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Effect of mixing methods of polyethylene and cellulose on volatile products from its co-pyrolysis

Nanta Sophonrat^{a,*}, Weihong Yang^a

^a*KTH Royal Institute of Technology, Stockholm 100 44, Sweden*

Abstract

Co-pyrolysis of biomass and plastic wastes is an alternative solution to produce fuel as well as to reduce environmental problem generated from municipal solid waste (MSW). Polyethylene (PE) and cellulose are the main compositions of waste packaging. To produce fuel from these two feedstocks by pyrolysis, the interaction/synergistic effect between them during pyrolysis should be studied. Due to that the interaction should be more pronounced if the two materials are in close contact, the mixing methods of the feedstocks can affect the product yield. In this work, the effect of mixing PE and cellulose on the volatile products from co-pyrolysis was investigated using Py-GC/MS with pyrolysis temperature of 600°C. The different mixing methods used are: mixing by melting (cellulose powder submerged in PE film) and not mixing. The results showed that when PE and cellulose are not mixed the change in products are not significant, only slight increase in acetic acid is observed. When mixed by melting, more oxygenated compounds were produced e.g. higher acetic acid, aliphatic ketones and some pyrans. However, the increases are small and does not significantly affect the main products which are aliphatic hydrocarbons from PE and levoglucosan from cellulose.

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Keywords: polyethylene; cellulose; co-pyrolysis; interaction

1. Introduction

Municipal solid waste is no doubt one of the main challenges in our society today. While sorting and recycling can be done to recover some materials, not small fractions are difficult to sort. Thermal treatment i.e. combustion is the

* Corresponding author. Tel.: +4-676-927-5998

E-mail address: nanta@kth.se

current options for recovering energy from this mixed fraction. However, the main energy application of biomass/waste combustion is district heating with lesser electricity production [1]. An alternative for tropical countries is to focus more on electricity or fuel production from this waste fraction. This can be done by gasification and pyrolysis. Pyrolysis is the most fundamental process in thermal combustion. Therefore, the understanding in the process can benefit other thermal process also.

Plastics and paper are the main materials for packaging wastes. While the main plastic compositions are polyethylene, polypropylene, and some smaller fractions of polystyrene, polyethylene terephthalate, and polyvinyl chloride, the main composition of paper is cellulose. Thus, it is crucial to first understand the interaction/synergistic effect of the main components of this fraction which are polyethylene (PE) and cellulose.

There are earlier studies on co-pyrolysis of polyethylene and cellulose. With thermogravimetric analysis, no significant changes in the mass loss curve was found indicating small to no interaction during thermal decomposition [2,3]. The products analysis with GC/MS indicated no formation of new products [4,5]. However, some changes in quantities of some products were found. Some furans derived from cellulose slightly increased and C5 – C22 hydrocarbons also increased, while char yield decreased.

Since packaging waste can be found in many form e.g. layers, composites, it is interesting to investigate if the mixing methods have any effect on the products of co-pyrolysis. The interaction between two materials should be more pronounced if they are in close contact. Moreover, when the materials are pyrolyzed in pyrolysis process, it can happen that they might or might not be in close contact. In this work, we investigate the volatile products from co-pyrolysis of polyethylene and cellulose with two mixing conditions which are mixing by melting at 105°C and not mixing. The main goal of co-pyrolysis is to produce pyrolysis oil or chemicals.

2. Materials and methods

2.1. Materials

Cellulose power with 50- μ m particle size was purchased from Sigma-Aldrich. Additive-free polyethylene film of 50-micron thick was bought from Good Fellow Ltd., UK. The fuel properties analysis of the two materials was shown in Table 1. To prepare the mixed sample, 1:1 weight ratio of both sample was used. Cellulose powder was put on top of PE film which is put on aluminum foil for easily removal. The sample is then put into the oven at 105°C. It was found that cellulose powder does not easily sink into polyethylene film. Then, ceramic plates were used to press the powder down to the film. This process occurs after 1 day in the oven. Short drying time of 2 hours was also investigated. The film of mixture was then cooled down in desiccator and was cut using a 1.5mm diameter circular cutting mold. The sample weights are around 0.15 mg.

Table 1. Proximate and ultimate analysis of feedstocks

Materials	Forms	Elemental analysis				Proximate analysis		
		C	H	N	O*	Volatile	Ash	Fix carbon
Cellulose	50 micron powder	44.1	6.3	<0.1 [†]	49.5	88.9	<0.3 [†]	11.1
Polyethylene (Low density)	50-micron thick film	84.8	13.7	<0.1	1.5	100	<0.3	-

* Calculated from 100% difference, † lower limit of detection

2.2. Py-GC/MS Experiments

The pyrolysis was done in Py-GC/MS system with Pyrola2000 Pt-filament pyrolyzer connected to Agilent 7890A gas chromatograph (GC) and Agilent 5975C mass spectrometer (MS). The Pyrola2000 pyrolyzer can sharply increase the temperature of the Platinum filament to the set temperature within 8ms and hold for 4s. The sample used in each experiment is approximately 0.1 mg. The pyrolysis products were then transferred to the GC with transfer line/GC liner holding at 280°C.

The GC was equipped with VF1701 column. Helium flow of 1 mL/min was used as carrier gas. The GC oven was hold at 45°C for 4 min then the temperature was increased with 3°C/min to 280°C and hold for 15 min. The split ratio

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