Torrefaction behaviour of various biomass types: kinetics of solid mass loss and release of volatiles

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Feedstock variability is a crucial issue for industrialization of biomass conversion processes. Indeed, this variability may imply large differences of chemical reaction rates and products yields and therefore differences of reactors design. In this context, the present study, which is part of the French-Brazilian ANR-FINEP project AMAZON, aims at characterising the behaviours of various biomass types during torrefaction in terms of solid mass loss kinetics and volatiles release. This should enable (i) to draw conclusions regarding their use in a process and (ii) to develop predictive kinetic models valid for various biomass feedstocks.

The experiments are performed on 17 biomass including different kinds of wood (French woods: beech, pine, eucalyptus, false acacia and poplar Short Rotation Coppice (SRC) and Short Rotation Forestry (SRF); Brazilian woods: angelim, faveira, maçaramduba) and agricultural biomass (wheat straw, immature annual crop: triticale, forage grass : tall fescue and perennial herbaceous crops harvested dry in late winter: :miscanthus, switchgrass;).

For study of solid mass loss kinetics, TGA experiments are performed during several hours at three final temperatures (230; 250 ; 280°C). For study of volatiles release, experiments are carried out at 250°C in a lab-scale reactor in which it is possible to close the mass balance during torrefaction of several grams of biomass. Gaseous species are continuously quantified thanks to a µGC, and condensable species contents are measured using a GC-MS analyser.

Three different kinetic behaviours can be observed depending on the species and their chemical composition, notably their hemicelluloses / xylose content. Mass loss is relatively slow for mature woods during the first hour, but then keeps on being significant even for very long durations. Initial mass loss is very sharp for the straw, the annual crop and the forage grass but then attains a plateau. Perennials and SRF/SRC exhibit the same behaviour, with an intermediate mass loss between mature wood and the other group of agricultural biomasses during the first hour and then a significant mass loss for long duration. These behaviours can be successfully modelled with the Di Blasi-Lanzetta scheme [1], based on two successive steps constituted of two parallel reactions, and able to describe the influence of temperature on solid yield. In a process viewpoint, to keep a reasonable mass loss, these results imply that agricultural biomass must be torrefied under less severe conditions than wood.

Regarding gas release, contents and distribution of water, condensable species and non condensable species depend on the type of biomass and their chemical composition. The same previous three main families can be observed. In particular, for condensable species, acid fraction is low for wood, more important for perennials, and is the major part for the straw, annual and forage crops family. Some products are typically found in significant amounts in one family (formaldehyde in wood; formic acid in perennials crops and glycoaldehydedimer in straw, annual and forage crops family). In a process viewpoint, this means that cleaning step and further products recovery may be different according to the biomass type.

[1] Di Blasi C, Lanzetta M (1997) Intrinsic kinetics of isothermal xylan degradation in inert atmosphere. Journal of Analytical and Applied Pyrolysis 40-41:287-303