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Thermogravimetric characteristics of typical municipal solid waste fractions during co-pyrolysis

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ABSTRACT

The interactions of nine typical municipal solid waste (MSW) fractions during pyrolysis were investigated using the thermogravimetric analyzer (TGA). To compare the mixture results with the calculation results of superposition of single fractions quantitatively, TG overlap ratio was introduced. There were strong interactions between orange peel and rice (overlap ratio 0.9736), and rice and poplar wood (overlap ratio 0.9774). The interactions of mixture experiments postponed the peak and lowered the peak value. Intense interactions between PVC and rice, poplar wood, tissue paper, wool, terylene, and rubber powder during co-pyrolysis were observed, and the pyrolysis at low temperature was usually promoted. The residue yield was increased when PVC was blended with rice, poplar wood, tissue paper, or rubber powder; while the residue yield was decreased when PVC was blended with wool.

1. Introduction

The amounts of municipal solid waste (MSW) are increasing rapidly (He et al., 2010). Traditional landfill method is facing many problems, such as land occupation, underground water pollution, and air pollution (Lee et al., 2014; Dong et al., 2003). MSW incineration has some advantages, such as volume reduction and energy recovery (Huai et al., 2008; Zhang et al., 2012). However, it also causes problems such as the release of dioxins (Zainal et al., 2014; Bogdal et al., 2013). In recent years, MSW pyrolysis is getting more and more concerns, because it may ease the problem of dioxins pollution and produce char, oil and syngas that can be further utilized (Luo et al., 2010; López et al., 2010).

MSW is a very complex mixture, and the composition of MSW varies from place to place and time to time. Therefore, research of MSW mixture is only meaningful for specific fractions of MSW, which means the experiments can be hardly repeated (Zhou et al., 2014). For this reason, increasing amounts of research began to focus on single fractions of MSW. For example, Luo et al. (2010) pyrolyzed three representative fractions (plastic, kitchen garbage and wood) in a fixed bed reactor to evaluate the influence of particle size on pyrolysis performance of single-component MSW. Zheng et al. (2009) studied the pyrolysis characteristics of six representative organic fractions of MSW (wood chips, fabric, food residue, rubber, PE and wastepaper) in a specially designed thermogravimetric analysis (TGA) apparatus with a maximum heating rate of 864.8 °C min^{-1}. Li et al. (1999) tested eight kinds of MSW fractions (paper, paperboard, waste plastics including PVC and PE, rubber, vegetal materials, wood, and orange husk) in a lab-scale rotary-kiln pyrolyser.

However, most of the research studies the characteristics of single fractions, while the fractions do not act independently during pyrolysis (Wu et al., 2014). Sorum et al. (2001) investigated possible interactions between different paper and plastic fractions, and it was found that the reactivity of cellulosic matter was increased in a mixture with PVC. McGhee et al. (1995) pyrolyzed the mixtures of PVC with straw, and reported that the char yields were greater than produced by pyrolysis of the individual fractions due to the interaction of HCl and cellulose below 600 K. Zheng et al. (2009) suggested that the presence of PE weakened the reaction intensity of biomass component during fast pyrolysis. This could be attributed to the endothermic reaction of PE pyrolysis to decrease the heating rate of the feedstock. However, when the heating rate was lower, its decrease caused by PE was comparatively lower. Most of researches focused on the binary interaction of two or three fractions, the interactions between various kinds of fractions have not been studied systematically.

The mean physical composition of MSW in Chinese cities is shown in Fig. 1. In combustible MSW, the contents of food residue, plastics, paper, textiles, wood waste and rubber, in decreasing order, were 55.86%, 11.15%, 8.52%, 3.16%, 2.94% and 0.84% (Zhou et al., 2014).

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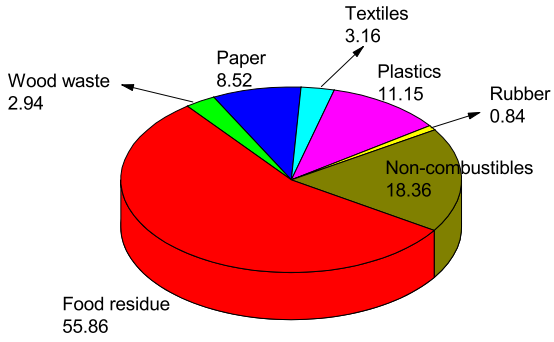

Fig. 1. The mean physical composition of MSW in China.

In this paper, nine kinds of MSW typical fractions were selected to study the thermogravimetric characteristics of interactions. According to the MSW fractions as reported in Fig. 1, orange peel and rice are representatives of food residue; poplar wood is representative of wood waste; tissue paper is representative of paper; wool and terylene are representatives of textiles; PE and PVC are representatives of plastics; and rubber powder was representative of rubber. The results of mixture experiments were compared with the calculation results of superposition of single fractions. Overlap ratio was applied to evaluate the interactions quantitatively.

2. Material and methods

2.1. Materials

The MSW fractions included orange peel, rice, poplar wood, tissue paper, wool, terylene, PE, PVC and rubber powder. Orange peel, rice and tissue paper were collected from the supermarket or restaurant in Tsinghua University, and poplar wood was collected from trees in Tsinghua University. Wool and terylene were collected from a shopping mall in Beijing, PE and PVC were provided by Shanghai Yangli Mechanical and Electrical Technology Co., Ltd. Rubber powder was provided by Hangzhou Boyang Rubber Chemical Co., Ltd.

The proximate and ultimate analyses of the samples were shown in Table 1. Poplar wood and rubber powder have relatively high ash content, plastics (PE and PVC) show the highest volatile, orange peel and rubber powder have the highest fixed carbon content. The highest volatile was also reported by other research (Sorum et al., 2001). PE and rubber powder have the highest elemental carbon content (more than 80%), and they have little oxygen content, as reported by Sorum et al. (2001). PE has the highest hydrogen content of 11.20%, which has also been reported by other research (Li et al., 1999). The nitrogen and sulfur content of all the samples are less than 2% with exception of wool. PVC has a chlorine content of 56.35%, which was also reported by Li et al. (Li et al., 1999). The high heating value (HHV) of the samples except PE and rubber powder varies from 17.25 to 20.92 MJ kg^{-1}, while

Table 1
Proximate and ultimate analyses of MSW fractions.

MSW classification	Samples	Proximate analysis			Ultimate analysis					HHV^d (MJ kg^{-1})
		A_d%	V_d%	FC_d%	C_d%	H_d%	O_d%	N_d%	$S_{t,d}$%	
Food residue	Orange peel	2.91	76.49	20.60	47.32	5.75	42.45	1.39	0.18	18.47
	Rice	0.40	84.42	15.18	45.79	6.32	45.56	1.68	0.25	18.14
Wood waste	Poplar wood	7.54	73.85	18.61	47.49	5.45	37.91	1.41	0.20	18.50
Paper	Tissue paper	0.52	90.47	9.01	44.95	6.10	48.07	0.25	0.11	17.25
Textiles	Wool	1.24	84.76	14.00	59.33	4.19	31.09	2.62	1.53	20.92
	Terylene	0.49	88.60	10.91	61.86	4.12	32.96	0.29	0.28	20.86
Plastics	PE	0.00	99.98	0.02	85.98	11.20	2.44	0.21	0.17	46.48
	PVC	0.00	94.93	5.07	38.34	4.47	56.35[a]	0.23	0.61	20.83
Rubber	Rubber powder	10.24	62.83	26.93	80.36	6.01	0.96	0.62	1.81	35.74

A: ash; V: volatile; FC: fixed carbon; HHV: high heating value; d: dry basis.
[a] It is Cl for PVC.

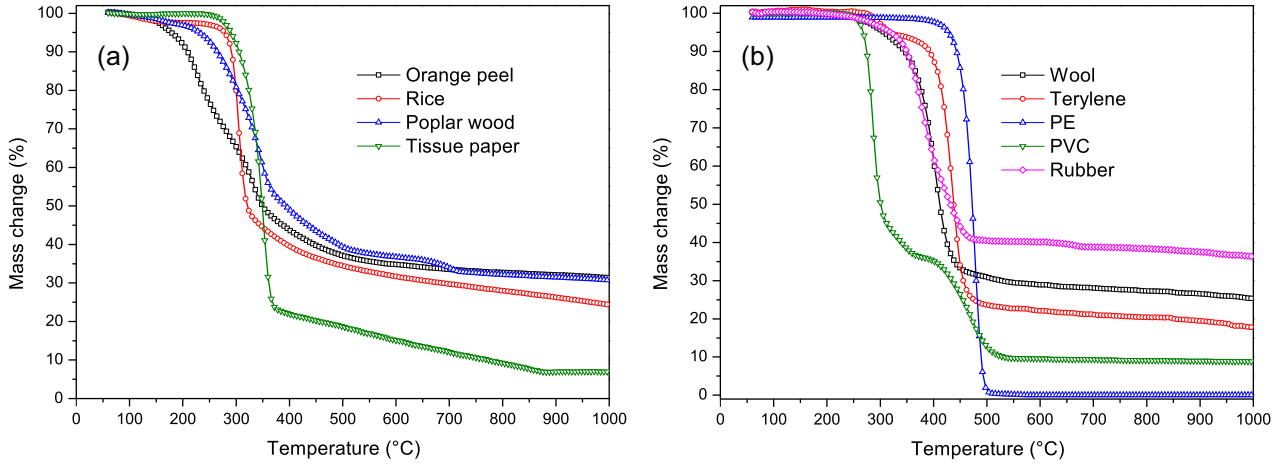

Fig. 2. TG curves of MSW fractions pyrolysis at a heating rate of 10 °C min^{-1}.