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Editorial: "Torrefaction Pretreatment for Biomass Upgrading: Fundamentals and Technologies"

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Editorial on the Research Topic

Torrefaction Pretreatment for Biomass Upgrading: Fundamentals and Technologies

Torrefaction is a relatively new biomass pretreatment technology, which, over the past decades, has been recognized as a very promising and technically feasible method to improve the performance of biomass with regard to storage, handling, transportation and energy conversion processes (Tumuluru et al., 2011; Nhuchhen et al., 2014). Several demonstration plants have seen the light these years, but still a very few commercial plants are currently operating. Despite of the global efforts to develop torrefaction technology, there are still several technical challenges to be addressed in order to realize biomass torrefaction in an economically feasible way at a commercial scale (Chen et al., 2021; Nhuchhen et al., 2014). The major bottlenecks are nowadays the limited control of the process parameters (Brachi et al., 2018; Brachi et al., 2019), in particular the temperature, but the fuel flexibility (size distribution and moisture content) and scale-up of the system are often a barrier as well.

In this Research Topic, the editorial team welcomed Original Research dealing with the latest advances in biomass upgrading through torrefaction, from both fundamental and practical points of view. The ultimate objective was to gain deeper insight into the biomass torrefaction to promote its technological development and commercialization.

Specific themes covered in this research topic include: 1) the state-of-the-art and perspectives of the torrefaction technology; 2) the optimization of process parameters for a specific feedstock or end-use application (e.g., pyrolysis, adsorption of emerging pollutants, etc.); 3) the design and the process control in torrefaction technologies; and the 4) the chemistry and the reaction kinetics of biomass torrefaction.

The articles were contributed by academics and researchers from various institutions in different countries including Canada, China, Belgium, Austria, United States, Taiwan and Brazil. In more details Wild and Calderón within the framework of their role as the President and the General Manager of the International Biomass Torrefaction Council (IBTC), respectively, provided in their article an interesting overview about where the biomass torrefaction sector is currently standing in terms of research, technology development and implementation, on the base of information collected via survey and personal interviews carried out by themselves in 2020, within the member companies of the IBTC.

Tumuluru et al. developed a model for designing a moving bed torrefier, considering the fundamental heat and mass transfer calculations. The model proposed includes a set of equations for basic calculations to configure the torrefaction reactor dimensions such as diameter and height of the moving bed torrefier for different capacities, based on target and calculated solids and gas velocities, residence times, and temperatures. The paper also briefly describes the solid feeding system, the gas supply unit, the recycle system, the solid product

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management, the torrefier gas monitoring, the control system and the dust emissions control unit. Different moving bed torrefaction and gas recycle concepts are also conceptualized to assess the main features as well as the advantages and disadvantages of each design and operating concept. Finally, the study is complemented by an investigation on the impact of the torrefaction treatment on the product quality in terms of biomass physical properties and chemical composition. Providing relevant design equations for estimating the dimensions of the torrefier based on its throughput, this study contributes to fill the gap in the literature related to the torrefaction reactor design aspects.

Yun et al. devoted their research efforts to find stand-alone solutions to enhance the net thermal efficiency of the torrefaction treatment. Specifically, the work provides a general method for linking the feedstock-specific parameters to the energy balance and pre-diagnosing the potential of auto-thermal operation for different biomass torrefaction and pyrolysis systems. Both solid and gas thermal properties under various torrefaction conditions are considered as well as their influences on the torrefaction system energy balances. Key parameters influencing the process of auto-thermal operation are analyzed, which include torrefaction reaction heat, torrefaction conditions, drying method, biomass species, and inert N_2 flowrate. Equations of torgas and biomass higher heating values (HHVs), as well as the torrefaction heat of reaction at different operating conditions are developed. The work is useful in the design and the operation of the torrefaction systems at both pilot and industrial scales particularly to improve process efficiency and predict product quality in a reliable and economic manner.

A more fundamental research study was instead carried out by Jiang et al. who focused their attention on the effect of oxidative torrefaction on the characteristics of biochar obtained from Phragmites australis (PAS) pyrolysis as well as its capacity to adsorb tetracycline (TC), one of the most widely used antibiotic, frequently detected in the water environment as an emerging pollutant. The findings of this work show that oxidative torrefaction could be an effective approach for improving the TC adsorption capacity of PAS biochar.

Again, McCaffrey et al. studied the effect of a range of torrefaction operating conditions (i.e., temperature and residence time) on the properties of almond and walnut shells as a fuel. In this study, almond shells of soft, semi-soft, and hardshell varieties, as well as walnut shells and almond wood, were torrefied at two different temperatures (230 and 290°C) and three different residence times (20, 40, and 60 min) in order to characterize the physicochemical properties. The thermal behavior of raw and heat-treated biomass was investigated by TGA analysis, elemental analysis, pH, helium pycnometry, FTIR spectroscopy, and dynamic vapor sorption analysis.

Finally, Xu et al. presented the results from a study on the torrefaction treatment of non-recyclable paper (fiber) wastes, mixed plastic wastes (MPW) and their blends at different ratios in the temperature range of 250–400°C through thermogravimetry analysis (TGA). The significant synergy between fiber and MPW was observed at the range 250–300°C, showing that the torrefaction of their blend can be achieved at lower temperatures and/or shorter residence times. The interaction between paper and MPW can be attributed to the plastic polymers acting as hydrogen donors during the reactive extrusion process.

CONCLUSION

This research topic highlights that torrefaction is a hot topic right now among scientists and technicians working in the field of biomass and bioenergy sector. Interesting outcomes retrieved from this collection encourage future research efforts on the research field of biomass torrefaction that, even though not yet commercially available, without any doubts, will find its way into the biomass-to-energy value chain in the coming decades.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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