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Effect of Ratio Composition and Particle Size to Pelletizing Combination Performance of MSW and Biomass Feedstocks

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Abstract: The purpose of this study is to analyze the effect of ratio composition and particle size on pelletization of various feedstocks. The feedstock materials were used leaves, wood, junk waste, shells of coconut and combination of any kind of pure feedstock materials with composition ratio 75:25, 50:50 and 25:75. The feedstocks with highest calorific value crushed and filtered using variation of mesh (20,40,60,80,100 and 120mesh) before pressing in mold dies diameter 6.5mm using multiple pellet press at 70kg/cm^2. The results showed that combination with wood results higher calorific value of feedstock, and larger particle size impact lower durability and lower density.

Keywords: Biomass; Calorific Value; Density; Durability; Wastes

1. Introduction and background

Indonesia has reserves of various energy sources. Nevertheless, some action needs to be done so these reserves can be used as the wealth that can be enjoyed by future generations, rather than spent by generations living today. This because long-term national energy problem concerning issues related to security of supply and sustainability of energy supply, so it can be supporting the development and needs of all the people of Indonesia in the long term. Long-term energy supply should be concern into several aspects, such as environmental, economic, and social aspects of humanity. Application of advanced technologies requires education and information reasonably sufficient to be accepted as part of the cultural community who have never interacted with a variety of new technologies and renewable energy and the impact on the utilization of social humanity.

Related to the above and pay attention to the increasing global energy consumption along with increasing industrialization and living standards. Then almost 80% of world energy consumption comes from fossil fuels which disturb the environment and health are associated with increased emissions of CO_2, NO_x and SO_2[1)]. Biomass is a renewable energy source applied to the production of clean energy to zero greenhouse carbon (CO_2) emissions and relatively low NO_x levels[2)]. After fossil fuels, biomass is the fourth largest energy source in the world. Biomass supply approximately 11-12% of primary energy consumption of the world[3)]. In developing countries, biomass is the most primary energy by the number of approximately 38% of total energy consumption in rural areas and approximately 90% of the total energy supply[1,4)]. With an estimated 90% of world population in the area will be developed in 2050, the biomass energy will remain a substantial source of reserve energy[3,4)].

In 2015, Indonesia produced landfill waste by 64 million tons/day. garbage will cause problems such as environmental pollution and health problems, if not done properly waste management. It would be excellent if it can be recovered by processing the fuel conversion of waste energy. Where the largest percentage of waste derived from organic waste components with a percentage up to 32%[5,6)]. Therefore, the organic waste can be used as a raw material mixture of biomass for efforts to increase the calorific value of the fuel conversion of waste energy[7)].

Today, with the increasing need to utilize the waste into energy (waste to energy), many researchers are focusing on research to transform waste into fuel both organic and inorganic. Generally, the distance between location of biomass production such as forests, agricultural land to location of industry or resident area is quite far and need qualified logistics for transportation and storage[8)]. Thus, one advance method that is effective and efficient of biomass utilization for energy is pelletization process[9)].

Therefore, this research is focused on improving the performance of the pellet production with several process from pre-treatment of feedstock materials, treatment of physical parameters on multiple pellet press and variations in the composition of municipal solid waste (leaves, wood, and junk waste) and biomass (coconut shell)[10)].

2. Method and experimental setup

2.1 Materials and selection

In this research, pure feedstock materials used leaves, wood, junk waste, and coconut shells as well as combinations of any type of pure feedstock materials with a comparison are 75:25, 50:50 and 25:75. Leaves and wood materials are obtained from the collection of leaf and wood waste in the park area of Universitas Indonesia which is dominated by perennials, including Mahogany trees (*Swietinia Mahagoni*), Kiara Payung trees (*Fellicium Decipiens*), Acacia Mangium trees (*Acacia Mangium*), Ketapang trees (*Terminalia catappa*) , Trembesi tree (*Samanea saman*), Melinjo tree (*Gnetum gnemon*), Angsana tree (*Pterocarpus indicus*), Buni tree (*Antidesma bunius*), Flamboyan tree (*Delonix regia*), Matoa tree (*Pometia spp.*), Rambutan tree (*Nephelium lappaceum*), and Coconut trees (*Cocos nucifera*)[11]. Junk waste material are obtained from collection of municipal solid waste in resident area. coconut shells are obtained from several entrepreneurs with coconut as raw material.

2.2 Multiple pellet press

The process of making pellets uses the single pellet press method[12,13]. The tool used is a shop press with a maximum compressive strength of 20 tons. This tool is equipped with a pressure gauge and hydraulic cylinder which is connected to a hydraulic pump. The hydraulic pump is used in the pressing mechanism by pushing the mold into the mold pellets. While the pressure gauge serves to demonstrate the amount of pressure the dies punch is giving to the die mold pellet.

Fig. 1: Multiple pellet press

2.3 Dies of pellet

In addition to multiple pellet press, dies punch and dies mold were needed to produce pellets according to the desired size. The size of dies punch and dies mold adapted with the optimum diameter in previous study regarding optimization production pellets to have a high durability. In reference study, they used three variations diameter pellets mold dies is the diameter of 6.5 mm, 8 mm and 10 mm[14,15]. Tests on the manufacture of display devices and testing this type of singles pellets six types of base material pellet material was carried out using a mold pellet diameter size by comparing two sizes of 6.5 mm and 8 mm. Test results obtained pellet with a smaller diameter can produce greater calorific value but with a temperature of 70 ºC, an additional adhesive in the form of lignin and a pellet length of about 12 mm[13,16,17].

In this study, used dies with diameter of 6.5 mm. In accordance with the testing Arnavat et. al, the smaller diameter pellet dies and molds it will be the optimum product yield pellets are formed[12]. It was adapted to the size and shape of the design of display devices pellets, material of construction tools, raw materials used as well as other parameters that affect the durability of pellets.

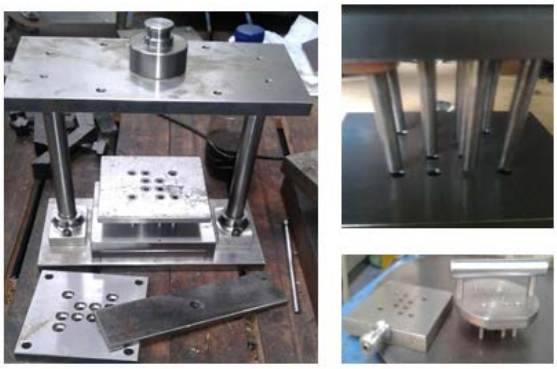

Fig. 2: Dies of pellet

2.3 Measurement parameter

Particle Size. Particle size distribution of pellet production in this study used sieve 20-120 mesh. Based on reference study, particle size will affect the value of the pellet durability[12,14]. The smaller the particle size, the porosity will be smaller and bulk density will be higher, so it will produce high durability pellets[18].

Fig. 3: Sieve variation

Bulk Density. The process of grinding and milling in biomass and organic waste as a feedstock material for making pellets affect the strength of the pellets were formed. The two processes affect the properties of pellets which changes the porosity and flame stability in utilization of pellets, such as gasification. The change of biomass particle size affects the bed of material density

and viscosity of the mixture in a process unit that affect its energy needs and ultimately affect the quantity of raw materials required and the quality of the flame on the burner that will be even better when the value of the greater bulk density.

Heating Value. Heating value measured with device called a bomb calorimeter. The bomb calorimeter consists of a combustion chamber with a constant volume as the specimen measured caloric value. This space is covered with water as a medium for measuring when a temperature change occurs due to the combustion process. The specimen is placed in the combustion chamber and ignited into flames by an expansion of the air as well as the rise in room temperature. The temperature rise would heat the water that surrounds the space, so we get the temperature before and after combustion of fuel. From the water temperature value is to be calculated calorific value of the fuel.

Fig. 4: Leco AC500 Bomb Calorimeter

Durability. Durability is an important physical quality of pellets. Durability defined as the ability of a pellet to withstand destructive materials and forces during transportation. Low pellet durability is undesirable because it can cause problems such as dust emission and an increased risk of fire explosion during pellet handling and storage. The 500 gram pellet sample was rotated at 50 rpm for 10 minutes. Samples in the box were taken, filtered and the percentage of pellet durability can be calculated.[13)]

Fig. 5: Durability tester

2.4 Experimental setup

This study starts from selection the potential feedstock from combination of leaves, wood, and coconut shell based on their calorific value. Pre-treatment of selected feedstock materials done by heat treatment method which is drying process. Drying feedstock material by oven at temperature 40 ºC within 1x24 hours[19,20)]. These was done to reduce the water content inside feedstock material. Testing characteristics of feedstock material needed to be done to determine the potential of raw materials and the best composition ratio predictions to be product pellet. The process continued with producing pellets using multiple pellet press. And the last step is testing the quality of pellet produced.

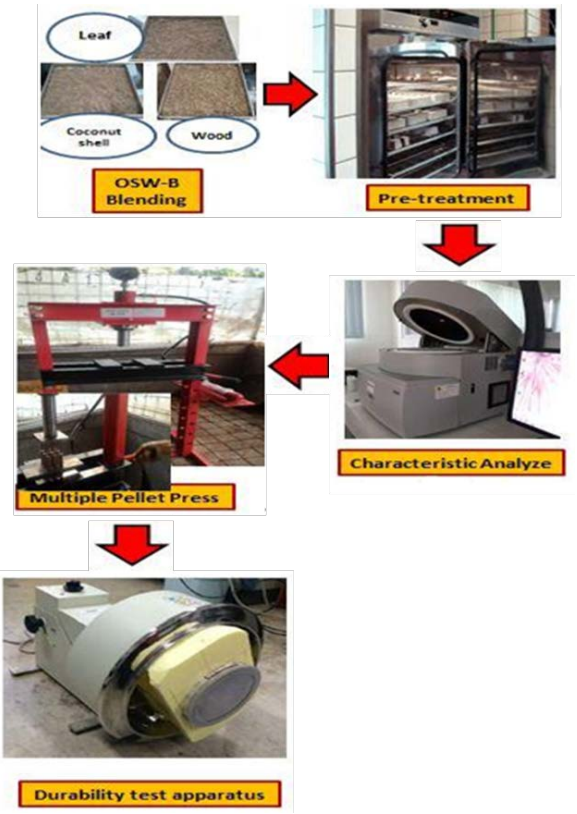

Fig. 6: Experimental setup

Preparation of each feedstock should be done with physical treatment such as sorting, crushing, and screening. The sorting process done manually by separation each feedstock. Crushing process go through two steps crushing, such as crusher machine and milling machine. Then, feedstock powder after milling process were screening by variation of sieve. Moisture content level of feedstock powder after separation each particle size were measured[21,22)]. Then the feedstock powder was blended with composition that will be analyzed. The feedstock powder must be evenly mixed before putting into the dies mold and pressed.

Standards operational procedure principal of multiple pellet press are when the hydraulic pump was pumped up, dies punch move down and pressing powder inside the

dies mold. Pellet volume was setting with a length 20 mm, so when the dies punch has been pressing the dies mold to a depth 20 mm, the pressing was stopped by stopping the swing of hydraulic pump. Then at the bottom of the dies mold given container or drawer to hold the pellets that had been formed after being pressured. The dies have been designed to make easier when capture pellet product just only push the container and the pellet product will be fell out from dies mold[15]. Pressure value at the pressure gauge should be recorded in every pellet production.

Pellets that produced out have different characteristics according to the variation in the diameter of dies and molds pellets. Where, obtained the best characteristics of the pellets is a diameter of 1 cm and cut every 1 cm[23,24].

The other parameter analysis such as proximate, ultimate, and Thermo Gravimetric Analyzer (TGA) were also tested to determine the completely quality of pellet production. The complete data useful to get optimization step including optimization of heat energy[25,26]. With the known data optimum output of heat energy, reducing efforts of emissions from the combustion process can be considered, so the utilization pellet can be environmentally friendly[14,27–29].

In the pellets production, optimization the durability of product becomes an important parameter to investigate the performance of the pellets. Without a high pellet durability, shape retention and quality pellets will not survive during the process of transportation or accommodation pellet product between the place[8]. Thus, after the screening process material samples and analytical characterization of fuel properties. Mechanical characteristic needs to be done to determine the level of pellet durability.

Table 1. Calorific value and composition of raw materials

No	Feedstock	Heating Value (MJ/kg)
1	Leaves	14.731
2	Wood	16.162
3	Coconut shell	15.465
4	Junk Waste	7.017
5	Leaves:Wood (50:50)	15.209
6	Wood:Coconut shell (50:50)	15.845
7	Coconut shell:Leaves (50:50)	14.997
8	Leaves:Wood (75:25)	14.672
9	Wood:Coconut shell (75:25)	15.787
10	Coconut shell:Leaves (75:25)	15.219
11	Leaves:Wood (25:75)	15.678
12	Wood:Coconut shell (25:75)	15.583
13	Coconut shell:Leaves (25:75)	14.782

3. Results and discussion

Pellets produced after analysis and selection on the characteristics of the feedstock material pellet product. First selection process, heating value which testing using a bomb calorimeter, of the feedstock materials were analyzed.

The goal was to get combination of appropriate feedstock material in pellet production with high calorific value and strong physically. The best calorific value will be selected to process became pellet.

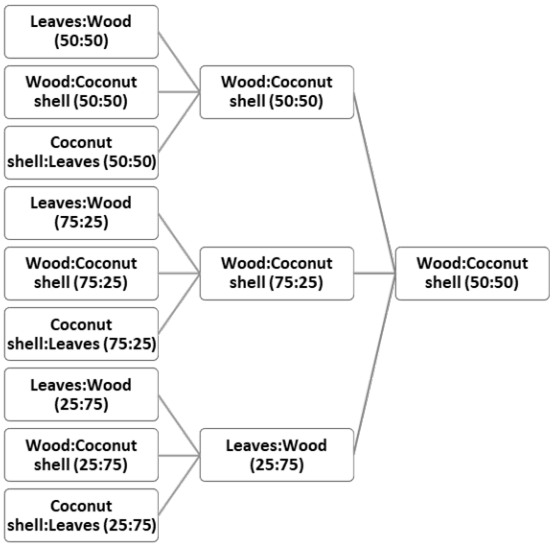

Fig. 7: Composition of experimental pellet

Since junk waste was too low than the other pure feedstock, it eliminated for the next step combination of feedstock. The combination of feedstock variated into ratio 50:50, 75:25, and 25:75. These 9 variations tested with bomb calorimeter with three test repetitions. Then, the test statistics with student T-test obtained three best combinations ratio such as wood:coconut shell (50:50), wood:coconut shell (75:25), and leaves:wood (25:75). Thus, the feedstock that processed for the next step is wood:coconut shell (50:50) due to the highest calorific value that is 3787.12 kcal/kg or 15.845 MJ/kg.

Fig. 8: Wood and coconut shell in each meshing size

Based on laboratory analysis, value of carbon powder composition wood:coconut shell (50:50) is 16.89% and

the moisture content is 12.72% and obtained the value of carbon pelletization wood:coconut shell (50:50) is 14.09% and the moisture content is 11.52%. Thus, pelletization results from a combination of wood:coconut shell (50:50) not only reduce the water content but also reduce the carbon value of the material.

Fig. 9: Pellet product

The larger the mesh size is directly proportional to the density and the pressure value is inversely proportional to the length of the pellets produced which causes the density to increase. The greater the pressure will increase the risk of the pellets not being (crushed). Higher nominal of meshing size, the particle size is lower. Highest bulk density of pellet with ratio wood:coconut shell (50:50) is 1,445.50kg/cm^2.

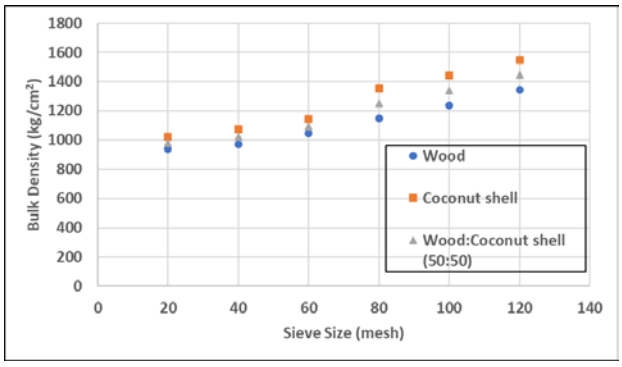

Fig. 10: Bulk density of various particle size

From the resulting pellets tested to determine the durability of the product formed by the durability test. Durability test results obtained from subtracting the final mass (after the sifter) with a mass start. The initial mass before the durability test of 500 grams. After the durability test its rest mass 473.2 grams and 482.2 grams. Durability testing is done twice repetition, where the first test of durability values obtained 94.64% and the second test values obtained 96.44%. So, the value of average value of durability pellets or called Pellet Durability Index (PDI) is 95.54%.

4. Conclusion

Based on these results which is used the composition of municipal solid waste (leaves, wood, and junk waste) and biomass (coconut shell), the materials have a great potential as feedstock for the manufacture of pellets because it has a high calorific value in accordance testing. From the combination of pure material composition obtained the best combination is the combination of the composition of wood:coconut shell (50: 50) at calorific value 3787.12 kcal/kg. Combination with wood results higher calorific value of feedstock, and larger particle size impact lower durability and lower density. Characterization of the best pellet product that is 6.5 mm in diameter with a length of 1 cm and water content (moisture) 10%. Results obtained from the PDI (Pellet Durability Index) is 95.54%. Pelletization results from a combination of wood:coconut shell (50:50) not only reduce the water content (reduce 2.80%) but also reduce the carbon value (reduce 1.2%) of the material.

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