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Pyrolysis behavior of different type of materials contained in the rejects of packaging waste sorting plants

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ABSTRACT

In this paper rejected streams coming from a waste packaging material recovery facility have been characterized and separated into families of products of similar nature in order to determine the influence of different types of ingredients in the products obtained in the pyrolysis process. The pyrolysis experiments have been carried out in a non-stirred batch 3.5 dm^3 reactor, swept with 1 L min^{-1} N_2, at 500 °C for 30 min. Pyrolysis liquids are composed of an organic phase and an aqueous phase. The aqueous phase is greater as higher is the cellulosic material content in the sample. The organic phase contains valuable chemicals as styrene, ethylbenzene and toluene, and has high heating value (HHV) (33–40 MJ kg^{-1}). Therefore they could be used as alternative fuels for heat and power generation and as a source of valuable chemicals. Pyrolysis gases are mainly composed of hydrocarbons but contain high amounts of CO and CO_2; their HHV is in the range of 18–46 MJ kg^{-1}. The amount of CO—CO_2 increases, and consequently HHV decreases as higher is the cellulosic content of the waste. Pyrolysis solids are mainly composed of inorganics and char formed in the process. The cellulosic materials lower the quality of the pyrolysis liquids and gases, and increase the production of char.

1. Introduction

One of nowadays most important waste is plastic. In Spain about 3 million tons/year of packing and packaging waste are generated of which about 30% of these waste are composed of plastics and metals (Ecoembes, 2009; Ecovidrio, 2009). In Spain and many other countries selective collection of packing waste is made by means of three municipal colored containers; blue for paper and cardboard, green for glass and yellow for plastics, drink cartons (Tetra-Brik©) and metals.

In Spain about 75% (≈675,000 tons) of plastic/metal packages are collected in the yellow containers and transported to material recovery facilities where the waste is separated in different fractions (steel cans, Tetra-Brik©, aluminum cans, and different plastics) that are then sent to recycling companies. However a significant amount of the income materials cannot be properly classified or separated and is rejected. The rejected fraction from these facilities amounts up to 35% (mean value of Spanish sorting plants).

In the European Union about 80 million tons/year of packaging waste (Eurostat, 2006) is generated. Assuming that EU collection and recycling rates are similar to those of Spain, more than 6 million tons/year of a waste that has not a clear alternative for recycling will be coming out from packaging sorting plants. The EU legislation (Packing and Packaging Waste Directive 2004/12/CE) obliges to recycle between 55% as a minimum and 80% as a maximum by weight of packaging waste. In EU about 34% of plastic waste is incinerated with energy recover while just 24% is recycled (Plastics Europe, 2009). Pyrolysis looks as an attractive alternative for increasing plastic waste recycling rates, especially complex waste or that refused from packaging sorting plants. Such waste is composed of many small size products composed of different materials and which are very much intermingled. An example of the look of the rejects of a packaging sorting plant is presented in Fig. 1. Consequently it is neither reasonable nor economically viable to separate pure fractions for mechanical recycling from such waste. Other alternative recycling technique for this type of complex waste is gasification. The main advantages of pyrolysis compared with gasification are that pyrolysis is carried at lower temperatures than gasification, and that it is a more direct route to obtain valuable chemicals (liquids) than gasification followed by synthesis processes.

In this study, pyrolysis, a chemical recycling process, was carried out on a laboratory scale as an alternative for valorising the rejected streams coming from industrial plants, where packing and packaging waste is classified and separated. In the pyrolysis process (heating without oxygen), the organic components of the material are decomposed generating liquid and gaseous products. The inorganic ingredients (e.g. fillers or metals) remain practically

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Fig. 1. Rejected waste from a packaging sorting plant (as received).

unaltered and free of the binding organic matter, and therefore they could be separated and hopefully reused; anyhow, the amount of waste to be treated and/or landfilled would have been drastically reduced.

The pyrolysis process can reduce the environmental problem in several ways: on the one hand if there are hazardous materials in the pyrolysis solids, they would be concentrated in a minor volume; on the other hand if pyrolysis liquids are used instead of fossil fuels, CO_2 emissions would be reduced since less fossil fuels are consumed; and finally, the liquid and gas products generated in the pyrolysis are valuable products which can be used as fuels and/or as sources of chemicals.

There are many references in the literature about the thermal decomposition of plastics. But most of the pyrolysis studies have been carried out with individual pure plastics (e.g. Faravelli et al., 2001; Levine and Broadbelt, 2009; Williams and Williams, 1999; Yoshioka et al., 2004), or with mixtures of pure plastics (e.g. Angyal et al., 2007; Demirbas, 2004; Kiran et al., 2000). Only a few studies have been published concerning pyrolysis of real municipal plastic waste (Kim et al., 1997; Kaminsky and Kim, 1999; Bhaskar et al., 2003; Lee, 2007) and there is no information about the effect of the waste composition on the pyrolysis process and the products obtained.

Previous studies carried out by the authors showed that, both pyrolysis yields and characteristics of pyrolysis products significantly vary with the composition of the raw material pyrolyzed (López et al., 2010). Obviously there are considerable differences among the compositions of the rejects of different material recovery facilities, due to differences in the separation processes, in the raw materials reaching the plants and in the season of the year. Therefore the determination of the pyrolysis behavior of the different type of materials contained in packing and packaging waste is of the most interest.

In this work samples coming from a material recovery facility have been characterized and separated into families of products of similar nature (plastics, cellulosics, inorganics, etc.). Both the whole samples and the subsamples have been pyrolyzed at 500 °C in a fixed-bed reactor at laboratory scale. The objective of this work was to determine the effect of the different waste components (plastics, cellulosics, inorganics) on the pyrolysis process.

2. Experimental study

2.1. Origin and characteristics of the samples pyrolyzed

The samples used in the experiments were waste samples provided by BZB, a material recovery facility in which the waste of packing and packaging municipal containers of Bizkaia (Spain) are separated and classified in different fractions (steel cans, Tetra-Brik©, aluminum cans, and different plastics) and the separated fractions are sent to recycling companies. Although the purpose of the recovery facility is the complete separation of the waste, there is a rejected fraction which amounts up to 20–30% of the income materials and is composed of many different materials (polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET), acrylonitrile butadiene styrene (ABS), Tetra-Brik©, aluminum, film and some others).

The contents of yellow municipal bins are received by truck daily in the sorting plant and are piled up all together previous to feeding the plant. No change in composition by hours or days are therefore expected but variations with season due to different citizens habits or with special dates (Christmas, local festivals) do are expected. This information was corroborated by the manager of the sorting plant. Once in the plant several automatic devices (trommels, magnetic units, Eddy current units, autosorters) separate the different plastics and materials. The non-separated materials are conducted by means of conveyor belts to 30 m^3 containers where the rejected materials are stored until they are transported to landfills or incineration plants. Two 25 kg waste samples were collected from the 30 m^3 containers after turning over and mixing thoroughly the waste in the container. One sample was collected in July 2010 (named as sample 1) and the other in October 2010 (named as sample 2). Representative 2 kg samples of each of the two samples were separated by manual mixing, coning, flattening, quartering, and discarding of two opposite-lying quarters, repeating the whole process two times. These representative fractions were manually separated into different materials based on the knowledge and experience of the operators. In doubtful cases, infrared spectroscopy or simple identification tests such as flame color, fumes characteristics, were used for identifying the material.