THE EFFECTS OF PARTICLE SIZE AND PRESSUREON THE COMBUSTION CHARACTERISTICS OF CERBERA MANGHASLEAF BRIQUETTES

Sutrisno[1,2], Willyanto Anggono[1,2], Fandi Dwi Suprianto[1,2], Andreas Wijaya Kasrun[1] and Ian Hardianto Siahaan[1]
[1]Mechanical Engineering Department, Petra Christian University, Surabaya, Indonesia
[2]Centre for Sustainable Energy Studies, Petra Christian University, Surabaya, Indonesia
E-Mail: tengsutrisno@petra.ac.id

ABSTRACT

CerberaManghas is a plant that is often used as urban greening so that this plant has the potential to be developed into a source of alternative fuel in Indonesia. The material of solid fuel briquette is waste leaves of *CerberaManghas* tree and tapioca flour are used as binder material. The composition of this briquette is 10% mass of tapioca flour and 90% mass of *CerberaManghas* waste leaves. The highest heating value (HHV) of this briquette is 4167 Kcal/kg. The particle size of this briquette affects the physical and burning characteristics. This optimizes research particle size and pressure of the press machine during the briquette forming process. The two parameters were evaluated for the combustion characteristics include Flame temperature, Ignition timing, Burning time, and Combustion rate. The higher value of flame temperature, ignition time and burning time are caused by the greater the hydraulic pressure. Besides better the briquettes'quality are obtained the smaller of combustion rate, so that the briquettes are more durable and required the ignition time length. The best briquettes of Cerbera Manghas leaves are those with particle size of 60 mesh and forming pressure of 2 MPa, which have a flame temperature of 522 °C, an ignition time 268 second, a burning time of 7293 second, and a combustion rate of 0.0026 gr/s.

Keywords: cerbera manghas, briquettes, renewable energy, green energy.

1. INTRODUCTION

Green energy is an energy source that has potential to be developed as future energy. Green energy for power generation is always done in a natural process, so as to prevent environmental damage. This energy is used raw materials derived from nature, such as waste oil, natural gas, animal waste, organic material, solar energy, tidal energy, wind energy, and sea wave energy. During the dry season in tropical climate zones, the wastes leaf scattered on the road and has potential to become urban waste. This brings the idea to utilize the wastes, since the waste leaf could potentially use as briquettes raw material. *CerberaManghas*/*Odollam*or Sea mango leaf is non edible, the costs of the non-edible waste cannot be obtained as they are currently not traded in the open market Gui *et al.*[2].

The usage of non-edible waste as a raw material for briquette cause production costs to be cheap, other than that the *Cerberamanghas*, especially in urban Indonesia is widely used as a plant green lining. *C*o this material is potentially to be used as one of raw material for briquette. Researchers have made the development of briquettes for household and industrial [5]. Raw materials used are such as almond leaves, ash wood and coconut fibers.

Several previous studies in briquette, employed edible materials such as those developed by Sellin *et al*[7]. The sections of banana tree which can be used as raw material for briquettes are leaf and presudostem. The utilization of edible material could be directly used by humans, while for non-edible needed detail analysis of the substances. The High Heating Value (HHV) for that briquette is (HHV) 17.7 MJ/kg and 14.9 MJ/kg.

The chemical structures in the Sea mango leave contain toxins. According to Po *et al.* [4], the chemical structures of *CerberaManghas* leaves are p-Hydroxybenzaldehyde, Benzamide, n-Hexadecane acid Monoglyceride, Oliolide, β-Sitosterol, Cerberin, Neriifolin, Cerleaside A, Daucosterol. Of the nine content of the above, there is a toxic substance namely Cerberin.
The chemical formula of Cerberin has the same chemical formula as alcohol, and its configuration is $C_{32}H_{48}O_9$. A study conducted by Chopra 0 was experimenting with the effect of Cerberin consumption by living things. It turned out that with a certain dose as much as 1.8 mg / kg in dogs and 3.1 mg / Kg in cats, Cerberin could cause death to the creatures. If a small dose of Cerberin can cause death to animals, then cerberin could also cause death if consumed by humans

According to the Regional Fruit Research Station, [6], the production of CerberaManghas needed operational costs between 360-690 (USD / ha) which is almost equivalent to the production of Jatropha 620 (USD/ ha). The production of jatropha oil in Indonesia is still not effective because the energy used during extraction process is greater than the amount of oil produced; therefore this oil is still not feasible for mass production.

Improvement in briquettes combustion process could be done by reducing the amount of CO_2 that acts as an inhibitor in external premix combustion [8]. In addition, increasing the turbulence of the flow could reduce energy loss in the flow [9]so as to improve the combustion process. This method is similar to increasing the flow swirl into the combustion process.

Research on *Cerberamanghas*as one of the non-edible material is indispensable in the development of

VOL. 12, NO. 4, FEBRUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

green energy, which is one component of renewable energy. In addition to that, this research seeks the extent of utilization of *Cerberamanghas* other than as green line plants in urban areas, and explores its potential to become one of alternative raw materials for Briquetting. The part of CerberaMang has that is mostly used is the fruit only. Fruit of the *CerberaManghas* is used as the raw material.

The utilization of *Cerberamanghas* as the briquette raw material has been raised by Anggono *et al.* [10].This briquette has a Higher Heating Value (HHV) of 4287.53 Kcal / kg or 17.95MJ / kg. This value is slightly higher than the HHV of banana leaves obtained by Sellin *et al.* [7]. This research would optimize particle size and pressure of the press machine during the briquette forming process. The two parameters were evaluated for burning characteristics includesFlame temperature, Ignition timing, Burning time, and Combustion rate.

2. METHODOLOGY

The flowchart in Figure-1 shows the research methodology. This research starts from literature review about briquette and *Cerberamanghas* leaves as the base material. Then the research collects fallen leaves on the urban road. The process is continued by drying *Cerberamanghas* leaves to remove their water content. The results of this process are followed by the grinding process in accordance with the size of wire mesh. The particle size of the powdered Sea mango leaves depends on the size of wire mesh.

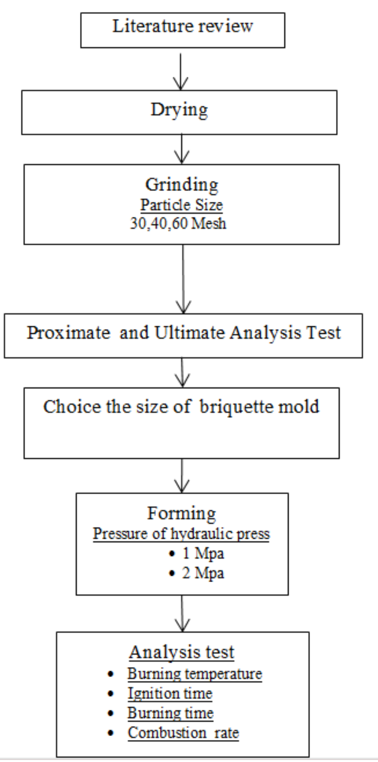

Figure-1. Research methodology flowchart.

Figure-2 shows the particle size variation of *CerberaManghas* leaves. The material particle size is smaller when used with large wire mesh. Third different particle sizes are prepared, i.e. more than 60 mesh (smaller than 250 μm), 40 mesh (smaller than 425 μm), and 30 mesh (smaller than 600 μm).

Variations in the size of the mesh were used to determine the right particle size, which would yield the best briquette quality in terms of its physical strength and its burning characteristics. Figure-2 shows the difference in particle size from the size of 30, 40 and 60 mesh. Before the forming process was performed, each powder of different mesh had been tested using proximate and ultimate analysis.

The process of forming briquettes made by mixing the raw material with adhesive. The material mixture is then inserted in the briquettes mold shown in Figure-3. Briquette's mold size has a diameter of 25 mm. Once the briquette is inserted into the mold, then it is pressed with a hydraulic machine. The hydraulic pressure was set with a variety of 1 and 2 MPa. It was observed that if the hydraulic pressure is more than 2 MPa, then the mold would be damaged.

Figure-2. Particle size variatoin of Cerberamaghas leaves.

Furthermore, these briquettes are evaluated for their burning characteristics. Burning temperature is the surface temperature reached by the time of burning briquettes. Measuring instruments used were thermocouples and infrared laser. Ignition time is the time needed to ignite each briquette from the start of ignition until it is burned continuously. The time duration was recorded using a stopwatch. Burning time is the time taken for each briquette to burn completely to ashes. The two parameters were measured using stopwatch. Combustion rate is defined as how quickly or slowly the reaction takes place. The reaction is expressed by the change in mass of briquettes from beginning to end, where the final mass equal to the mass of ash.

ARPN Journal of Engineering and Applied Sciences

Figure-3. Briquettes mold.

3. RESULTS AND DISCUSSIONS

The most effective briquettes are those with a composition of 90% raw material and 10% binder. The HHV of briquettes form *CerberaManghas* leaves without carbonization process is 4164 Kcal / Kg with 12.2 wt.% of water content. If the briquettes have been through the carbonization process, then the heating value will increase. The decrease in water content will also affect the flame speed of the briquettes, because the lower the moisture content in the briquettes, the faster the ignition process will be. The moisture content had a significant influence on the composition's proximate analysis results. In Table-1 above, there are two columns, As Received and Dried Basis. As Received testing means the proximate analysis based on materials that have been received at the time of the test, without applying the drying process in the first place. Whereas in Dried Basis, the drying process was applied to remove moisture (Moisture Content) on the material, before the proximate analysis was done. The analysis result shows that the heating value in As received and Dried basis are consecutively 4164 Kkcal / Kg and 4742 KKcal / Kg. Comparison of the heating values resulted from proximate analysis with different basis indicates that the moisture content affects the proximate results.

Volatile matter in the leaves is 66.8% of the total mass. The highly volatile matter content in dry *Cerberamanghas* leaves indicates that the material can be burnt easily. In fact, this value is relatively high compared to the value of fixed carbon. So it can be said that dry CerberaManghas leaves are flammable material, as the fixed carbon is a component that is difficult to burn. The briquettes of CerberaManghas leaves have a value of only 12.4 wt.% fixed carbon. The ash content is the ash that remains after the combustion process. Ash content contained in the leaves are not too high, it even can be said that they have relatively low ash content. Having a small number of ash content is one of the criteria of a good fuel.

Table-1. Proximate analysis [10].

Proximate analysis	Unit	Value	Test method
Total Moisture	%wt	12.2	ASTM D 2961-11
Ash Content	%wt	8.6	ASTM D 3174-12
Volatile Matter	%wt	66.8	ASTM D 3175-11
Fixed Carbon	%wt	12.4	ASTM D 3172-13
Total Sulfur	%wt	0.19	ASTM D 4239-14e1
Gross Heat Value	Kcal/kg	4164	ASTM D 5865-13

The results of ultimate analysis obtained levels of the chemical elements such as C, H, O, N and S. The most important elements in combustion are element of C and H. In the chemical reaction, the C elements together with oxygen act as a reactant to produce CO_2. CO_2 is a combustion product which is released back to the surrounding air after the combustion process. The higher the percentage of C content in Fuel, the heating value will also be higher. Element H together with oxygen acts as reactant will produce H_2O after the combustion process. Element H is also used as a parameter of heating value calculation and a parameter in calculating the moisture content. O element in the fuel indicates the oxygen content in the fuel, and it is used as an indicator of how easy to ignite the fuel. While elements N and S, are elements which cause pollution in combustion because these elements can react with the surrounding air and producing NO_x and SO_x. The amount of elements N and S from the result of laboratory analysis are consecutively 0.45% and 0.19%. The results of ultimate analysis are shown in table 2. In an experiment conducted by Raju *et al*[5], it was said that the pollution of fuel combustion would not be dangerous if the amount of N and S in the fuel does not exceed 1 wt.%. This is due to the lesser amount of NO_x and SO_x produced from combustion when there are not much N and S in the reactant.

Table-2. Ultimate analysis[10].

Ultimate analysis	Unit	Value	Test method
Carbon	%wt	40.37	ASTM D 5373-14
Hydrogen	%wt	5.17	ASTM D 5373-14
Nitrogen	%wt	0.45	ASTM D 5373-14
Sulfur	%wt	0.19	ASTM D 4239-14e1
Oxygen	%wt	33.01	ASTM D 3176-15

 ISSN 1819-6608

ARPN Journal of Engineering and Applied Sciences

Briquettes are formed by pressure and a certain particle size. Raw materials are sifted to particle size of 30 mesh 40 mesh, and 60 mesh. Hydraulic pressure variation begins with 1 MPa (10 bar) up to 2 MPa (20 bar). Smaller particle size gives benefit in increasing physical strength of the briquette. This is due to the greater ability of additive to bind the smaller sized particles. Figure-4 shows the physical appearance of briquettes, each with hydraulic pressure 2Mpa. Based on the figure, the briquettes with particle size of 20 Mesh cannot be formed completely because the structure is too fragile. Raw materials with particle size of 20 mesh cannot be used as briquette because they will be crumbled, both in hydraulic pressure 1 and 2 MPa. The Briquettes are produced with a pressure of 2 MPa have a better shape compared to those with a pressure of 1 MPa.

Figure-4. Briquette from *Cerberamanghas* leaves.

Figure-5 shows that the smaller the particle size, the higher the flame temperature of briquettes. Thus, a higher forming pressure will correspondingly increase the flame temperature. Experimental data with a particle size of 60 mesh and a pressure of 2 MPa shows the highest the flame temperature of 522 ° Celsius.

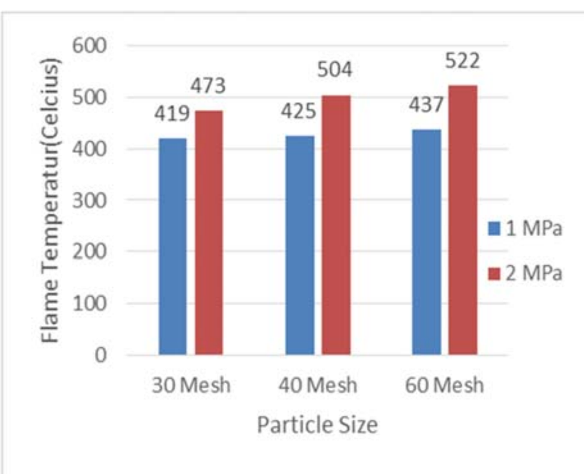

Figure-5. Flame temperature characteristics.

Figure-6 shows the effect of particle size on the ignition time. Based on the figure, the smaller the particle size of raw material, the longer the ignition time of briquettes. The pressure also affects the duration of briquettes' ignition time. The higher the pressure, the longer the ignition time of briquettes. It can be seen in the figure that briquettes with a particle size of 60 mesh and hydraulic pressure of 2 MPa have the longest ignition time, which is 268 seconds.

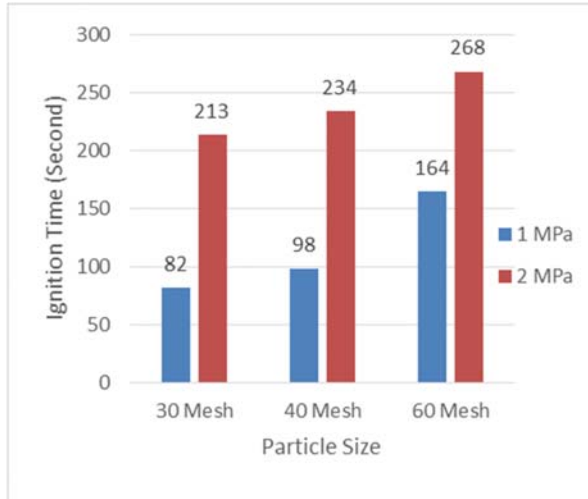

Figure-6. Ignition time characteristics.

Figure-7 shows the effect of particle size to the burning time value. Raw materials with a smaller particle size will have a longer burning time. Similarly to the pressure, the greater the hydraulic pressure than the combustion duration will be longer. In the figure, briquettes which have the longest burning time of 5821 seconds are those with a particle size of 60 mesh and the hydraulic pressure of 2 MPa.

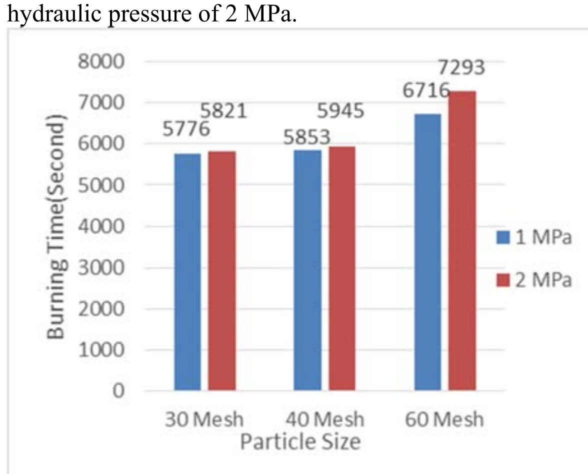

Figure-7. Burning time characteristics.

Figure-8 shows the effect of particle size on combustion rate. Based on the figure, it can be concluded that combustion rate will be higher if the particle size is greater, and when the pressure is lower. In the graph, the lowest firing rate is produced by briquettes with a particle size of 60 mesh and with the hydraulic pressure of 2 MPa.

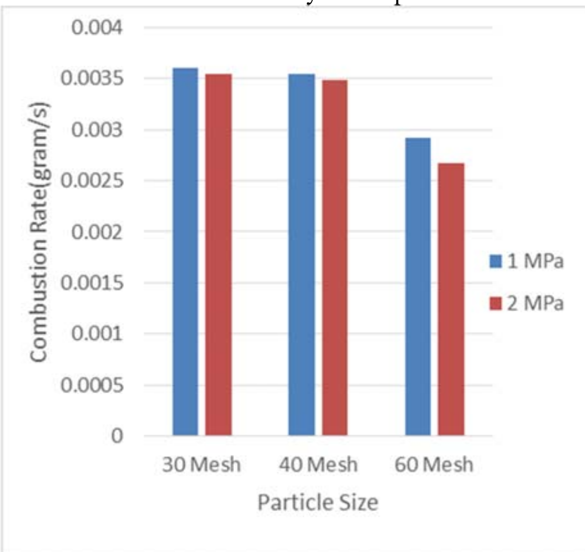

Figure-8. Combustion rate characteristics.

This *CerberaManghas* of leaves briquettes have a reasonably high heating value that can be compared with other briquettes. Figure-9 shows a HHV comparison chart of Cerberamanghas leaves briquettes and other briquettes made of different materials. All data other than the CerberaManghas leaves briquettes are based on research conducted by Lela *et al*[3]

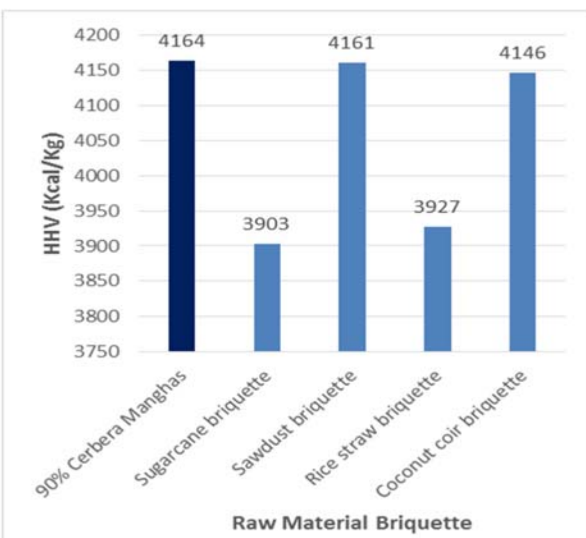

Figure-9. Compore HHV with others briquette [3].

The heating value of CerberaManghas leaves briquette has the potential to be a good quality briquette. This is due to the relatively high value of its HHV compared to the HHV of other briquettes. The HHV of CerberaManghas leaves briquette is approximately equal to the HHV of sawdust and coconut coir. Sawdust has a value of 4161 HHV Kcal / kg, and coconut coir has HHV value of 4146 Kcal / kg. While the medium quality briquettes such as rice straw and sugarcane that has a value HHV of 3927 and 3903 Kcal/gr. Therefore, the results suggest that the *CerberaManghas* leaves briquettes have good quality and have the potential to be developed into mass production.

4. CONCLUSIONS

The highest HHV result of briquettes made of *Cerbera manghas* leaves was obtained at the composition of 90% mass of *Cerbera Manghas*waste leaves and 10% mass of tapioca flour. The particle size of more than 30 Mesh (smaller than 600 μm) has been failed to be molded and hence could not be used as briquette material. The effect of particle size on the briquette was found that the smaller the particle size, the better the briquettes' quality. The effect of the hydraulic pressure in the briquette was found that the greater the pressure, the better the briquettes' quality. The effect of hydraulic pressure that occurs is opposite to the particle size.The higher value offlame temperature, ignition time and burning time are caused by the greater the hydraulic pressure. Besides better the briquettes'quality are obtained the smaller of combustion rate, so that the briquettes are more durable and required the ignition time length. The best briquettes of CerberaManghas leaves are those with particle size of 60 mesh and forming pressure of 2 MPa, which have a flame temperature of 522 °C, an ignition time 268 second, a burning time of 7293 second, and a combustion rate of 0.0026 gr/s.

ACKNOWLEDGEMENTS

The authors wish to thanks to the Ministry of Research, Technology and Higher Education, Republic of Indonesia through the Research Grant Programs and Faculty of Industrial Technology, Petra Christian University Surabaya for their supports.

REFERENCES

[1] Chopra R.N. and I.C. Chopra. 1933. Indigenous Drugs of India, Kolkata, India: Academic Publishers. pp. 316-318, ISBN 818508680X,

[2] Gui M. M., Lee K. T., Bhatia S.2008. Feasibility of edible oil vs. non-edible vs. waste edible oil as biodiesel feedstock. Energy. 33, pp.1646-1653.

[3] Lela B., Barišić M., Nižetić S.2016. Cardboard/sawdust briquettes as biomass fuel: Physical–mechanical and thermal characteristics, Waste Management: Refuse Derived Fuel/Solid Recovered Fuel. 47: 236-245.

[4] Po Z. X., Hu P. Y., Sheng L. M., Li K. S., Qing Z. J. 2010. Chemical constituents from the leaves of Cerbera manghas. Asia Pacific Journal of Tropical Medicine. 109-111.

ARPN Journal of Engineering and Applied Sciences

[5] Raju Ch. A. I., Jyothi K. R., Satya M. and Praveena U. 2014. Studies on Development of Fuel Briquettes for Household and Industrial Purpose. International Journal of Research in Engineering and Technology Vol. 3, ISSN :2319-1163, 54-63.

[6] Regional Fruit Research Station, Vengurle. PJ. Kshirsagar, G.M. Waghmare.Mango varieties in Konkan region. Report, March 1999. http://www.indiaagronet.com/indiaagronet/Research%20Update/contents/mango_varieties_in_konkan_region.htmS.

[7] Sellin N., Bianca. G, Marangoni C., Souza O., Pedro N., Novais T. M. 2013. Use of Banana Culture Waste to Produce Briquettes. Chemical Engineering Transactions. Vol. 32. ISSN 1974-9791, 349-354.

[8] Suprianto F.D., Anggono W., Tanoto M.S.C.2016. Effect of carbon dioxide on flame characteristics in biogas external premix combustion, International Journal of Applied Engineering Research. Vol. 11. ISSN 0973-4562, pp. 2240-2243.

[9] Sutrisno Mirmanto H., Sasongko H., Noor D.Z. 2015. Study of the secondary flow structures caused the addition forward facing step turbulence generated: Case study: Horseshoe vortex between 9C7/32.5C50 body and endwall, Advances and Applications in Fluid Mechanics. 18: 128-144.

[10] Anggono W,. Suprianto F. D., Sutrisno, Kasrun A. W.2016. Investigation on Biomass Briquette as Energy Source from Waste Leaf Cerbera Manghas. Internasional Journal of Industrial Research and Applied Engineering. 1: 11-14.