**Woody and Agricultural Biomass Torrefaction: Modelling Solid Conversion and Volatile Species Release by Extracted Macromolecular Components.**

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**Highlights**

* 14 woody and agricultural biomasses were deeply characterized in torrefaction.
* Extracted cellulose, hemicelluloses and lignin from five biomasses were also torrefied.
* Biomass characterization and family type strongly impacted its behavior in torrefaction.
* Biomass behavior in torrefaction was better represented by the extracted components.

**1. Introduction**

Due to its diversity and dispersion, biomass waste is currently underexploited. To face this issue, the European project MOBILE FLIP proposes to develop mobile conversion processes, among which torrefaction. This mild thermal treatment (200-300°C, 10min to 1h, default-oxygen atmosphere) gives rise to a solid with optimized processing properties and condensable coproducts with high-added value as “green” chemicals.

Biomass is a highly diverse resource, whose properties are very different from a coniferous to a deciduous wood, or from an agricultural by-product to an herbaceous crop. This diversity may impact biomass thermochemical conversion, together with biomass macromolecular composition in cellulose, hemicelluloses and lignin [1]. The upscaling of biomass torrefaction to industrial units requires therefore the modelling of both solid conversion and gases released versus feedstock type and its macromolecular composition. Up to now, only few studies, typically based on a reduced number of biomasses, have characterized and modelled both solid and condensable species during torrefaction versus biomass type. Furthermore, torrefaction tests on macromolecular components are scarce and based on commercial constituents [1,2].

The objective of this study is to develop a torrefaction model able to predict both solid and volatile species yields versus operating conditions and biomass type. Experimental data is obtained from extracted macromolecular components from 5 woody and agricultural biomasses.

**2. Methods**

14 biomasses were selected as representative of the European diversity and of the main biomass families: pine, pine forest residues, Scot pine bark (coniferous wood); ash wood, beech, poplar, willow (deciduous wood); miscanthus, reed canary grass (herbaceous crops); corn cob, grape seed cake, sunflower seed shells and 2 wheat straws (agricultural by-products) [3]. From them, five were identified as reference biomasses for analyzing the impact of biomass characteristics in torrefaction and further modelling: ash-wood, beech, miscanthus, pine and one wheat straw. An optimized extraction procedure was proposed to recover cellulose-, hemicellulose- and lignin-based fractions from the five reference biomasses. The extracted fractions and the raw biomasses were characterized in terms of sugar composition (except lignin) and torrefaction behaviour.

Experiments were performed on a thermogravimetric analyzer coupled to a gas chromatography mass spectrometer device through a heated storage loop system (TGA-GC/MS). Solid degradation and volatile species release were studied in torrefaction experiments in chemical regime [4].

**3. Results and discussion**

The results obtained with the raw biomasses confirmed that their macromolecular composition strongly influences their behaviour in torrefaction. The heterogeneity of the resource, particularly in the case of agricultural biomasses, highlights this result [3].

A very different behaviour was observed for the extracted components compared to commercial compounds, particularly in the case of cellulose. This suggests that a limitation could be induced by the common use in literature of commercial compounds for torrefaction modelling. Macromolecular component properties were shown to strongly impact their behaviour in torrefaction, particularly hemicellulose sugar composition and cellulose crystallinity.

Furthermore, differences in release kinetics of volatile species during torrefaction were observed, even for volatiles belonging to the same chemical family (acids, furans, ketones).

Derived from these results, a torrefaction model based on the additive contribution of extracted cellulose, hemicelluloses and lignin to biomass behaviour in torrefaction was proposed, and this for the 5 representative biomasses. Two levels of detail were proposed (mod 1 and mod 2), in function of the extracted fractions considered (Figure 1, models for pine and wheat straw).



**Figure 1.** Remaining solid mass loss versus temperature and time in torrefaction for pine and wheat straw in
TGA-GC/MS (exp) and modelled through the first-level model (mod 1 curves) and the second-level model (mod 2)

An improved representation of the behavior of biomass in torrefaction in terms of solid mass loss kinetics was achieved with the proposed model. This improvement was especially remarkable for deciduous and coniferous wood, while the representation was less accurate for agricultural biomasses. This torrefaction model was extrapolated to the 14 raw biomasses initially selected.

**4. Conclusions**

Biomass family and macromolecular composition were shown as key factors determining biomass behavior in torrefaction. Compared to previous models based on commercial compounds, the use of macromolecular components directly extracted from different biomasses through an optimized procedure allowed improving the representation of raw biomass behaviour in torrefaction.

**References**

1. Nocquet T., Dupont C., Commandre J-M., Grateau M., Salvador S.: Energy, 72, 188–194 (2014).
2. Chen, W-H., Peng, J., Bi, X.T.: Renewable Sustainable Energy Rev., 44, 847-866 (2015).
3. González Martínez M., Dupont C., Meyer X.-M., Gourdon C., Biomass Bioenergy, 119, 43–53 (2018).
4. González Martínez M., Dupont C., Meyer X.-M., Gourdon C., Chem. Eng. Trans., 50, 61–66 (2016).