoa decreases significantly. This was because the higher the air flow rate, the activation energy required for the combustion reaction was smaller. Activation energy depends on the calorific value of the briquette, the activation energy will be low if the fuel has a high fuel value, this occurs in young coconut waste briquettes. Higher air flow speeds have more oxygen.
content that could help make changes more perfect. Because it has burned more completely, it will require low activation energy (Aries, et al., 2013).

4. Conclusion
The use of sections to divide the text of the paper was optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in table 2 should be used.

- The highest calorific value obtained in the old coconut waste briquette was 6,927 cal/g at 400°C carbonization temperature for 90 minutes compared to young coconut waste and cocoa;
- The price of briquette density was high, the heating value has a high price;
- The reaction rate of old coconut waste briquette burning was lower (0.10% / minute) compared to young coconut waste briquettes and cocoa.

Acknowledgement
We thank the honorable ones:

- Directorate General of Strengthening Research and Development, Ministry of Research, Technology and Higher Education with letter No. SP DIPA A-04206.1.401516 / 2017 and Letter of Agreement Number: 035 / SP2H / LT / K7 / KM / 2018 Between Coordinator of Kopertis Region VII and Chancellor of Merdeka University Madiun on February 26, 2018
- Chair of the Polymer Test Laboratory, P2F-LIPI Bandung.
- Chair of the Engineering Physics Department, ITS Surabaya Physics Engineering.
- Head of School and Head of the Analytical Chemistry Laboratory at Madiun University.

References
[1] Afif M.Almu, Syahrul, Yesung AP 2014 Analisa Nilai Kalor Dan Laju Pembakaran Pada Briket Campuran Biji Nyamplung (Calophyllm Inophyllum) Dan Abu Sekam Padi Jurnal Dinamika Teknik Mesin 4 No 2m Juli 2014
[2] Aries D Himawanto 2013 Penentuan Energi Aktivasi Pembakaran Bruket Char Sampah Kota Dengan Menggunakan Metode Thermogravimetry Dan Isothermal Furnace. Jurnal Rotasi 15 No 3 Juli 2013.
[3] ESDM 2004 Kebijakan Pengembangan Energi Terbarukan Dan Konservasi Energi. Keputusan Menteri ESDM No.0002 Tahun 2004
[4] Himawanto, DA Indarto, Saptoadi, H Rohmat TA 2011 Karakteristik Dan Pendekatan Kinetika Global Pada Pirolisis Lambat Sampah Kota Terseleksi Reaktor ISSN 0852 0798 13 Juni 2011 141-146
[5] Himawanto DA, Sidhi PR, Indarto, Saptoadi H, Rohmat TA 2011 Analisa Thermogravimatry Pembakaran Briket Char Bambu Jurnal Teknik 11 No 1 77-84
[6] Himawanto DA, Indarto, Saptoadi H, Rohmat TA 2012 Thermogravimetric Analysis and Global Kinetics of Segregated MSW Pyrolysis Modern Applied Science 6 (1) 120-119
[7] Kurniawan Eddy, Budi Wahyudi S, Muslichin H 2012 Karacteristisasi Dan Laju Pembakaran Biobriket Campuran Sampah Organik Dan Bungkil Jarak (Jatropha curcas L.) Jurnal Rekayasa Proses 6 No. 2 2012
[8] Kurniawan Eddy 2012 Model Matematis Laju Pembakaran Biobriket Campuran Sampah Organik Dan Bungkil Jarak (Jatropha curcas L.)
[9] Mahajoeno Edwi 2005 Energi Alternatif Pengganti BBM Potensi Limbah Biomassa Smart Sebagai Sumber Energi Terbarukan.
[10] Nuriana W 2013 Synthesis Preliminary Studies Durian Peel Bio Briquettes As an Alternative Fuels Energy Procedia Journal 47 295-302
[11] Nuriana W 2018 Karakteristik Biobriket Limbah Kelapa (Tua, Muda) Dan Kakao Sebagai Energi Terbarukan Pada Variasi Waktu Karbonisasi. Kementrian Hukum Dan Hak Asasi
Manusia

[12] Scroder Eliabeth 2006 *Experiment on the Generation of Activated Carbon from Biomass* (Germany : Institute for Nuclear and Energy Technologies Forschungs Karlsruhe 106-111 )
[13] Tirono M, Sabit, 2011 Efek Suhu Pada Proses Pengarangan Terhadap Tempurung Kelapa *Jurnal Neutrini* 3 No. 2. Fakultas Sains dan Teknologi UIN Maulana Malik Ibrahim Malang
[14] Syamsiro M. Harwin Saptoadi 2007 *Pembakaran Briket Biomassa Cangkang Kakao: Pengaruh Temperatur Udara Preheat* Seminar Nasional Teknologi Teknik Mesin UGM Yoyakarta.
[15] Sulistyanto Amin 2005 *Pengaruh Variasi Bahan Perekat Terhadap Laju Pembakaran Biobriket Campuran Batubara Dan Sabut Kelapa*
[16] Subroto 2006 Karakteristik Pembakaran Biobriket Campuran Batubara, Ampas Tebu, Jerami. *Media Mesin* 2 Juli 2006 47-54