CHEMICAL ENGINEERING TRANSACTIONS
VOL. 56, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Jiří Jaromír Klemeš, Peng Yen Liew, Wai Shin Ho, Jeng Shiun Lim
Copyright © 2017, AIDIC Servizi S.r.l.,
ISBN 978-88-95608-47-1; **ISSN** 2283-9216
DOI: 10.3303/CET1756278

Biomass Briquettes using Indonesia Durian Seeds as Binder Agent: The Effect of Binder Concentration on the Briquettes Properties

Rochim B. Cahyono*[,a], Joko Santoso[b], Ria Miliati[c]

[a]Department of Chemical Engineering, Gadjah Mada University (UGM) Yogyakarta, Indonesia
[b]Master Program of Engineering System (MST), Gadjah Mada University (UGM) Yogyakarta, Indonesia
[c]Departement of Food and Agricultural Technology, Gadjah Mada University (UGM) Yogyakarta, Indonesia
rochimbakti@ugm.ac.id

Biomass briquette is an energy source, available abundantly in Indonesia that can prevent world energy crisis when used in efficient ways. In the conventional system, starch from food commodities are applied in the briquettes production causing conflict of interest between energy and food consumption. Durian seeds, which are agricultural waste, contain large amount of starch especially amylose and amylopectin and have the potential as binder agent to replace conventional binder. Several tests were done on briquettes made using durian seed as the binder agent with different binder concentrations. The results show that the durian seed has potential to be utilised as binder agent due to its high shear strength properties. The physical properties of the briquettes can also satisfy standards values of commercial wood charcoal briquettes such as density, heating value, compressive strengths and shatter index.

1. Introduction

World energy demand is increasing to fulfil the energy requirement in industrial sectors and daily life. The energy supply is very limited to fossil fuel source which is unsustainable for future life (Dargay et al., 2010). To prevent the crisis, alternative energy sources must be developed and utilised in the effective ways, namely wind energy, solar energy, hydropower, bio-fuel and biomass. Utilisation of renewable energy is highly dependent on several factors such as the technology availability, society knowledge, geographical location, climate condition and availability. Indonesia is one of the countries that has the biggest potential in the biomass energy sector but the sector is still underdeveloped (Hata et al., 2009). Low income Indonesian people in the village burn the biomass directly without any treatment to get energy for cooking and small industrial processes. Biomass usually contains a high content of moisture, making it necessary to remove the moisture content before combustion for an efficient process. It is also problematic to be used as feedstock for transportation fuels because it has lower densities. Based to these reasons, direct biomass combustion is not practical. There are several technologies available to solve the problem such as pyrolysis, gasification and briquettes production.
Briquettes production means converting biomass using simple, inexpensive technology and also suitable for developing countries community. It is also beneficial for small to medium industrial scale and rural population due to its simple production system and low investment cost. Previously, several studies related to briquetting production were done by researchers. There are several biomass raw materials available for briquettes such as waste paper and wheat straw (Demirbas, 1999), mustard stalk, maize stalk, and groundnut shells (Tripathi et al., 1998), palm oil residues (Husain et al., 2002), cotton stalks and saw mill waste (Singh, 2004). The effect of pressure on the banana peel briquette was also studied (Wilaipon, 2009). During briquettes production, binder agent is needed to increase the compressive strength and shelter index. Utilisation of starch as binder agent in the conventional process caused problem related with competition between energy and food fulfilment. Several materials were proposed to solve that problem such as coal tar, petroleum residues, synthetic polymers, plastic waste, and wood pulp waste liquor with limited result. It is well known that cellulose, semi-cellulose, and lignin which are biomass components, have binding agent properties after heated or hydrolysed (Zhang et al., 2001).

Please cite this article as: Cahyono R.B., Santoso J., Miliati R., 2017, Biomass briquettes using indonesia durian seeds as binder agent: the effect of binder concentration on the briquettes properties, Chemical Engineering Transactions, 56, 1663-1668 DOI:10.3303/CET1756278

Durian is one of the favourite fruits in the Southeast Asia, especially Indonesia. This fruit has a very distinguished smell and its skin is thorny and hard. Indonesia has high production of this fruit, which was 759,055 t in 2013 (Soesilowati et al., 2016). Durian consumption generated a lot of inconsumable wastes (around 70 %) in the form of shells and seeds. Based on the chemical composition, durian shell and seeds have high amount of amylose and amylopectin which are good binder agents (Wahyono, 2009). The purposes of this paper are to investigate the possibilities of utilising durian seeds as binder agents and its effects on briquettes properties. Utilisation of durian seeds can also solve problems related to waste generation after consumption of durian fruit.

2. Materials and Methods

2.1 Materials

Durian seeds were collected from Semarang, Jawa Tengah, Indonesia. The composition analysis of durian seeds can be shown in the Table 1.

Table 1: Durian seeds composition

Components	Amounts (wt%)
Carbohydrate	67.40
Protein	6.43
Fatty acid	1.48
Sugar	4.89
Cellulose	6.15
Calcium	0.92
Phosphor	0.89
Water	11.84

Testing of the durian seed as binder agent was performed in the briquettes which were produced from mixture between coconut chars and durian chars shell. Coconut shell was collected from Boyolali, Jawa Tengah, Indonesia. The durian shell was also collected from same region with durian seeds. The proximate analysis of the briquettes raw material is listed in the Table 2.

Table 2: Proximate analysis of briquettes raw material

Biomass type	Proximate Analysis (wt%)			HHV (kJ/g)
	Volatile	Fixed C	Ash	
Coconut shell	74.87	24.42	0.71	18.098
Durian shell	41.90	47.95	10.15	15.273

2.2 Experiment methods

To produce binder agent, certain amount of durian seeds was washed and dried in the oven for milling preparation. Milling process was done to get powder form around 50 mesh. Binder agent was produced by mixing between powder and water in ratio 1 : 10 under heating in the temperature 70 °C and atmospheric pressure. Coconut and durian shells char was produced by pyrolysis under temperature 700 °C and atmospheric pressure in the reactor. These chars were milled for getting small size around 35 mesh. Briquetting experiments were performed using a hydraulic press with maximum pressure is 150 kg/cm^2. The cylindrical briquetting has inner diameter 3 cm and height 6 cm. For the experiments, briquettes were made from coconut and durian shell char in ratio 1 : 1 with variation of binder concentration 4 %, 6 %, 8 %, 10 % and 12 % (wt%). The products were dried under sunlight for testing. The overall process can be seen in the Figure 1. In order to know the performance of durian seed binder agents and the effect of the binder concentration in the briquettes properties, several standards tests were applied to determine the density, compressive strength, shatter index, heating value, and proximate analysis.

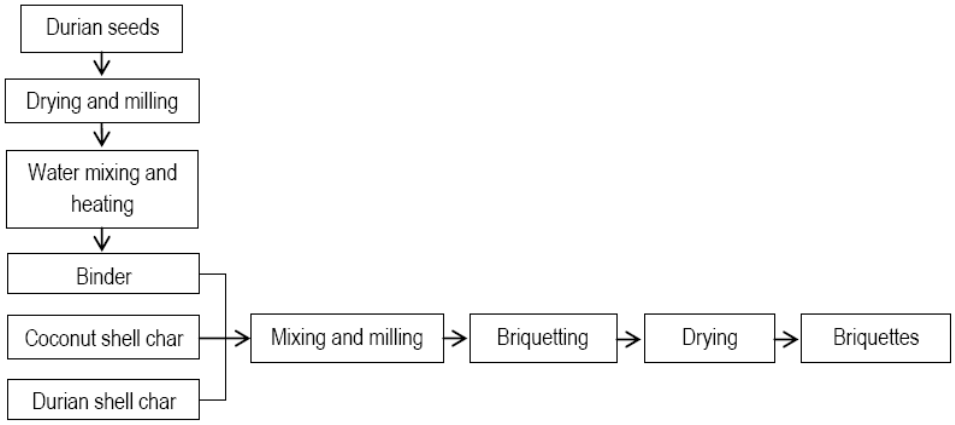

Figure 1: Experimental procedure of biomass briquettes using durian seeds as binder agent

3. Results and discussion

3.1 Prospect of durian seeds as binder agents

The main important property of the binder agents is shear strength, which is the ability of the material to resist shear force. High shear strength indicates that the binder has good performance to prevent binding material for breakaway due to certain force. To evaluate performance of durian seeds as binder agent, the shear strengths are compared with the conventional binder agent (starch powder). The result of the shear strength properties can be seen in the Table 3.

Table 3: Testing of shear strength property

Binder agents	Shear strength (kg/cm^2)
Durian seed powder	2.70
Starch powder	1.33

Durian seeds binder has higher shear strength than conventional binder, starch powder. The durian seed contains not only amylose and amylopektin but also other materials as shown in Table 1. These materials improve the strength performance. It is means that durian seeds binder produced more stable briquettes compare to starch binder. Durian seed acts as the potential prospect for binder agents.

3.2 Effects of binder concentration on briquettes properties

3.2.1 Density

Density is the ratio between the mass and volume of briquettes and would have effect on the moisture contents, ash, volatile matter and fixed carbon. High density briquettes result in high compactly, high fixed carbon and low moisture contents. The results of briquettes density testing at a variation of binder concentration were listed in the Figure 2. Briquettes density increased continuously in the high binder concentration. It as shown that more binder agents result in high compact material and less volume. According to the viscosity data, the durian seeds binder has a viscosity of around 388.33 mPa.s (starch binder 4,083.33 mPa.s). Durian seeds binder has the ability for smooth flowing over char material, resulting in high compact briquettes. The density properties also very important for transportation process, as high density briquettes give less volume for transportation.

3.2.2 Heating value

Heating values are primary indicators for commercial fuel source and is affected by the proximate component of the material. High water moisture and ash content result in low heating value while high fixed carbon content.

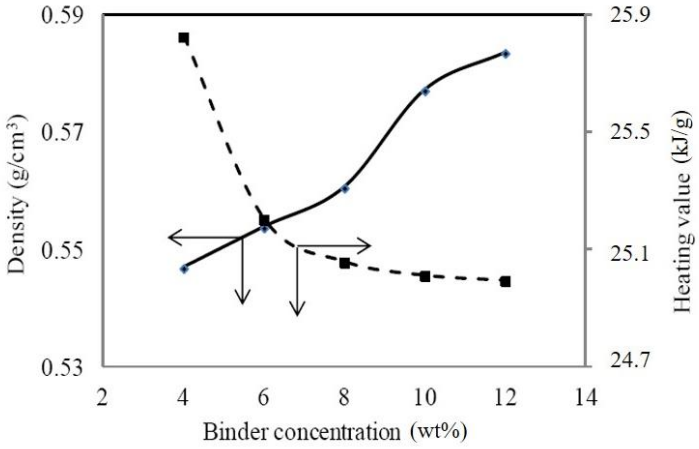

Figure 2: Density and heating value testing of durian seeds briquettes at differences binder concentration

Figure 2 shows heating value of briquettes decreased when binder concentration were changed from 4 to 8 % and remained constant after that binder concetration. High binder concentration generated more water and volatile content so the fixed carbon would decrease when total mass was kept constant. Decreasing fixed carbon means heating value was also getting lower. When the binder concentration higher than 8 %, water and volatile content had insignificant effect to the total water and volatile of the material due to saturation condition and resulted the constant heating values.

3.2.3 Compressive strengths

The ability of the material to withstand axially directed pushing forces is needed for storage and package the briquettes. This value must be as high as possible in order to get good briquettes. The flat surface of material was placed on the horizontal metal plate of the standards equipment testing. A screw was slowly reduced the distance between metal plate which was material placed and second one parallel to it. The reducing distance would give increasing load to material with constant rate until cracking or breaking. Dividing the load at the breaking point by cross sectional plane of the material would produce compressive strength. The result of this testing at binder concentration variation can be seen in the Figure 3.

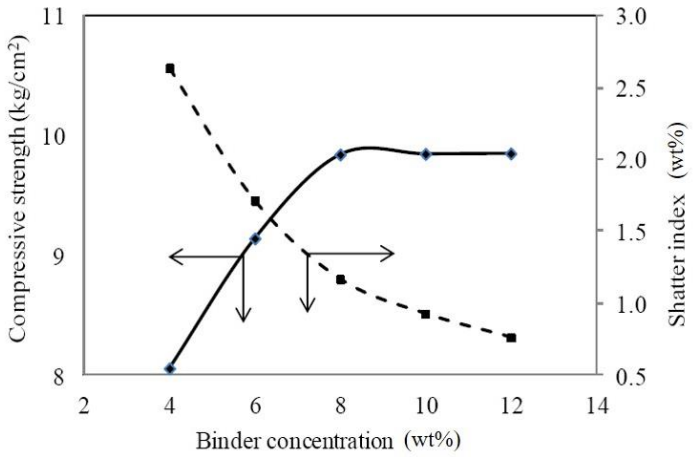

Figure 3: Compressive strength and shatter index testing of durian seeds briquettes at differences binder concentration

Figure 3 shows compressive strength increased at high binder concentration. A binder agent has function to load char pore resulting high interaction between char material. High binder agents prompt dense pore char material and increasing compressive strength properties. At binder concentration of 8 %, the compressive

strength was constant while binder concentrations were increased. It can be predicted that binder concentration reached saturation concentration so the addition of binder agent cannot increase the compressive strengths. This saturated binder concentration agrees with the result of heating value testing.

3.2.4 Shatter index

Shatter index is the percentage of material remaining on sieve equipment after the sample has been subjected to a standardised dropping procedure. This index is absolutely required to determine the storage and transportation method of the material. The value must be as lower as possible to get good briquettes. The standard methods for the testing is dropping each material from a height of 180 cm onto a steel plate and measuring the percentage of the sample retained on the sieve having an opening of 20 mm (ISO 616, 1995). Figure 3 shows shatter index decreased continuously in while binder concentrations were increased. Binder agent would be distributed smoothly in the char material and lead char material distance reduced. When the distance reduced, char particle bonding would be stronger resulting lower shatter index.

3.2.5 Proximate analysis

Briquettes quality is most determined by proximate compositions such as volatile matter, ash content, fixed carbon and water moisture. Based on Indonesia National Standards, SNI 01-6235-2000 (National Standardization Agency of Indonesia, 2000), the proximate analysis was done.

Table 4: Proximate analysis of briquettes in different binder concentrations

Binder concentration (wt%)	Proximate Analysis (wt%) (Wet basis)			
	Volatile	Fixed C	Ash	Water
4	7.79	75.92	10.99	5.31
6	8.19	75.43	10.88	5.50
8	8.79	75.02	10.45	5.74
10	9.13	74.59	10.36	5.92
12	9.54	74.29	9.94	6.23

The purpose of the briquettes process is to get high fixed carbon fuel. Table 4 shows fixed carbon content was slightly decreased due to increasing of binder concentration. Durian shell and seeds has lower fixed carbon compare to coconut shell. High binder concentration resulted low fixed carbon because of binder agent made from durian seed. The water content increased simultaneously with binder concentration. At the beginning, binder agent contains more water that char briquettes material due to the water mixing of the powder binder agent. Mixing process of char and binder agent cause water particle detained in the char pore material so water content would be high. Ash content consist some components such as calcium, potassium, magnesium and silica. High ash content would reduce fixed carbon and heating value. Using this property, combustion furnace operation and the emission of briquette combustion can be predicted. In the binder concentration variation range, ash content is almost similar. According to the ash content fuel standard, the value was still high. Based on Table 2, durian shell contained higher ash compare to coconut shell. As the experimental procedure, briquettes were made from mixing between coconut and durian shell char in the ratio 1 : 1 so the products have high ash content. In order to clarify this reason, experiment with different ratio of coconut and durian shell char was done in the ratio 3 : 1 (coconut to durian shell chars) with binder concentration 10 %. The ash content decrease from 10.36 to 5.95 %, it agrees with the explanation above.

3.2.6 Briquettes standards comparison

In order to know the performance of the durian seed as binder agent, the product briquettes was compared with comersial or standards coalchar briquettes. The comparasion with Indonesia national standards can be listed in the Table 5.

Table 5: Comparison of briquettes properties with Indonesian National Standards

Briquettes properties	Experimental data	SNI – 01 – 6235 – 2000
Water content (wt%)	5.31 – 6.23	Max 8
Volatile matter (wt%)	7.79 – 9.54	Max 15
Ash content (wt%)	9.94 – 10.99	Max 8
Fixed carbon (wt%)	74.30 – 75.92	Min 78
Heating value, kJ/g	24.993 – 25.863	Min 20.92

Based on the Table 5, all properties could satisfy the standard except ash content and fixed carbon. In order to satisfy the standards, based on Table 2, the ratio of coconut to durian shell char should be increased due to the origin of the materials.

4. Conclusions

The evaluation of durian seeds as binder agent for briquettes process was performed through investigation main properties of briquettes product. The main results can be summarised as follows:

1. The durian seed had potential as binder agent for briquettes production. It was proved by the product briquettes that still fulfill the standards requirements.
2. The saturated concentration of durian seed binder agent in this experiment was around 8 % binder concentration regarding the heating value and compressive strengths testing.
3. The ash content could be reduced by increasing the ratio of the coconut to durian shell or substitute durian shell with other material which have low ash content. Similar treatment could be selected in order to get higher fixed carbon content. The combustion testing would be interesting topics in the future in order to investigate the burning performance.

Reference

Dargay J.M., Gatelay D., 2010, World oil demand's shift toward faster growing and less price-responsive products and regions, Energy Policy 38, 6261-6277.

Demirbas A.,1999, Physical properties of briquettes from waste paper and wheat straw mixtures, Energy Conversion and Management 40, 437-445.

Hata Y., Purwanto H., Hosokai S., Hayashi J., Kashiwaya Y., Akiyama T., 2009, Biotar Ironmaking Using Wooden Biomass and Nanoporous Iron Ore, Energy and Fuels 23, 1128–1131.

Husain Z., Zainac Z., Abdullah Z., 2002, Briquetting of palm fibre and shell from the processing of palm nuts to palm oil, Biomass and Bioenergy 22, 505–509.

International Organization for Standardization (ISO), 1995, ISO 616:1995, Coke : Determination of shatter indices (in Indonesian).

National Standardization Agency of Indonesia, 2000, Indonesian National Standards (SNI) 01-6235-2000, Wood charcoal briquettes (in Indonesian).

Purwono S., Murachman B., Wintoko J., Simanjuntak P., Sejati P., Permatasari N.E., Lidyawati D., 2011, The effect of solvent for extraction for removing nicotine on the development of charcoal briquettes from waste of tobacco stem, Journal of Sustainable Energy and Environment 2, 11-13.

Singh R.N., 2004, Equilibrium moisture of biomass briquettes, Biomass and Bioenergy 26, 251–253.

Soesilowati E., Dian Wisika P.S., Mohd Salleh L., Md. Sail. R., 2016, Strategic Policies for Increasing the Competitive Powers of Indonesian Horticultural Products in ASEAN Markets, Pertanika Journal of Social Sciences & Humanities 24, 95-110.

Tripathi A.K., Iyer P.V.R., Kandpal T.C., 1998, A techno-economic evaluation of biomass briquetting in India, Biomass and Bioenergy 14, 479-488.

Wahyono, 2009, Characteristic of edible film from durian shell and starch of durian seed for strawberry packages, Research report of biological education, Faculty of education, Surakarta Muhammadiyah University, Indonesia.

Wilaipon P., 2009, The effects of briquetting pressure on banana-peel briquette and the banana waste in northern Thailand, American Journal of Applied Sciences 6 (1), 167–171.

Zhang X., Deping X., Zhihua X., Cheng Q., 2001, The effect of different treatment conditions on biomass binder preparation for lignite briquette, Fuel Processing Technology 73, 185–196.