International Proceedings of Chemical, Biological and Environmental Engineering, V0l. 90 (2015)
DOI: 10.7763/IPCBEE. 2015. V90. 22

A Comparative Study on the Efficiency of SRF and Different Kinds of Source-Separated Household Wastes as a Solid Fuel

Min-Gyeong Gu [1+], Da-Young Nam [1], Min-Jeong Gu [2], Hak-Ho Nam [2], Hyun-Jeong Park [3] and Chan-Jin Park [3]

[1] Bugae Girls' High School

[2] Bugae High School

[3] Incheon National University

Abstract. The purpose of study is to compare efficiency of solid fuels among 11 types of combustible household wastes segregated from SRF (Solid Refuse Fuel). As a result of studying three contents, it has turned out that among 12 types of combustible wastes, plastic substance (Styrofoam, PS, PE, PP)holds high combustible materials and low moisture content. And from the results of analyzing elements, it turned out that combustible household wastes have no heavy metal content other than 0.60% of titanium(Ti) in PP. Based on the revised fuel quality standard(heating value of 3500Kcal/kg or more), coffee sludge and green tea wastes proved unsuitable as solid fuel.

Keywords: Combustible wastes, solid fuel, SRF

1. Introduction

The amount of household wastes is significantly increasing compared with the number recorded 10 years ago. In particular, the increase of urban waste caused by economic growth and high population density is emerging as a big problem to be addressed [1].

In the situation where it is hard to develop new landfill and incineration sites, utilization of waste as fuel may serve as an instrument to recollect much energy. In that sense, it is recognizable that manufacturing combustible waste as solid fuel and using it as fuel is very useful in responding to high oil price and global warming. In the situation where policy support and financial aid are falling short of expectations due to distrust for product safety and low demand, the market is yet to be growing.

2. Research Objectives and Methods

2.1. Research objectives

Considering this, we concluded that it is necessary to develop environment-friendly and economically optimized way to handle waste to utilize recycling energy for sustainable development. To this end, we recollected combustible household wastes, analyzed chemical characteristics, elements and caloric value of household wastes and studied ways to identify household waste type which may maximize production yield rate among household wastes through the comparison with current SRF.

2.2. Research methods

+Corresponding author. Tel.: 82-10-8910-4894; fax: 82-32-835-0726.
E-mail address: tonson77@hanmail.net.

The study sampled 11 types of household wastes discharged from 2 apartment sites in Incheon from Oct. 2014 through Feb. 2015, sampled SRF in Incheon City and then analyzed three contents, elements and caloric value of 12 types of household wastes.

First, we analyzed combustible household wastes by classifying them into three elements (moisture content, combustible content and ash content).

Second, we studied wastes likely to yield air pollutants when they are burnt for element analysis.

Third, we analyzed caloric value to compare SRF and different types of segregated combustible household wastes to identify their quality as solid fuel.

3. Research Result and Discussions

3.1. Analyze combustible wastes to identify three contents

3.1.1. Research procedures

We sampled household waste contained in standard plastic garbage bag and the sampled them by materials and type from waste segregation site in apartment buildings. We divided sampled combustible household wastes into 11 types such as food, paper, vinyl, plastic {PP(polypropylene), PE(Polyethylene) and PS(Polystyrene)}, textile, wood, rubber, green tea waste, coffee sludge and Styrofoam and then sampled SRF in Incheon City [2].

3.1.1.1. Collection and transportation

Transporting collected household waste to the laboratory.

3.1.1.2. Classification

Classifying based on type (food, paper, vinyl, plastic(PP, PE, PS), textile, wood, rubber, green tea waste, coffee sludge, Styrofoam and SRF)

3.1.1.3. Prior treatment

Wear germ-free gloves for easier analysis of three contents to finely put them into pieces with scissor

3.1.1.4. Sampling

Create aluminum foil box to prepare samples

3.1.2. Analysis of three contents

Three contents refer to moisture content, combustible content and ash content, which are burned to some degree as long as they are physically prepared samples, and may be used as the number to identify ash content after they are burned. Such content may be identified by using the following method. The overall results are shown in Table 1.

3.1.3. Moisture content

By measuring the weight after getting them dried and comparing weight before and after getting them dried, it is possible to identify moisture content when making samples. By using drier, it is necessary to dry them for about 2 hours for 3 days until the weight of samples is kept constant in temperature of 105±5℃. If the weight remains constant, it is necessary to measure the weight of samples and calculate moisture content of each sample by using the following formula.

3.1.3.1.Measuring weight of evaporating dish

To measure weight of pure sample, we measured weight of evaporating dish.

3.1.3.2.Measuring weight of initial sample

We measured initial weight of each different sample before getting it dried and left the record.

3.1.3.3.Drying with large-sized dryer

We maintained dryer temperature at 105 Celsius Degree and then dried it for 2 hours for 3 days.

3.1.3.4.Measuring weight of sample after getting it dried

By measuring weight of sample after getting it dried, we calculated moisture content by sample.

3.1.4. Ash content

- Use crusher to pulverize dried samples into pieces less than 2mm and then further finely pulverize them on several occasions.
- Take the appropriate amount into a crucible to measure the weight.
- Heat samples in electric furnace in temperature of 600±25℃ for 4 hours to carbonize.
- After applying cool storage to completely combusted samples and drying them for 2 hours in temperature of 105±5℃, apply cool storage to the samples for about 30 minutes in drying container and then measure the weight to calculate weight of samples before and after they get burned.
- The ash content of each sample is calculated by using the following formula.

3.1.5. Combustible content

Combustible content refers to the content leaving out ash content and moisture content from the whole humid wastes. The combustible content based on moisture content may be identified as follows when W and A refer to moisture(%) and ash content(%) of moisture standard.

3.1.6. Research result

As a result of studying three contents, moisture content turned out to be high in the order of PE(28.85%), PS(18.63%), rubber(15.75%), SRF(9.64%) and Styrofoam(2.13%).

Table 1: Research results of combustible wastes

Types / Ingredient	Combustible waste											
	PP	PE	PS	Paper	Aliment	Wood	Rubber	Styrofoam	Vinyl	green tea	Coffee	SRF
moisture content(%)	20.72	28.85	18.63	30.47	61.51	65.25	15.75	2.13	30.77	53.62	51.31	9.64
combustible content(%)	77.42	70.57	77.80	46.59	33.32	28.13	69.39	97.68	57.11	42.36	47.79	76.02
Ash content(%)	1.85	0.57	3.56	22.93	5.16	6.61	14.86	0.17	12.10	4.02	0.9	14.34
Total	100	100	100	100	100	100	100	100	100	100	100	100

As for combustible content not containing moisture content and ash content, it turned out to be high in the order of Styrofoam (97.68%), PS(77.80%), PP(77.42%), SRF(76.02%) and PE(70.57%). Paper turned out to hold ash content of 20% or more. Among the 12 types of combustible wastes, plastics (Styrofoam, PS, PE and PP) and SRF turned out to have low moisture content and high combustible content.

3.2. Close look at air pollutant waste through element analysis

3.2.1. Research procedures

The equipment, usually used for analysis of high-resolution, high magnification and less-damaged surface, enables qualitative and quantitative analysis of unknown samples. SEM(Scanning Electron Microscope), which was developed by Carl Zeiss in 1846 in Germany with 50-year or longer history, disallows wavelength with half-wave or less reflected from samples to be identified through optical microscope. Because electrons used by E-GUN are too small, it is possible to make the measurement based on Nano, while major parts include column, detector chamber, table and PC. Upper part of the column includes Electron-GUN and emits high-voltage electrons. Below Electron-GUN lie condenser lens (focusing lens collecting beam), scan coil prompting electrons to be set in motion, stigmator designed to complement image (adjusting imbalanced image) and Probe Lens. If electrons are injected into samples through probe lens, they will respond to sample and emit signal creating image(secondary electrons emitted from sample through the response to E-Beam).

3.2.1.1.Preparing samples

Completely remove moisture from 12 types of combustible wastes by using dryer and pulverize them to create those samples which are 1 to 2mm big.

3.2.1.2.Prior treatment of element analysis

Wear germ-free gloves, fixate them into sample table and then prepare surface coating.

3.2.1.3.Coating platinum

Considering that electrons push away electronic beam after getting accumulated in samples to get warped image, we performed platinum coating.

3.2.1.4.Getting installed in FE-SEM(Field emission scanning electron microscope)

By injecting electron-ray into sample made aloft in the air, we detected signals generated from the surface of samples, enlarged them and then analyzed types of samples and elements making up the sample.

3.2.2. Research result

To analyze elements, we intensively analyzed content of chlorine and Sulphur likely to generate dioxin and sulfurous acid gas among C, H, N, O, S, Cl in the case of combustion.

Table 2: Analysis of chemical elements

Types / Element	Combustible waste											
	PS	PE	Rubber	Paper	General Vinyl	Wood	SRF	Coffee sludge	Food Waste	Green tea waste	pp	Styrofoam
C	99.60	69.69	77.47	49.53	99.84	38.31	59.69	69.51	62.48	69.33	99.31	99.85
H	·	·	·	·	·	·	·	·	·	·	·	·
O	·	30.23	18.02	46.48	·	59.98	38.42	30.30	37.11	30.01	·	·
N	·	·	·	·	·	·	·	·	·	·	·	·
S	·	·	**0.79**	·	·	·	**0.09**	**0.05**	·	·	·	·
Cl	·	·	**1.9**	·	·	**0.2**	**0.47**	**·**	·	·	·	·
Na	·	·	·	·	·	·	0.40	·	·	·	·	·
Mg	0.07	·	0.07	0.18	·	·	·	·	·	0.17	·	·
Al	·	·	·	0.29	0.16	·	0.10	0.08	·	·	·	0.07
Si	0.19	0.08	0.15	0.53	·	·	0.26	·	·	·	·	·
Ca	0.14	·	1.13	3.00	·	0.24	0.4	·	0.1	·	·	0.08
K	·	·	0.05	·	·	1.08	0.17	0.06	0.2	0.41	·	·
Zn	·	·	0.42	·	·	·	·	·	·	·	·	·
Pd	·	·	·	·	·	0.18	·	·	0.11	0.08	0.09	·
Ti	·	·	·	·	·	·	·	·	·	·	0.60	·
Total	100	100	100	100	100	99.99	100	100	100	100	100	100

The results are shown in Table 2. It turned out that rubber, wood and SRF contain combustible wastes with chlorine, rubber, SRF and coffee sludge contain combustible wastes with Sulphur. In particular, Sulphur likely to generate air pollutants in the case of combustion emits sulfurous acid gas(SO_2), while Chlorine(Cl) emits dioxin in high temperature(250~350℃) by triggering heavy metal (particularly copper) catalyst action in the event of combination with carbon. Given this, it is necessary to consider combustion of rubber, wood, SRF and coffee sludge in the course of waste treatment. As a result of analyzing content of heavy metal, it turned out that PP contains titanium (Ti)(0.60%) without other heavy metals such as mercury, cadmium, lead and arsenic being detected.

3.3. Comparison of solid fuel quality for SRF and 11 types of wastes based on analysis of heating calorie

3.3.1. Research procedures

Caloric value refers to calorie yielded when 1 kg of waste is burned out. When designing waste incinerator, qualitative characteristics serve as the basis. The method for calculating caloric value is divided into three types: direct calculation based on Calorimeter, on element analysis and estimate type based on three content [3]. Caloric value may be divided into Higher Heating Value and Lower Heating Value. Direct estimation involving Calorimeter involves the use of Bomb calorimeter, through which heating value is determined by measuring rising water temperature of water tank shrouding housing jar based on combustion heat in reactor shell [4].

3.4. Measuring weight of samples

Put 0.45 grams of each different sample into sample dish, point meter to zero point and then adjust it to specified grams.

3.5. Placing sample

Allow pointer of meter to point to sample and put a lid to Bomb calorimeter for injection of oxygen.

3.6. Combustion

Place samples into dish, inject oxygen until air pressure reaches about 20 to 25, place the whole body into water chaloriemeter, connect wires and trigger ignition to combust.

Table 3: Analysis of calorific values

Division	Combustibles											
	PP	PE	PS	Paper	Aliment	Wood	Rubber	Styrofoam	Vinyl	green tea waste	Coffee sludge	SRF
Dry Higher Heating Value (kcal/kg)	9743.12	5287.12	9161.54	2735.14	3516.47	4148.21	6721.30	8613.26	8933.90	3789.00	4562.86	4592.53
lower heating value (kcal/kg)	**7674.49**	**3588.68**	**7342.96**	1718.92	984.42	1050.00	**5568.]19**	**8417.01**	**6000.31**	1435.61	1913.79	**4091.97**
Quality Standards Compliance (3500kcal/kg)	○	○	○	×	×	×	○	○	○	×	×	○
elements analyzing (S,Cl Contains)	·	·	·	·	·	·	○	·	·	·	·	○
Solid fuel individualized recommendation	○	○	○	·	·	·	·	○	○	·	·	·

3.6.1. Research result

For heating value, we analyzed heating value as to combustible waste samples and displayed measured values of Dry Higher Heating Value by using automatic heating value meter. As a result of measuring Dry higher heating value, it turned out that PP(9743 kcal/kg) has the highest, followed by PS(9161 kcal/kg), Vinyl(8933 kcal/kg), Styrofoam(8613 kcal/kg) and rubber(6721 kcal/kg). Compared with plastics, green tea waste(3789 kcal/kg) and coffee sludge (4562 kcal/kg) have lower heating value, while they hold higher heating value compared with that of dried food waste(3516 kcal/kg) and wasted paper(2735 kcal/kg).

As a result of analyzing moisture content in Research 1 from Dry Higher Heating Value and element analysis in Research 2, hydrogen content(%) was used to calculate Moisture-based Lower Heating Value as shown in Table 3. It turned out that seven types have met solid fuel quality standards with Lower Heating Value of 3500 kcal/kg or more, while Lower Heating Value was high in the order of Styrofoam, PP, PS, vinyl, rubber, SRF and PE.

4. Conclusion and Suggestions

The research made qualitative comparison among 12 types of wastes and analyzed characteristics of combustible wastes which may be used as alternative energy of fossil fuel amid high oil price. In doing so, the study aims to take a closer look at efficiency of recycling energy and the potential by analyzing characteristics of segregated household wastes. The result of analysis through experiment is described as follows.

As a result of studying three contents, it turned out that plastics(Styrofoam, PS, PE and PP) has the lowest moisture content and highest combustible content among the 12 types of combustible wastes [5]). Compared with plastics, green tea waste(3789 kcal/kg) and coffee sludge(4562 kcal/kg) have lower heating value, while they hold higher heating value compared with dried food waste (3516 kcal/kg) and paper waste(2735 kcal/kg).

Simple combined incineration of wastes is short of efficiently utilizing potential energy of combustible wastes among household wastes. Thus, the study result will serve as the basis for research on the use of combustible wastes by maximizing recollection of combustible wastes as recycling resource and maximizing recycling and energy recovery.

5. References

[1] Sang-Soon Lee, Ha-Ig Jeong. Characterization of waste energy heating value of solid fuels. *Korea Soil Environment Society*. 2009, vol.9, pp. 330-333.

[2] Ha-Baek Yi. *Economic feasibility study of combustible solid waste into fuel facility*, 2010.

[3] Ministry of Environment. *To strengthen the institutional foundation for resource circulation policies suppress generation, reuse and recycle*, 2006.

[4] Seok-Jun Gim. *RDF (Refused Derived Fuel) technology trends at home and abroad*, 2007.

[5] Jun-Woo Yi. *RDF technology. Korea Institute of Science and Technology Information*, 2007.