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Potentials of pyrolysis processes in the waste management sector

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Abstract

The fundamentals of pyrolysis, its latest developments, the different conditions of the process and their relative residues are of great importance to evaluate the applicability of the pyrolysis process within the waste management sector and waste treatments. In particular the type of residues and their further use or treatment is of extreme interest as they could become the source of secondary raw material or generate beneficial influence in waste treatments. The main area of focus of this paper is the investigation of the link between the pyrolysis conditions, the chemical and mineralogical composition of their products and the benefits of pyrolysis in the waste management sector. More specific the paper covers the fast, intermediate and slow pyrolysis of organic and a mixture of inorganic/organic charge from households. The catalysts influence during fast pyrolysis on products yields and composition is not being considered in the review.

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Keywords: household waste; MSW; biomass; paper; plastics; food waste; pyrolysis

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1. Introduction

Each person consumes a certain amount of produce, but during this process a large amount of waste is produced and discarded. The disposal of excess products and waste has been at the forefront of combating climate change... In modern societies, the amount of waste generated by the average consumer is staggering and constantly increasing. It is estimated that the statistical inhabitant of Western Europe produces more than 450 kg of garbage per year [1]. Generally, municipal solid waste (MSW) covers waste from households and consists of plastics, paper, metals, textile, organic waste, leather, rubber, metals, glass, ceramic, earthen materials and miscellaneous other materials. Typical households waste contain a wide range of materials that significantly vary in composition depending on the type of community and its consumers' incomes and lifestyles, and its degree of industrialisation, institutionalism and commercialism [2]. In some areas such as China, more than half of waste produced in household are food waste [3].

Pyrolysis is the thermochemical decomposition of organic material at high temperature and in absence of oxygen or inert gases atmosphere. Nowadays, pyrolysis is getting attention for its flexibility to generate a combination of solid, liquid and gaseous products in different proportions just by the variation of operating parameters such as temperature or heating rate. It also gives possibility to transforms materials of low-energy density into bio-fuels of high-energy density and recover higher value chemicals [4,5]. Different types of pyrolysis have been developed: fast, catalytic fast, intermediate, slow, vacuum. Moreover, different types of reactors have been investigated. One of the great advantages of this process is that many types of raw material can be used, including industrial and domestic residues. The fractions of MSW subjected to pyrolysis mainly include food waste, paper, cloth, plastics, and yard waste. It is then easy to understand the high variability of conditions and consequently of residues obtainable. Prerequisite for pyrolysis successful application is the appropriate choice of input materials and setting of optimal process conditions. For these reasons, suitability or unsuitability of selected types of waste and their mixtures for the pyrolysis process was verified by laboratory experiments many times with subsequent assessment of the quantity and quality of the individual products of pyrolysis [6].

2. Types of waste treated by pyrolysis

Depending on feedstock for pyrolysis process, conditions and the type of reactor used, the yields and the composition of pyrolytic products can be significantly different. Several examples of products yields form pyrolysis process according to the process parameters are shown in Table. 1. Furthermore, analysis of composition and properties of gas, liquid and solid pyrolysis products are made below.

2.1. Food waste

It is estimated that as much as 50% of the food produced is wasted before and after reaching the consumer, accounting for over 1.3 billion tons per year of food globally produced for human consumption [7]. Food waste contains lipids, carbohydrates, amino acids, phosphates, vitamins and other substances containing carbon, thus it can be a valuable source of fuels [8]. The food waste can be divided into several groups as follows: organic crop residue, catering waste and derivatives (including used cooking oils), animal by-products and mixed domestic food waste [7]. Pyrolysis of selected food waste, like: fruit peels [9–11], potatoes peels [12], nuts shells [13–15] or bones and meet [16,17] were investigated and has been commonly noted in literature. However, many of works focused on bio-chars. Moreover, there is limited information about pyrolysis of mixed food waste from households.

Liu at el. [18] investigated the treatment of food waste by pyrolysis with microwave heating. Food waste was collected from a residential area in China. Fruits, plastic and shells were removed from the raw food waste, thus the remaining; three main components were white rice, vegetable leaves, and meat/ bones, with proportions of 32.69%, 44.23% and 23.08%, respectively. The measurement of the temperature profiles of food waste under different microwave powers was one of the main aims of this work. The composition of the obtained products has not been considered. The yield of solid residue decreased sequentially, the gas yield increased continuously, and the bio-oil yield first increased, and then decreased when the microwave power increased from 300 to 600 W. The optimal level of power for pyrolysis was 400 W. In turn, *Zhang at al.* [19] studied the fast pyrolysis of food waste. The composition of the study was very similar like the investigation mentioned above. For the fast pyrolysis of food waste at 600 °C,