# The Influence of Municipal Solid Waste Components Composition on Main Parameters of Torrefaction to Produce High-Calorie Solid Fuel

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**ABSTRACT**: Municipal solid waste is a mixture of various components of waste. The composition of municipal solid waste varies from one place to another place. In the process of municipal solid waste torrefaction, main parameters of torrefaction, that is temperature and residence time is determined by the composition of waste components. In this research carried out tests to determine the influence of the composition of municipal solid waste components on the main parameters of torrefaction to get the product as the high-calorie solid fuel. The results showed that the torrefaction process on municipal solid waste which is dominated by twigs and leaves produces the best calorific value at a temperature of 300°C and the residence time of 45 minutes. While the torrefaction process on municipal solid waste which is dominated by the food waste (rice, orange skin and banana skins), best calorific value obtained at temperature of 275°C and residence time of 15 minutes.

**Keywords**: municipal solid waste, torrefaction, main parameters of torrefaction, high-calorie solid fuel

## 1. INTRODUCTION

The world primary energy was still dominated by petroleum, natural gas, coal, nuclear, and hydroelectric. The three largest sequence of the primary energy were the form of fossil fuels, which would be exhausted in a short time. In Indonesia, the situation was even worse because there is no use of nuclear energy, while hydroelectric had small portions, so that practically only depended on petroleum, natural gas, and coal. Data from 2007 showed that consumption of primary energy in Indonesia annually reached 114.6 million toe (tonnes oil equivalent) [1].

To ensure continuity of the domestic energy compliance, it would need to immediately find new energy sources as an alternative energy that was renewable. The energy alternative has two advantages at once that is as a substitute for fossil fuels and prevent global warming caused the rate of CO2 production from burning fossil fuels. The alternative source promising is biomass from agricultural residual and municipal solid waste.

The usage of municipal solid waste as solid fuel is a quick solution for the urban community than composting the waste which require a long time process. However, the usage of municipal solid waste directly as a fuel has many obstacles because of the waste consists of multiple components that are difficult to control the quality of combustion, as well as the nature of high water content, so the waste is a poor fuel, which is characterized by a low calorific value. To improve the properties of municipal solid waste as fuel, it takes a thermal process, where the waste components undergo decomposition so it’s calorific value increase.

The continuous research joint with the research team of Thermodynamics Laboratory ITB has produced solid fuel derived from municipal solid waste through a process Torrefaction [2]. The result is a solid fuel with quality equivalent to the calorific value of coal Subbituminous (HHV) 4900-6800 kcal/kg.

Municipal solid waste is a mixture of various components of waste. The composition of municipal solid waste components are different at each location and can also be changed from time to time. The main parameters that influence torrefaction products are temperature and residence time [3]. Torrefaction experiment on individual components of municipal waste showed that the higher calorific value for organic components (twigs and leaves) is obtained at higher temperature and longer residence time. Meanwhile, for the others components, ie, foods waste (rice, orange skin and banana skin), the higher calorific value is obtained at a lower temperature and shorter residence time [4]. This paper will discuss the influence of waste composition to optimum temperature and residence time to produce high-calorie solid fuel.

## 2. WASTE TORREFACTION

Torrefaction is a thermal treatment process of solid material at temperature of 200-300°C and atmospheric pressure in absence of oxygen. Torrefaction has been applied to homogeneous materials such as woody biomass and peat, and managed to increase its calorific value. In this study will be developed the torrefaction method for multi-component used as a waste processing technology. This method expected able to improve fuel characteristics of municipal solid waste so that become high-calorie solid fuel, equivalent to subbituminous C coal according to ASTM D 388 standard qualifications.

### 2.1. Sample Preparation

The samples used in this experiment are the combustible materials and any components that not utilized by scavengers, i.e. biomass fraction and non-recycled plastics which come from municipal solid waste. The sample composition can be divided into three main groups i.e. the organic components (twigs and leaves), food waste (rice, orange skins and banana skins) and non-recycled plastic (food packaging plastic)

Before experiment, samples are dried for approximately one week for consistency of moisture until it is used. Samples used are also clean and dry. All sample material is cut into small pieces. Twig chosen is the size of less than 1 cm in diameter and cut into approximately 1 cm long. Leaves, orange skin, banana skin and plastic, cut small with a size of about 1 cm2. Rice is not treated specially, just maintained so as not to agglomerate in order to remain appropriate grain size.

### 2.2. Methodology

Waste components that is varied in composition is the organic component and food waste, because their amount is large enough, i.e. around 49% (organic) and 31% (food waste) compared to plastic which is only about 8% of the total weight of municipal waste that can be burned and not taken by scavengers [5]. For each experiment, the samples were mixed manually according to the each component proportion based on percent by weight to obtain the total sample weight of 20 grams.

Torrefaction experiment conducted in two steps for each composition. First step is testing for temperature variation and second step is testing for residence time variation. Testing for temperature variation conducted to determine the optimum temperature that is the temperature which gives the highest calorific value at certain composition. After that, at the optimum temperature, testing for residence time variation conducted to obtain optimum residence time that is the residence time which gives the highest calorific value. Composition and variation of experimental parameters is showed in Table 1.

**Table 1**: Composition and parameters of torrefaction experiment.

| Sample | Composition (wt-%), adb | | | Temperature (°C) | Residence time (min) |
|---|---|---|---|---|---|
| | Organic waste | Food waste | Non-recycled plastic | | |
| Mixed-702010-T250t45 | 70 | 20 | 10 | 250 | 45 |
| Mixed-702010-T275t45 | 70 | 20 | 10 | 275 | 45 |
| Mixed-702010-T300t45 | 70 | 20 | 10 | 300 | 45 |
| Mixed-702010-T300t15 | 70 | 20 | 10 | 300 | 15 |
| Mixed-702010-T300t30 | 70 | 20 | 10 | 300 | 30 |
| Mixed-207010-T250t45 | 20 | 70 | 10 | 250 | 45 |
| Mixed-207010-T275t45 | 20 | 70 | 10 | 275 | 45 |
| Mixed-207010-T300t45 | 20 | 70 | 10 | 300 | 45 |
| Mixed-207010-T275t15 | 20 | 70 | 10 | 275 | 15 |
| Mixed-207010-T275t30 | 20 | 70 | 10 | 275 | 30 |

### 2.3. Experimental Set-up

Waste torrefaction equipment is a bench-scale torrefaction reactor and use superheated steam as medium. The schematic figure of torrefaction equipment is shown in Figure 1.

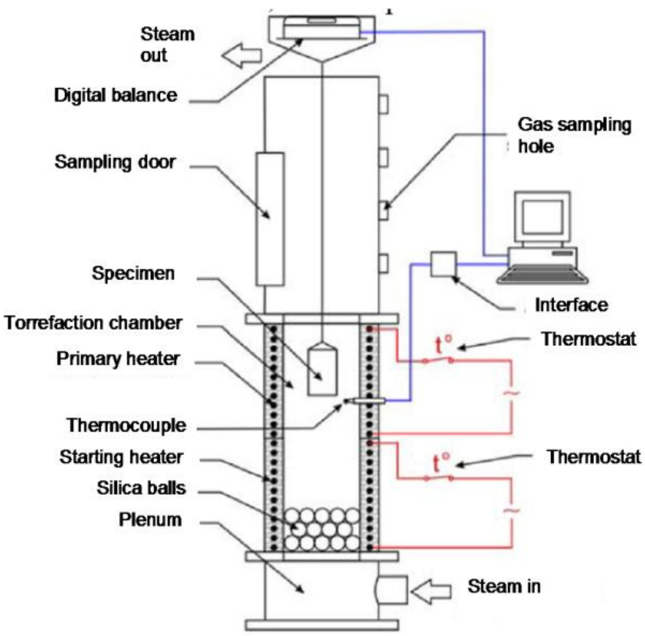


**Figure 1**: The schematic figure of torrefaction equipment.

The sample was put in a stainless steel mesh container. The container was placed at the center of reactor chamber, which was the main part of the apparatus. The chamber was heated by an electrical heater and controlled electronically. The superheated steam got into the reactor through a flow regulator valve. A centrifugal blower was needed for start up and shut down purpose. The weight loss of sample was monitored with a digital balance and recorded by a data acquisition system.

## 3. RESULTS AND DISCUSSION

3.1. Weight Loss of Experimental Sample

The graphs of weight loss for various samples of waste components, that is the relative mass of specimens which measured at any time divided by the mass of initial sample obtained from the experiment showed in Figure 2. Weight loss profiles of the samples with various composition show the same pattern, where the rate of mass loss is relatively rapid at the beginning of the process, then slow down and eventually tend to be asymptotic at end of the process. For the same composition but varying in temperature process, the time taken until reach a constant weight was more quickly for higher temperatures than the lower one. The relative weight remains at the end of process is smaller for higher temperature at the same composition.

Biomass which has a high content of hemicelluloses would undergo greater alterations in its properties during torrefaction so that leave fewer solid product [6]. Torrefaction process on mixed municipal solid waste which is dominated by food waste remains smaller relative weight of sample than mixed municipal solid waste which is dominated by organic components. It indicates that hemicelluloses content in the food waste is greater than in the organic waste.

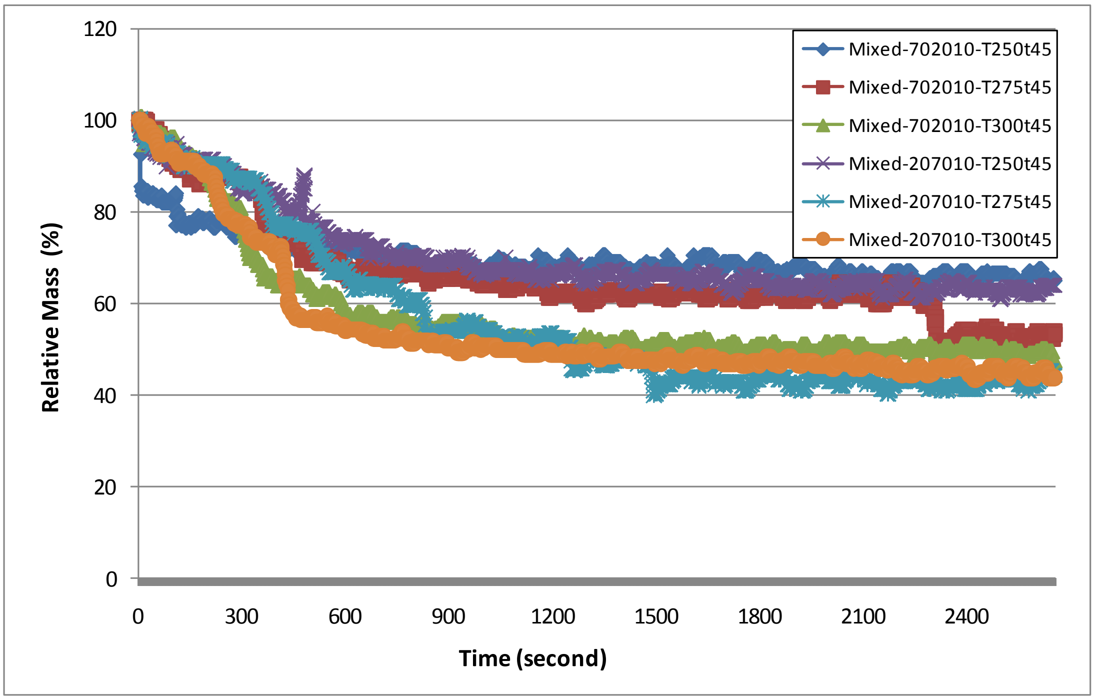


**Figure 2**: Curve of weight loss for various temperatures of experimental samples.

3.2. Calorific Value of Torrefaction Products

The calorific value of torrefaction products for municipal solid waste composition which dominated by organic component is shown in Figure 3. Figure 3 (a) show the calorific value obtained from the temperature variation, and Figure 3 (b) show the calorific value obtained from residence time variation. Calorific value increases for higher temperature and longer residence time. The highest calorific value was obtained at temperature of 300°C and residence time of 45 minutes, that is 5430 kcal/kg or increasing of 9% compared to calorific value of raw materials in the same composition, that is 4980 kcal/kg.

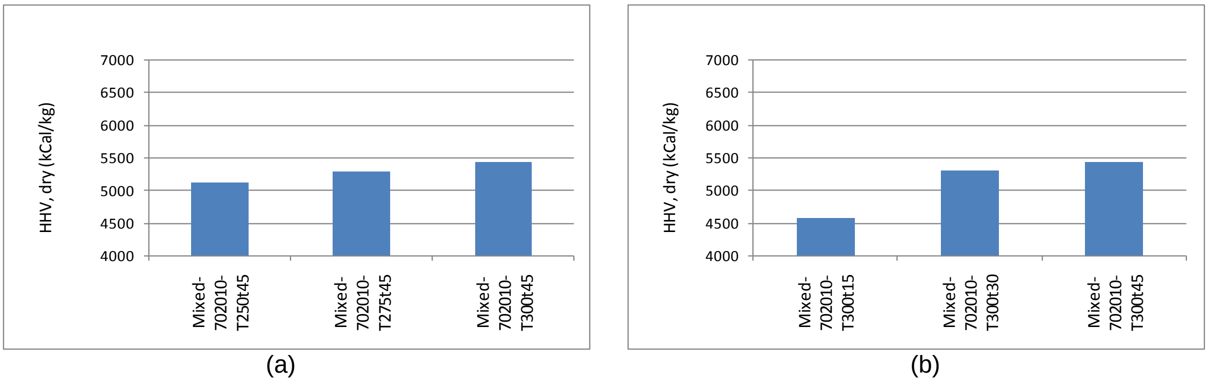


**Figure 3**: Graphs of calorific value of municipal solid waste which is dominated by twigs and leaves: (a) for various temperatures and, (b) for various residence times.

Figure 4 show the calorific value of torrefaction products for municipal solid waste composition which dominated by food waste. The calorific value obtained from the temperature variation shown in Figure 4 (a), and the calorific value obtained from residence time variation shown in Figure 4(b). Differ from the waste composition which dominated by organic components, the highest calorific value was obtained at temperature of 275°C and residence time of 15 minutes. The maximum calorific value obtained from this composition is also higher, that is 6940 kcal/kg or increasing of 21% compared to calorific value of raw materials in the same composition, that is 5730 kcal/kg.

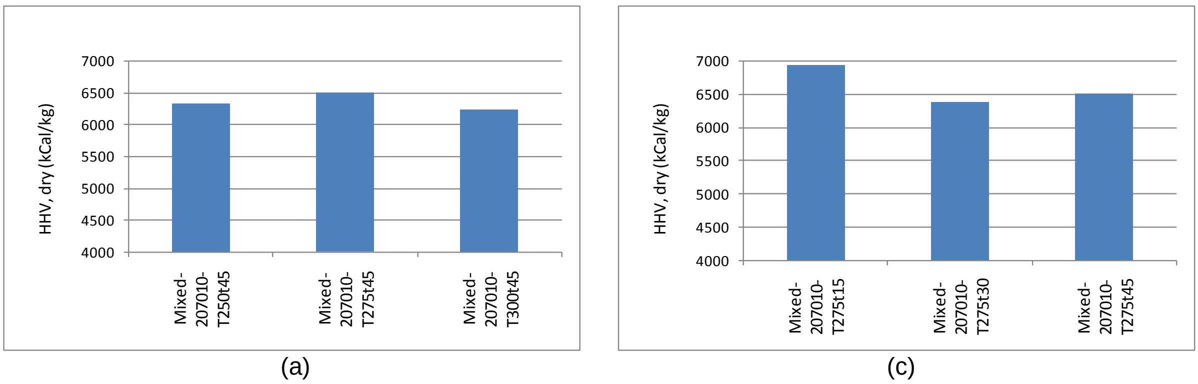


**Figure 4**: Graphs of calorific value of municipal solid waste which is dominated by food waste: (a) for various temperatures and, (b) for various residence times.

The results of torrefaction experiment on municipal solid waste for the variation of this composition can become considering in determine the optimum main parameters in torrefaction experiment for various other compositions. The optimum main parameters (temperature and residence time) will produce solid fuel with the best calorific value and more economical operating costs.

## 4. CONCLUSION

The main parameters of torrefaction process, temperature and residence time, is influenced by the composition of municipal solid waste components. The optimum main parameter is temperature and residence time that able to produce the solid fuel with the highest calorific value. The composition of municipal solid waste which is dominated by twigs and leaves produce the best calorific value (5430 kcal/kg) at relatively high temperatures and relatively long residence time, that is 300°C and 45 minutes. Meanwhile, the composition of municipal solid waste which is dominated by food waste (rice, orange skins and banana skins), produce the best calorific value (6940 kcal/kg) at not too high temperatures and relatively short residence time, that is 275°C and 15 minutes.

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