Co-pyrolysis of biomass and plastics from waste in an induction heated reactor

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Keywords: solid waste, pyrolysis, gasification, synergistic interactions.
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Pyrolysis and gasification have gained attention in the last years as thermochemical conversion pathways for energy recovery of solid waste. Produced syngas can be further used in the production of energy, heat, or derived chemicals, however, large-scale application still needs to overcome some technical barriers. High calorific fractions of solid waste, which cannot be reused or recycled, are increasingly used in the production of alternative fuels for the purpose of energy recovery, like Refuse Derived Fuel (RDF) or Solid Recovered Fuel (SRF). Biomass and plastic materials are the main components of these blended feedstocks, therefore the increasing interest on the comprehension during its co-processing. Several studies have reported the presence of synergistic effects interactions between the two components (Burra & Gupta, 2020), which influence the yield and composition of the final products.

Product distribution is also influenced by temperature, heating rate and residence time, features that are directly related to reactor configuration. So far, most of the laboratory scale studies have been conducted by TGA (thermogravimetric analysis), where samples between 5 and 50 mg are normally used to reduce heat and mass transfer limitations. However, some of the reaction conditions found in TGA and other laboratory-scale devices are not representative of full-scale reactors, which present high heating rates and good gas-solid contact. Induction heating is an interesting alternative without the shortcomings of conventional heating (non-uniform temperature distribution, slow heating rates). Nevertheless, the literature regarding pyrolysis or gasification applications at laboratory scale using this method is very scarce. The present work investigates the synergistic effects between biomass and plastics from solid waste by performing co-pyrolysis tests of beech wood, polyethylene, polypropylene, and its mixtures in an induction heated reactor. Carbon conversion to products and the composition of permanent gas were evaluated for the mixtures, and experimental results were compared to the weighted value from the pyrolysis yields of individual components.

Beech wood (BW) was selected as model material for the biogenic and lignocellulosic fraction while low density polyethylene (LDPE) and polypropylene (PP) were selected as references for plastics. All materials were grounded and sieved to a particle size of 1.2 mm, then 50/50 wt% mixtures of BW/PE (Mix#1) and BW/PP (Mix#2) were pressed to produce pellets thus to ensure close contact between the two materials and to enhance the possible interactive effects. Elemental composition (C, H, N, S, O), moisture and ash content were determined for all the samples.

A laboratory-scale device consisting in a stainless-steel tube (560 mm in height, 30.15 mm in internal diameter) heated externally by induction was used to perform the pyrolysis experiments. Sample crucible was filled with 2 to 3g of dried feedstock (24h at 105°C) and placed in the isothermal zone of the reactor. N_2 (0.5 L/min) supplied from the bottom of the reactor was used to purge the system and to carry the produced volatiles. The reactor was heated up to 800°C, with a heating rate of about 70°C/s, and then held at this temperature for about 20 minutes. Released volatiles flowed upwards the reactor to the tar trapping system, where five gas washing bottles filled with 2-propanol collected the condensable species (water and tar) present in the stream. Permanent gaseous species (H_2, CO, CO_2, CH_4, C_2H_n, C_3H_n, C_6H_6 and C_7H_8) were monitored by gas chromatography and non-dispersive Infrared detection (NDIR). Condensable species were sampled and then analyzed by GC-FID (Flame Ionized Detector). Solid residue was collected and weighed at the end of each test. Every test was performed at least two times, the values did not differ by more than 3%.

The carbon distribution into each of the pyrolysis main products (permanent gases, tar, char) was determined and is presented in Figure 1 for each test. In all cases most of the initial carbon was converted into gas,

as the high temperature and heating rate enhanced the thermal degradation of primary volatiles. The carbon fraction in solid was under 2% for PE and PP, and it was much greater in the case of beech wood (37,4%) as a result of its oxygen content. The missing carbon fraction could be attributed to condensable products that are deposited in the reactor outlet despite of tracing, and to hydrocarbons that cannot be identified or quantified in the GC -MS/FID analysis. Gas produced by PE presented the highest H_2 yield (2 wt%), and the highest fraction of C_2 hydrocarbons (27 wt%), mainly composed by ethylene. PP produced higher yields of propene (10 wt%) and methane (18 wt%), possibly due to the cracking of its methyl group. As expected, oxygen content in BW was responsible for high yields of CO (25 wt%) and CO_2 (11 wt%).

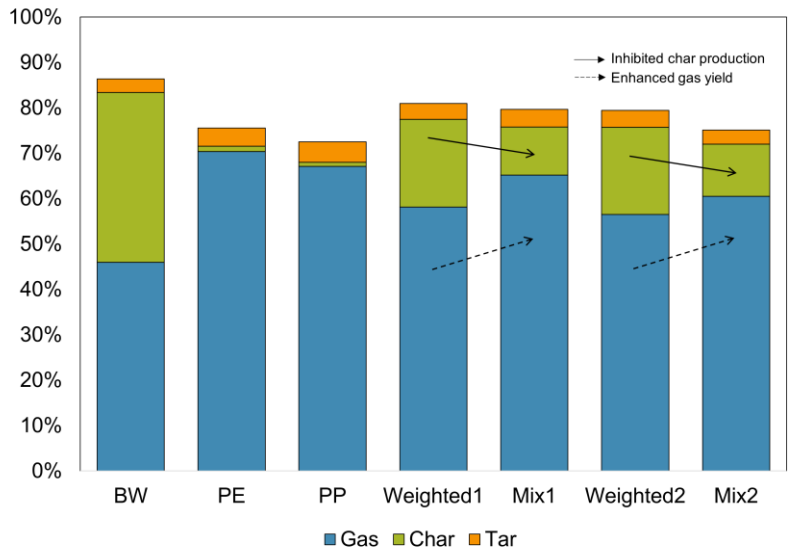

Figure 1. Carbon distribution to pyrolysis products for individual materials and their mixtures.

Experimental results for the mixtures were then compared to the linear sum of each individual materials to assess the synergistic effect between biomass and plastics. For both mixtures, the carbon conversion to gas products was greater than expected, while the solid residue was reduced to almost the half of the weighted sum values. For the PE/BW mixture (Mix1) CO and C_2H_2 yields were enhanced by 16% and 38% respectively. For the PP/BW Mix 2, H_2 and CO yields were enhanced by 16% while light hydrocarbons were slightly lower. The observed synergistic effects can be attributed to reactions between the oxygen containing radicals from biomass pyrolysis and hydrogen donor species from plastic pyrolysis, which enhances the production of oxygenated compounds as CO and CO_2 and reduces the yield of light hydrocarbons as seen in the work of Liu et al., 2020. The reduction of char observed in both cases suggests a reduction of condensation and aggregation of wood pyrolysates, which are initially dispersed in the plastic melt and then are evaporated participating in diverse interactions in the vapor phase.

Tests in gasification conditions will be shortly continued. The findings of this work will help to elucidate the relation between the initial components of waste derived fuels and the obtained reaction products, so as for the development and validation of accurate prediction models.

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