ABSTRACT

Significant nitrogen losses from commercial fertilizers through leaching, volatilization, and denitrification necessitate the development of enhanced-efficiency fertilizers (EEFs) that better match plant nutrient uptake rates. The urea-gypsum cocrystal (URCASU) shows promise as an EEF, demonstrating slowed nitrogen release and improved nitrogen use efficiency compared to market urea alone. This investigation focuses on developing and optimizing a continuous, scalable method of URCASU synthesis via mechanochemistry utilizing a twin-screw mixer (TSM).

To optimize this continuous process, initial operating boundaries and residence time distribution (RTD) profiles were established using a colorimetric tracer to characterize internal flow dynamics. Chemical conversion of the resulting extrudate was quantified using *ex-situ* powder X-ray diffraction (pXRD) and Rietveld refinement.

It was found that URCASU cocrystallization is dependent on thermal saturation and residence time. While elevated barrel temperatures (100 ˚C) were successful in driving conversion, excessive material feed rates prevented uniform heat penetration, and excessive screw speeds could reduce the residence time below the necessary threshold. Under optimized conditions (30 and 50 rpm, 100 ˚C, 0.4 kg/h feed rate), the TSM consistently achieved greater than 97% conversion. This TSM process operated at an effective production rate of 0.389 kg/h, which is nearly 13 times faster than the standard ball-milling baseline (0.030 kg/h). By eliminating additional heating steps and secondary solvent washing, The TSM is proven to be an efficient, cost-effective, and scalable method to synthesize EEFs.