Preparation of Cow Dung Bio-briquettes (CDBs) for Gassification Stoves as Renewable Energy Sources

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Abstract. Enormous demand on fossil fuels has led to massive exploitation. Because of its non-renewable sources, the stock will decrease rapidly. Therefore, investigation on renewable energy sources is necessary to be done. One of the renewable energy sources is biomass of cow dung, which will converted into energy via gasification process. In some cases, cow dung is so abundant that is not completely fed to biodigester to produce biogas. Commonly in the countryside, the cattle sheds places closely to the housing and un-utilize cow dung will causes health problems in the rural environment. Cow Dung Bio-briquettes (CDBs) preparation is one of the pre-handling methods for biomass gasification process to obtain syngas. Cow dung were processed in several stages, those are sun drying, grinding, sieving, and briquetting using a hydraulic press. In this study, the effects of particle size of cow dung powder and tonnages of hydraulic pressure were investigated. The cow dung powder were screening in 20, 40, 60, and 80 mesh. The pressure of hydraulic press were varied in 2, 3, and 4 tonnages. CDBs quality were determined based on Indonesian National Standard SNI 01-6235-2000. The acceptable CDBs was made used cow dung with particle size of -20+40 mesh and 4 tons of hydraulic pressure.

1. Introduction
High dependence on fossil fuel sources (petroleum and coal) has led to massive exploitation of these two of energy sources, so that they will decrease rapidly. Fossil fuel cannot be renewed, therefore renewable energy sources needs to be sought. The rate of energy consumption in Indonesia tends to increase every year. Oil, natural gas, and coal as main energy sources and were supplied 41.46%, 19.36%, and 35.81% respectively of Indonesia's total energy needs. Meanwhile, Indonesia's consumption of renewable energy sources was only 1.48% of the total energy consumed [1]. Renewable energy sources are relatively non-sulfur, so its do not cause air pollution [2]. One of renewable energy sources is biomass, especially waste of the farming process. Biomass is dry matter of organic material and can be used as an alternative energy source because of its hydrocarbon content [3].

Badan Pusat Statistik - Indonesia (2016), listed that the number of cows in Indonesia is 16,626,421 consist of 3.2% of dairy cows and 96.8% of beef cattle. A cow will produces manure about 8-10 kg/day [4, 5]. Improper handling of cow dung will causes environmental pollution, unpleasant odors, endemic diseases, and water infiltration in soil and river. One of promising methods for cow dung utilization is transformed it into Cow Dung Bio-briquettes (CDBs). Briquette is a suitable form for the
further utilization of biomass as feed in combustion, gasification, and pyrolysis processes or as an adsorbent.

Manure of cattle is the result of metabolic waste that has been mixed with urine [6]. The composition of manure are carbohydrates, especially cellulose and fiber, in addition to protein and fat [7]. Bio-briquette is a solid fuel made from organic waste, industrial waste, and urban waste. This solid fuel is potentially becomes a cheap alternative fuel because of its needs simple technology and simple equipment relatively to fossil fuel [8].

The qualities of CDBs are determined as physical and chemical properties, such as density, particle size, water content, calorific heating value, ash content, and smoke point [8, 9, 10, 11, 12]. The maximum water content of CDBs according to SNI 01-6235-2000 is 8%bw. The higher water content will affect to slower burning process. The heat generated from combustion will be used firstly to remove water in the CDBs [13]. Lindley and Vossoughi (1989), said that density of CDBs depends on the briquetting pressure, especially on briquetting without binder. Higher compressive force will higher the density of CDBs [14].

Fengel and Wegener (1995) define ash content as the amount of residue that was generated after complete burning of organic matter, whose main components are mineral, calcium, potassium, magnesium, and silica [15]. Higher ash content will reduces the quality of the fuel in terms of calorific heating value [16]. The volatile matter evaporation occurs before the oxidation of carbon and the main content of this volatile matter is hydrocarbons with small extent of nitrogen [15].

In this study, preparation of CDBs as feed in gasification stove was conducted, in which the size of cow dung powder and the pressure level of hydraulic press were varied. There were no binder or others chemicals used in this study. The quality of produced CDBs in terms of physical properties, chemicals content (proximate analysis), and calorific heating value were then investigated and compared to bio-briquette quality standard of Standar Nasional Indonesia (SNI).

2. Methodology
In this study, sun dried cow dung was obtained from dairy cattle in Klaten district of Central Java - Indonesia.

Small stainless grinder with capacity of a hundred grams and maximum blade rotation of 28,000 rpm was used for powdering cow dung for a minute grinding time. This powder was then classified by automatic sieve in the order of 20, 40, 60, and 80 mesh for 20 minutes operation. The density and moisture content of cow dung powder in certain meshes were determined.

Hydraulic press machine with 4.8 cm piston diameter and maximum compressive strength of 20 tons was used for pressing a quantity of cow dung powder in a cylinder die (mold) with 4.8 cm inside diameter and 10 cm length. In this study, the hydraulic pressures were varied in 2, 3, and 4 tonnages for 30 seconds pressing time.

Some characteristics of produced CDBs such as moisture content, dimension (diameter and length), and density were measured by standard methods and equipments. The axial compressive strength test, proxymate analysis, and calorific heating value analysis also conducted. Moisture content measurement was carried out by ASTM D-3173 procedure. Weight measurement was conducted by digital weighing tool by Adventurer Ohaus with accuracy of 0.001 gram. Universal Testing Machine QC-503B1 (maximum press capacity of 10 tons and weighs 800 kg) was used to measure the axial compressive strength of briquettes by ASTM E-910 procedure. Proxymate analysis and calorific heating value analysis were conducted at the Faculty of Forestry Universitas Gajah Mada – Yogyakarta.

3. Results and Discussions
3.1. Grinding Process, Powder Size Distribution, and Water Content of Cow Dung Powder
Particle size distribution of grinded of sun-dried cow dung were shown in Table 1. The powder passing out of each sieves were collected and weighed. There are no differences in particle size distribution for different grinder speed or operation time.
Table 1 shows also the water content of sun-dried cow dung after grinding process. It can be seen that the lowest water content value is found in -80 mesh of particle size with the value of 7.95% bw, while the highest water content is found in -20+40 mesh of particle size with the value of 12.20% bw. The smaller of the powder size, the higher particles density, so that the water inside particle difficult to be evaporated. Bahri (2008) stated that the higher the density, the cavity of bio-briquette particles will higher, because the particles are collected and the empty space which is filled with moisture becomes smaller [17]. CDBs that have low density are more easily absorb water from the ambient [18].

### 3.2. Height Depreciation and Mass Depreciation of CDBs

Height depreciation is the reduction in height of the cow dung powder in the cylinder die before and after pressing process. Whereas, mass depreciation is the reduction in mass of cow dung powder before and after pressed into CDBs. Data of height and mass depreciation are listed in Table 2.

| Tyler Mesh | Particle Size (mm) | Weight (kg) | Fraction (%) | Water Content (%) bw |
|------------|--------------------|-------------|--------------|----------------------|
| + 20       | d ≥ 0.840          | 1.74        | 8.85         | -                    |
| -20 +40    | 0.420 ≤ d ≤ 0.840  | 4.17        | 21.21        | 12.20                |
| -40 +60    | 0.250 ≤ d ≤ 0.420  | 4.14        | 21.06        | 10.86                |
| -60 +80    | 0.177 ≤ d ≤ 0.250  | 4.76        | 24.21        | 9.05                 |
| -80        | d ≤ 0.177          | 4.85        | 24.67        | 7.95                 |
| Total      | -                  | 19.66       | 100.00       | -                    |

The highest height depreciation is occurs on -20+40 mesh of particle size with 4 tons of hydraulic pressure. Whereas, the biggest mass depreciation was experienced by the particle size of -40+60 mesh with the hydraulic pressure of 2 tons. The irregularity of mass depreciation occurs because there is a portion of the mass of cow dung lost during the pressing process, especially at the first time of the piston contacted with the cow dung powder. The cow dung will be attend pressed out of the mold.

### 3.3. Density, Water Content, and Compressive Strength of CDBs

Density is the ratio of weight and volume of CDBs. The density is influenced by the size and homogeneity of the powder size. The density of CDBs of each pressure are shown in Table 3.

In Table 3, it can be seen that the differences of density of cow dung powder before and after briquetting. The density of cow dung increase due to the increasing of hydraulic pressure that decrease the volume of pressed cow dung. CDBs with 4 tons pressed and -80 mesh of particle size has the highest density value or more dense than others, which is 0.9924 g/cm³. Whereas, CDBs with 2 tons pressed and -20+40 mesh of particle size has the lowest density value of 0.5800 g/cm³. This is because in the briquetting process, bio-briquette with a greater pressure and smaller particle size has a tendency for the CDBs pores to be smaller which causes the bio-briquette volume to decrease and so the density will increase. Based on bio-briquette quality standards according to SNI 01-6235-2000, the acceptable
of density value for bio-briquette is 0.447 g/cm³, so that all of the produced CDBs in experiment have met the SNI quality standard.

Water content measurement of CDBs’ on various particle size and hydraulic pressure are also shown in Table 3. It can be seen that the CDBs with -80 mesh of particle size and 4 tons hydraulic pressure has the lowest water content, which is 3.86\%bw. While, the CDBs with -20+40 of particle size and hydraulic pressure of 2 tons has the highest water content of 7.97\%bw. Sudiro (2014) stated that bio-briquette has hygroscopic properties in which this property causes the bio-briquette to adsorb and release water to adjust to its environmental conditions [21]. The ability of adsorption and desorption relates to amount of water content. It possibly change depend on the water content in bio-briquette after pressing and level of humidity of ambient.

Water content affects the quality of bio-briquette and it is expected to be as low as possible. Lower water content will lead the higher of calorific heating value and the material will be easy to ignite. Based on the bio-briquette quality standard SNI 01-6235-2000, all of produced bio-briquette in experiment have met SNI quality standards which is not more than 8\%bw.

### Table 3. Density, Water Content, and Compressive Strength of CDBs

| Particle Size (mesh) | Density of Cow Dung Powder (g/cm³) | Hydraulic Pressure (ton) | Density of CDBs (g/cm³) | Water content of CDBs (%bw) | Compressive Strength (kg/cm²) |
|----------------------|-----------------------------------|--------------------------|------------------------|-----------------------------|-------------------------------|
| -20 +40              | 0.2817                            | 2                        | 0.5800                 | 7.97                        | 20.0                          |
|                      |                                   | 3                        | 0.6981                 | 7.51                        | 152.0                         |
|                      |                                   | 4                        | 0.7437                 | 7.19                        | 171.3                         |
| -40 +60              | 0.3654                            | 2                        | 0.6464                 | 8.61                        | 10.7                          |
|                      |                                   | 3                        | 0.7292                 | 6.62                        | 76.4                          |
|                      |                                   | 4                        | 0.7860                 | 6.35                        | 131.7                         |
| -60 +80              | 0.5701                            | 2                        | 0.6503                 | 5.94                        | 10.2                          |
|                      |                                   | 3                        | 0.7658                 | 5.74                        | 38.4                          |
|                      |                                   | 4                        | 0.8485                 | 5.39                        | 75.0                          |
| -80                  | 0.6799                            | 2                        | 0.8334                 | 4.37                        | 0.9                           |
|                      |                                   | 3                        | 0.9138                 | 4.04                        | 9.6                           |
|                      |                                   | 4                        | 0.9924                 | 3.86                        | 14.9                          |

The value of the compressive strength of bio-briquette depends on the particle size as constituent particles and the strength of the briquette. The smaller of the particle size will cause the higher of the density and if it is exposed to a little pressure it will be easily destroyed. Meanwhile, the larger of the particle size will cause the lower of the density and if it is exposed to a pressure it will be solidify first and will not break easily. The greater of the compressive strength of CDBs will cause the bio-briquette more compact and more solid. This causes the CDBs to be difficult to disintegrate. CDBs with particle size of -20+40 mesh and 4 tons hydraulic pressure has the highest compressive strength of 171.3 kg/cm². While, the CDBs with -80 mesh of particle size and 2 tons of hydraulic pressure has the lowest value of 0.9 kg/cm².

Based on the bio-briquette quality standards according to SNI 13-4931-2010, the minimum compressive strength value for bio-briquette is 6 kg/cm², only one sample of CDBs in the experiments does not meet the standard SNI quality which is CDBs with -80 mesh of particle size and 2 tons hydraulic pressure.

#### 3.4. Proximate Analysis and Calorific Heating Value of CDBs

The results of the proximate analysis and the calorific heating value measurements of CDBs are shown in Table 4.

High moisture content in briquettes will make briquettes difficult to ignite. This is because energy will be used first to evaporate water in briquettes. Based on Table 5, the resulting briquettes have relatively low water content so that it facilitates the ignition.

The ash content of bio-briquettes will have increasing tendency of small particle size [21]. Cow dungs with high density will produce charcoal with high bonded carbon values and low ash content and moisture content [22]. Ash content are expected to be as low as possible, because high ash content...
will reduce heat values and slow down the rate of combustion process. The amount of ash in the CDBs tends to increase, because water and other flammable substances will come out or evaporate during drying and pyrolysis stage, thereby reducing the mass of material [21]. Based on Table 4 it can be seen that the smaller of the particle size, the greater of ash content.

**Table 4. Proximate Analysis and Calorific Heating Value of CDBs**

| Particle Size (Mesh) | Hydraulic Pressure (ton) | Water Content (%) | Ash Content (%) | Volatile Matter (%) | Fixed Carbon (%) | Calorific Heating Value (cal/g) |
|----------------------|--------------------------|-------------------|----------------|--------------------|-----------------|---------------------------------|
| -20 +40              | 2                        | 4.36              | 30.51          | 49.62              | 15.50           | 3,325.015                      |
|                      | 3                        | 5.84              | 32.02          | 52.27              | 9.87            |                                 |
|                      | 4                        | 6.39              | 29.99          | 52.01              | 11.62           |                                 |
| -40 +60              | 2                        | 3.36              | 36.86          | 49.34              | 10.43           | 3,243.454                      |
|                      | 3                        | 2.67              | 36.36          | 51.30              | 9.67            |                                 |
|                      | 4                        | 2.81              | 37.24          | 47.75              | 12.20           |                                 |
| -60 +80              | 2                        | 3.25              | 39.70          | 48.11              | 8.93            | 3,046.380                      |
|                      | 3                        | 3.38              | 41.63          | 43.89              | 11.10           |                                 |
|                      | 4                        | 2.39              | 42.52          | 43.76              | 11.33           |                                 |
| -80                  | 2                        | 3.87              | 57.88          | 32.82              | 5.43            | 2,928.826                      |
|                      | 3                        | 4.63              | 54.95          | 31.77              | 8.65            |                                 |
|                      | 4                        | 4.23              | 55.33          | 32.39              | 8.04            |                                 |

In the smaller particle size of bio-briquette, the lower volatile matter is obtained. This is probably caused by volatile matter content in CDBs which is evaporated and flamed at maximum pyrolysis temperatures [23]. As a result, at the interval time of measurement, it is obtained that CDBs has low volatile matter content compared to charcoal briquette quality criteria.

Fixed carbon is fraction of atomic carbon (C) that is bound in charcoal briquettes in addition to the water, ash, and volatile matter fractions. The value of the bounded carbon content was obtained by substracted the weight of sample with the amount of water content, ash content, and volatile matter content. Bounded carbon is a solid fuel that is left in the furnace after the volatile material is distilled. In terms of particle size, the smaller of the particle size, the lower of the bounded carbon content [21]. Based on Table 4, it can be seen that the smaller of the particle size, the lower of the value of bounded carbon.

The calorific heating value of CDBs is between 2,928.826 until 3,325.015 cal/g. The value has not met the quality standards and characteristics of briquettes because it is less than 5000 cal/g (SNI 01-6235-200). The biggest calorific heating value was obtained from bio-briquette of -20 +40 mesh of powder size. It is noted that the SNI standard is dedicated for charcoal briquettes. Besides water content, calorific heating value is also affected by the ash content. The lower of the ash content there is tendency higher the calorific heating value. According to Saputro et al., (2012), calorific heating value is also influenced by the levels of carbon bound, in which the higher of the level of carbon bound, then the higher the calorific heating value. Compared with the peat briquette calorific heating value of 4,103.91 - 6,183.22 cal/g and sengon wood briquette of 4,274 cal/g, the calorific heating value of CDBs has not been able to compete with its quality.

4. Conclusions
1. Based on the research that has been carried out, the produced of CDBs have largely met SNI 01-6235-2000 and SNI 13-4931-2010 in terms of density, moisture content, and compressive strength.
2. Based on the proximate analysis, the produced CDBs does not meet the standards of SNI 01-6235-2000 in terms of ash content and volatile matter content.
3. The calorific heating value of produced CDBs is ranging in 2,928.826 - 3,325.015 cal/g depend on the particle size of cow dung.
4. Based on physical characteristic, the best CDBs was made from -20+40 mesh of particle size and 4 tons hydraulic pressure.
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References

[1] Badan Pusat Statistik, 2017, *Populasi Sapi Perah di Indonesia Menurut Provinsi Tahun 2009-2016*, Jakarta: Badan Pusat Statistik

[2] Surya U., 2012, Pemanfaatan Biomassa Limbah Jamur Tiram sebagai Bahan Bakar Alternatif untuk Proses Sterilisasi Jamur Tiram, Turbo: ISSN 2301-6663 Vol. 2 No. 2 Hal 17-22, Metro: Fakultas Teknik Universitas Muhamadiyah Metro

[3] Sunaryo, dan Wahyu W., 2014, Penelitian Nilai Kalor Bahan Bakar Biomassa pada Limbah Kotoran Hewan, Jurnal Apekt, Vol. 6 No. 1 Hal: 87-95

[4] Huda S., dan Wiwik W., 2017, Pemanfaatan Limbah Kotoran Sapi Menjadi Pupuk Organik Sebagai Upaya Mendukung Sapi Potong di Kelompok Tani Mandiri Jaya Desa Moropelang Kec. Babat Kab. Lamongan, Aksiologiya: Jurnal Pengabdian Kepada Masyarakat, Vol.1 No.1 Februari 2017 Hal: 26 – 35

[5] Sahidu S., 1983, Kotoran Ternak Sebagai Sumber Energi, Jakarta: Dewaruci Press

[6] Harpasis dan Rahardjo, 1980, *Pemanfaatan Limbah Sembur Energi*, Bogor: Institut Pertanian Bogor

[7] Suryanto, 1993, Pemanfaatan Limbah Sembur Energi, Jakarta: Dewaruci Press

[8] Haygreen dan Bowyer, 1989, *Hasil Hutan Dan Ilmu Kayu Suatu Pengantar*, Alih Bahasa Surjipto A. Hadikusumo, Yogyakarta: Gadjah Mada University Press

[9] Yuwono, J., 2009, *Pengaruh Penambahan Bahan Pemula Pada Briket Arang Dalam Mengurangi pencemaran lingkungan di Nangroe Aceh Darussalam*. (Thesis). Program Pendidikan Pasca Sarjana: USU Medan

[10] Lindley, J. and Vossoughi, M., 1989, *Physical Properties of Biomass Briquettes. Transaction of the ASAE*. Vol 32(2) pp 361-366

[11] Fung, D., & Wegener, G., 1995, *Kayu Kimia Ultrasruktur Reaksi Kimia*, Gadjah Mada University Press, Yogyakarta

[12] Moelyadi, 2008, *Pemanfaatan Limbah industri kayu untuk pembuatan briket arang dalam mengurangi pencemaran lingkungan di Nangroe Aceh Darussalam*. (Thesis). Program Pendidikan Pasca Sarjana: USU Medan

[13] Nurhayati, T. & Adalina, Y. (2007). Analisis teknis dan finansial produksi arang dan cuka kayu dari limbah industri penggaraman dan pemanfaatannya. Jurnal Penelitian Hasil Hutan, 27 (1), 374 – 380.

[14] Patabang D., 2012, *Karakteristik Termal Biobriket Arang Sekam Padi dengan Variasi Bahan Perekat*, Jurnal Mekanikal, Vol. 3, No. 2, Hal: 286-292, Palu : Fakultas Teknik Universitas Tadulako
[21] Sudiro, dan Suroto S., 2014, Pengaruh Komposisi Dan Ukuran Serbuk Biobriket Yang Terbuat Dari Batubara Dan Jerami Padi Terhadap Karakteristik Pembakaran, Surakarta: Politeknik Indonusa Surakarta

[22] Sudradjat, R., 2001, The Potential of Biomass Energy Resources in Indonesia for the Possible Development of Clean Technology Process (CPT), Laporan Penelitian, Jakarta.

[23] Suryaningrat I.B., Dan Taruna I., 2015, Pemanfaatan Kotoran Sapi Sebagai Bahan Bakar Alternatif Pada Proses Pembakaran, Jember: Fakultas Teknologi Pertanian Universitas Jember