**Reaction technology change from semi-continuous to continuous pyrolysis of beech wood**

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**Highlights**

* Same reaction parameters yielding the maximum bio-oil yield for both reactors.
* Varying pyrolysis temperature impacted significantly on the product distribution while varying gas residence time did not.
* Many non-compliant observations were obtained between the semi-continuous and the continuous setups.

**1. Introduction**

This study aims to investigate the pyrolysis of the beech wood in a drop tube reactor (DTR) so as to examine the liquid and gas pyrolytic product distributions and also, compare these results with those obtained in a semi-continuous reactor [1].

**2. Methods**

The pyrolysis runs were done in a semi-continuous quartz tubular set up [1] and in a stainless steel DTR. In the DTR, the biomass was introduced using a screw-fed conveyor. A condenser and a flask, placed inside a cold bath to recover the bio-oils formed from the condensation of pyrolytic vapours were found at the end of the circuit. A sampling bag was used, in which the non-condensable gases were recovered to be later analysed. A flow of 500 mL/min of nitrogen was used as carrier gas. The cold bath and the refrigerant were both kept at a constant temperature of -10 °C. For the purpose of this study, the pyrolysis experiment was conducted in a stainless steel DTR at different temperatures of 500, 550 and 600 °C with varying vapour residence times by changing nitrogen flow rates to 500, 1000 and 2000 mL/min. Gas chromatography-mass spectrometry (GC-MS) and gas chromatography-thermal conductivity detection/flame ionisation detection (GC-TCD/FID) technologies were used to identify and quantify the various components found in the bio-oils recovered and the non-condensable gases collected. Concerning the bio-oils, the components belonging to the same chemical family, that is, possessing the same functional group, were grouped together and their percentage by weight evaluated.

**3. Results and discussion**

It was firstly seen that the experiment at 500 °C under 500 mL/min N2 yielded the highest amount of bio-oil (58.8 wt. %). This coincided with the findings from the semi-continuous setup (max. yield of bio-oil: 58.18 wt. % at 500 °C). In contrast to Guizani *et al*. [2], it was seen from this study that the major chemical families present in the collected oils were carboxylic acids (58 mol. %), phenols (16 mol. %) and alcohols (12 mol. %); this trend was not far from what was found from the semi-continuous setup [1]. However, the percentage for each family differed: the percentage of acids was higher in the DTR (58 mol. % vs. 35 mol. % in the semi-continuous setup). Then, while it was verified that varying the vapour residence times did not impact the product distributions significantly as the reaction regime did not change, varying the DTR temperature did affect the product distributions. It was also observed that both the percentages of carboxylic acids and alcohols tended to decrease with increasing temperature, while phenols demonstrated the opposite trend. This corroborated an inversely-correlated relationship between acids and phenols. This relationship was not observed in the semi-continuous reactor; the inversely-proportional relationship of carbohydrates and acids was more obvious in the latter setup.

Then, it was seen that increasing the reaction temperature favoured the dehydration reaction of the alcohol, carbohydrate and carboxylic acid groups. It was also found that the oxygen content of the bio-oils decreased with mounting DTR temperature. This observation goes along the fact that higher reaction temperatures tend to privilege cracking reactions, and hence, smaller, gas molecules formation. However, the overall oxygen content of the bio-oils remain quite elevated (29-40 mol. %) as compared to that of fossil-derived fuels (~1 %) [3], but also to the oils obtained in the semi-continuous reactor (~33 mol. %). This difference was directly linked to the higher percentage of acids present in the DTR bio-oil samples.

As for the non-condensable gases (NCG) fraction, the species present in majority was CO (58 vol. %), as for the semi-continuous reactor (45 vol. %), but, again comprising a slightly higher percentage. In the DTR, while CO2 experienced a reduction in its percentage, the CO percentage remained quite stable, contrary to the semi-continuous reactor, where CO increased while CO2 decreased.

**4. Conclusions**

It was found that despite not using the same installation, the reaction parameters yielding the maximum bio-oil yield were the same: 500 °C under 500 mL/min N2 (~58 wt. % in both cases). Also, while varying the temperature impacted significantly on the product distribution (higher temperatures yielded higher gas products and a more acidic oil), varying the gas residence time did not quite alter the product distribution as it was found that the pyrolysis was still taking place within the intermediate regime, and that the reaction was governed by the biomass particle residence time. Finally, many non-compliant observations were obtained between the semi-continuous and the continuous setups. This fact highlighted the heightened error margin present for using results obtained in a semi-continuous or discontinuous setup to globally model pyrolysis as a continuous reaction.

**References**

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