Effect of Binder Adding to The Physical Properties of Municipal Solid Waste (MSW) Pellets

D Nursani, S R H Siregar and A Surjosatyo

Department of Mechanical Engineering, Universitas Indonesia
Kampus UI Depok 16424, Indonesia
E-mail: adisuri@eng.ui.ac.id

Abstract. Utilization of MSW as solid fuel has been developed through the process of gasification and pyrolysis. To improve energy efficiency during combustion, it needs uniformity of form and compaction, therefore MSW is formed in the form of pellets. The purpose of this research was to determine the physical characteristics of MSW pellets with the addition of binder and pellet drying process. Pellets consist of organic material, plastic, paper and leaves which are dried and crushed to reduce size. The material is mixed with the tapioca flour binder content of 0%, 3% and 6% and then compacted in the form of pellets. After the milling process, the pellets are dried with a treatment of 0, 6 and 12 hours to measure physical characteristics, moisture content and caloric value. Physical measurements consist of tests of density, durability and hardness. The developed pellet had a size length of 23.6 – 24 mm and diameter of 7.8-8.2 mm and 1.16-1.36 grams of weight the individual pellet. From the results of measurements and observations, pellets with 0% binder adding and 12-hours of drying can produce better quality, in the absence of fungal contamination and have a higher caloric value. MSW pellets from that process have achieved European pellet standards for physical properties, moisture content and caloric value.

1. Introduction

Waste and energy are challenges for Indonesia's development. Economic growth, rising living standards and swelling urban populations are driving growth in the volume of municipal solid waste (MSW) and energy demand [1]. World Bank states that in addition to increasing population, the amount of waste production per person has increased from 0.64 kg/person/day in 2002 and is estimated to be around 1.42 kg/person/day in 2025 [2]. In that year, the total population of Indonesia is estimated at 284.8 million with waste production of 404.4 thousand tons/day [3]. The amount of waste if not handled properly will cause a big problem.

MSW handling is currently in the form of landfill and incineration causing environmental problems. Therefore several attempts have been made to utilize MSW for fuel sources using the gasification and pyrolysis process [4]. However, MSW has a high moisture content, low density, and low heating value thereby reducing energy efficiency [5]. To improve energy efficiency during combustion, it needs uniformity of form and compaction, therefore MSW is formed in the form of pellets. Solid fuels in the form of pellets make it easier to store, distribute and make the combustion process more perfect and stable [6, 7].

To improve the quality of pellets, several studies have added binders to help particles of raw materials adhere to each other. Qiang Hu et al. [8] conducted a study on the addition of binders in producing biochar pellets, the result show that adding binders could enhanced mechanical strength and promoted
combustion performance. Therefore, this study aims to investigate the effects of binder adding and pellet drying to the physical properties of municipal solid waste (MSW). The study was designed to find the exact formula and processes for making large quantities of MSW pellets in a quality that achieve the standards. Going forward, the MSW pellet is expected to replace solid nonrenewable fuels such as coal, so that it can solve the waste and energy problems simultaneously.

2. Material and Method

2.1. Materials
The material used is municipal solid waste based on the composition of waste in Jakarta, consist of 70% organic waste, 12% plastic, 10% paper and 8% leaves. The binder uses tapioca flour in a form that has been cooked with the composition of flour: water 1: 4. Tapioca is used by considering ease in mass production.

2.2. Experimental Setup
The organic waste was roughly chopped with shredding machine and then dried with natural drying up to 30-35% moisture content (4 days). Then the entire composition of the waste is mixed and destroyed using a disk mill machine with a 20 mesh filter hole. After getting smooth raw material mixed with the binder with variation of treatment 0%, 3% and 6%. In this study, the plate die-roller pellet mill type was used for the pellet production with die temperature up to 55-60°C. Pellets are dried by natural drying with physical measurements of 0, 6 and 12 hours. Figure 1 shows the stage of the pelleting process of MSW pellet.

![Figure 1. Stage of pelleting process](image)

2.3. Properties Test
Physical parameters and properties of MSW pellets were the size (diameter, length, and weight), density, durability and hardness. The purpose of this study is to determine whether the addition of binders and drying time can improve the quality of pellets as fuel. The pellet density measurement is done by measuring diameter, length, and weight. The lengths and diameters of pellets were measured by a digital caliper while the weight of the pellet was measured by a digital balance with two decimal points accuracy [9, 10]. The hardness of the pellet was measured by performing the compression test [11]. This experiment was designed to simulate the pressure impact that could occur in lower layer pellets due to the weight of the upper layers during handling and storage [12]. The durability experiment was carried out by dropping a single pellet from a height of 1,85 m into a stainless pan and measuring the largest
The durability is calculated by dividing the weight of the largest broken piece between the weight of the original pellet and the percentage reported [13].

The chemical properties test is done by measuring the moisture content and caloric value. The moisture content was measured with the oven method for every treatment pellets [14] and use infrared moisture tester for raw materials. Moisture content on pellets affects the physical quality in terms of fungal contamination. Fungi can damage chemical and physical structure including affecting the caloric value of pellets. The pellet caloric value was measured for 0%, 3% and 6% binder adding only for pellet sample after 12 hours drying, this test use bomb calorimeter (ASTM standard D 2015-73).

3. Results and discussion

3.1. Density
The developed pellet had a size length of 23.6 – 24 mm and diameter of 7.8–8.2 mm and 1.16-1.36 grams of weight the individual pellet. Raw material as a pile of MSW has an average density of 0.135 gr/cm$^3$ at an average moisture content of 32.3%, after chopping the density increase to 0.149-0.159 gr/cm$^3$ at water content of 23.39%–40.38%. After compacted, density increased to 0.988-1.009 gr/cm$^3$ and during drying process density is reduced due to decreased moisture content. The average density after drying is 0.76-0.97 gr/cm$^3$ (fig. 2) and after 12 hours drying pellet bulk density of 0%, 3% and 6% binder adding is 490.9 kg/m$^3$, 435.07 kg/m$^3$, and 383.9 kg/m$^3$. The particle density achieves the European standard for pellet quality for particle density. The density standard is <1.12 g/cm$^3$ for Austrian standard ONORM M 7135 and < 1.2 g/cm$^3$ for German standard DIN 51731 [15]. The biggest density is better for pellet quality, that 0% binder adding is selected to produce the MSW pellet.

![Figure 2. Effect of drying time and binder adding to the pellet density](image)

3.2. Hardness
The harder pellet is better for maintains its shape during the distribution and storage. On figure 3, pellet hardness is getting higher after drying, and the higher binder content make the harder of pellets. The increase of pellet hardness after the drying process is very high, this shows that the drying process of pellet is very important to do, not only to decrease the moisture content to avoid fungal contamination but also to increase the hardness of pellet.
3.3. Durability
The durability is described as breaking the pellet’s resistance. This reflects the value of the long-lasting pellet during transport from agitation, vibration, shear, impact and tumbling. This is often reflected by the single drop test [11, 13]. The durability on table 1 is as the percentage loses weight of pellet after dropped. The value of durability achieves European standard for pellets durability. The durability standard is <2.3% for Austrian standard ONORM M 7135, < 2.3 % for German standard DIN 51731, and <0.8% for Swedish standards: SS 187120 [15].

Table 1. Durability of MSW pellets

| Drying time (hours) | 0%  | 3%  | 6%  |
|---------------------|-----|-----|-----|
| 0                   | 0.975 | 0.397 | 0.763 |
| 6                   | 0.642 | 0.549 | 0.673 |
| 12                  | 0.495 | 0.651 | 0.623 |

3.4. Moisture content
Pellet raw materials are organic waste, plastic, paper, and leaves that have been destroyed and mixed with an average water content of 5.94%. Pellet compacting can be done with a water content of 20-40%, so it needs the addition of water and binder. The moisture content before pelleting for each treat is 0%, 3% and 6% is 23.39%, 29.22% and 40.38%. During the printing process, there is a rise in temperature due to material friction up to 55-60°C and causes a decrease in water content of 18.2%, 21.13% and 27.17% respectively. The moisture content is still high, it needs drying to hydrate fungal contamination. Figure 4 can be seen that a 12-hour drying can reduce water content by an average of 4.5%. Standard of pellets for fuel in Europe standard is <10 % for Austrian standard ONORM M 7135, <12% for German standard DIN 51731, and <10% for Swedish standards: SS 187120 [15].
3.5. Fungal contamination
The possibility of fungus contamination in MSW pellets is very high because the material used is mostly organic material that is easily affected by fungi and other microbes, especially in high water content. Fungi growth decreases the quality of pellets due to structural changes both chemically and physically. The observation of this fungal contamination was done by looking directly at fungus growth in pellets on 0 hour, 6 hours and 12 hours drying time. The observation shows that drying can avoid fungal contamination. A 0-hour drying Sample is subjected to fungal contamination on the 5th day, while a 6-hours drying is subjected to fungal contamination on the 15th day. Thus, a 12-hours drying is required to maintain the quality and lifetime of pellets. Figure 5 shows the comparison of MSW pellets without fungal contamination and with fungal contamination. The observation shows that to get good quality MSW pellets without any contamination of fungus need to be done drying for 12 hours.

![Figure 5. Pellet without fungal contamination (a) and with fungal contamination (b) ](image)

3.6. Caloric value
Caloric value is an important parameter for determining how much energy is available in the fuel. The calorific value is measured only on the pellet sample by drying for 12 hours. This is because the samples with drying treatment 0 and 6 hours of drying have been contaminated by fungus. The measurement results indicate that the influence of the addition of binders on the calorific value of MSW pellets. From table 2, it can be concluded that binder adding decreases the caloric value. The European standard of pellet calorific value is $>4302 \text{ kCal/kg}$ for Austrian standard ONORM M 7135, $3705-4661 \text{ kCal/kg}$ for German standard DIN 51731, and $>4039 \text{ kCal/kg}$ for Swedish standards: SS 187120 (group 1) [15]. The calorific value of pellet with 0% binder adding achieves the European standard. Thus, to get MSW pellet that has a high calorific value is no needed binder adding.

| Binder adding | Caloric Value (kCal/kg) |
|---------------|-------------------------|
| 0%            | 4360.84                 |
| 3%            | 3783.02                 |
| 6%            | 3290.71                 |

4. Conclusion
The developed MSW pellet had a size length of 23.6 – 24 mm and diameter of 7.8-8.2 mm and 1.16-1.36 grams of weight the individual pellet. The average moisture content of the MSW pellets after 12 hours of drying is 4.5%, the average density of 0.76-0.97 gr/cm$^3$, as well as the average hardness of 17.68-21.37 kg. The MSW pellet processing exact formula is 0% of binder adding, 12 hours pellet drying, moisture content below 5% for good quality with no contamination fungi and long lifetime. The
pellets that are produced from that formula achieve the standard pellets from physical properties and caloric value according to pellet standards in several countries in Europe.

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