Monitoring dewatering performance of anaerobic digestate using low-field nuclear magnetic resonance

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Abstract: In this paper, we are presenting initial experimental results regarding the application of low-field NMR relaxometry to Anaerobic Digestate (AD) samples while undergoing flocculation and mechanical dewatering. A series of laboratory experiments were conducted at various flocculant dosage levels, ranging from 0 to 5.25% by weight. The preliminary results illustrate that monitoring AD samples during the flocculant dosing phase has the potential to predict the cake structure during the subsequent mechanical dewatering process. These initial findings encourage further exploration of low-field NMR as an in-line tool for assessing the optimal flocculant dosage prior to mechanical dewatering, which could complement existing optical monitoring techniques.

Keywords: Anaerobic Digestate; Dewatering; Low field NMR monitoring.

Introduction

The growing challenges of industrial waste management in the context of increasing human development have led to a heightened emphasis on environmental, logistic, and financial impacts. This has driven the development of strategies rooted in circular economies, aiming to convert organic waste sources into valuable resources. As an illustration, solid waste resulting from anaerobic digestion (AD) in red meat processing plants is transformed into bio-based fertilizers (Ramirez, 2021; Drosg, 2015). The critical dewatering step, accomplished through coagulation and flocculation treatment followed by mechanical dewatering, necessitates precise monitoring. In this study, low-field NMR relaxometry is employed to assess the solid-liquid separation of AD during flocculation and mechanical dewatering, enabling non-invasive tracking of the solid layer's structural changes in response to varying flocculant dosages (Bertizzolo, 2023; Maillet, 2022).

Material and Methods

In this research, a comprehensive analysis of industrial anaerobic digestate samples in triplicate was conducted. These samples were subjected to flocculation utilizing a commercial flocculant, encompassing a dosage range from 0 to 5.25 wt.% in increments of 0.75 wt%, resulting in the generation of eight distinct sample batches with varying flocculant concentrations. The evolution of water-to-solid structure alterations within the samples was monitored through low-field NMR, employing CPMG NMR T_2 relaxometry. Both pre- and post-mechanical dewatering assessments were carried out in the laboratory setting. The mechanical dewatering process was executed using an IEA Cylinder Press, applying a pressure of 2 bar for two minutes.

Results and Conclusions

Figure 1 illustrates the NMR T_2 relaxation distributions in relation to flocculant dosing, showing an apparent increase in the longest T_2 peak (P1) as the flocculant dosage increases. The T_2 relaxometry results reveal a direct correlation between higher flocculant concentrations and an increased free water signal, indicative of effective solid-liquid separation. Following mechanical dewatering, the three highest flocculant concentrations tested (3.75, 4.5, and 5.25 wt.%) exhibited a desirable solid cake structure, as illustrated in Figure 2, which displays photographs of the flocculated samples and the resulting solid cakes. Figure 3 presents the T_2 relaxation results for three samples (0, 2.25, and 5.25 wt. %) both before (T2f) and after (T2s) mechanical dewatering, revealing the persistence of the shortest T2 peak (Peak 3) due to retained surface water. Moreover, the highest flocculant-dosed samples displayed a shift in T_2 to lower values, indicating improved water drainage and aligning with literature observations for similar sludge systems (Qi, 2011).

To assess the predictability of NMR for dewatering performance, a T2 cutoff of 1 second and a signal fraction (SF) of 0.4 were employed during the flocculation step. These criteria were utilized to predict the likelihood of achieving a suitable solid cake structure during subsequent mechanical dewatering, as demonstrated in Figure 4, which reveals that the three highest flocculant-dosed samples (3.75, 4.5, and 5.25 wt %) were anticipated to yield the best dewatered solids. Validation of the dewatering quality was conducted by industry experts through visual assessment and by monitoring the weight of the solid cakes formed in relation to flocculant dosing.

This preliminary research underscores the potential of low-field NMR relaxometry in predicting the quality of solid cakes during mechanical dewatering of anaerobic digestate. Further investigations are recommended based on these promising results, including monitoring a larger sample of industrial AD to evaluate the technique's performance across common AD sample variations. If sufficiently reliable, this technology could drive the development of an inline sensor integrated into continuous AD control systems, enhancing and optimizing flocculant dosing. Such technology could have a significant impact on dewatering applications where monitoring solid layer structure can improve industrial dewatering efficiency. Additionally, NMR-based techniques could complement traditional optical methods, particularly in cases where sampling window fouling poses a significant source of error.

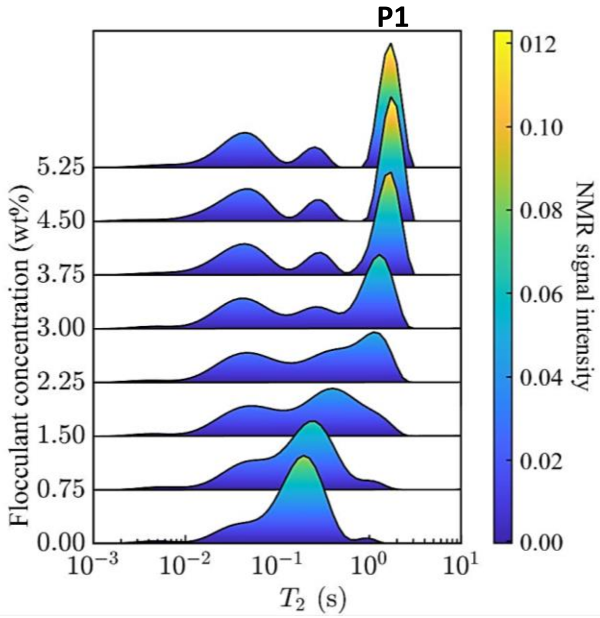

Fig. 1. T_2 distributions of flocculated samples showing an increase in T_2 value of the longest T_2 peak (P1) with increasing flocculant dosing.

Sample	Dosing (% wt)
1	0.00
2	0.75
3	1.50
4	2.25
5	3.00
6	3.75
7	4.50
8	5.25

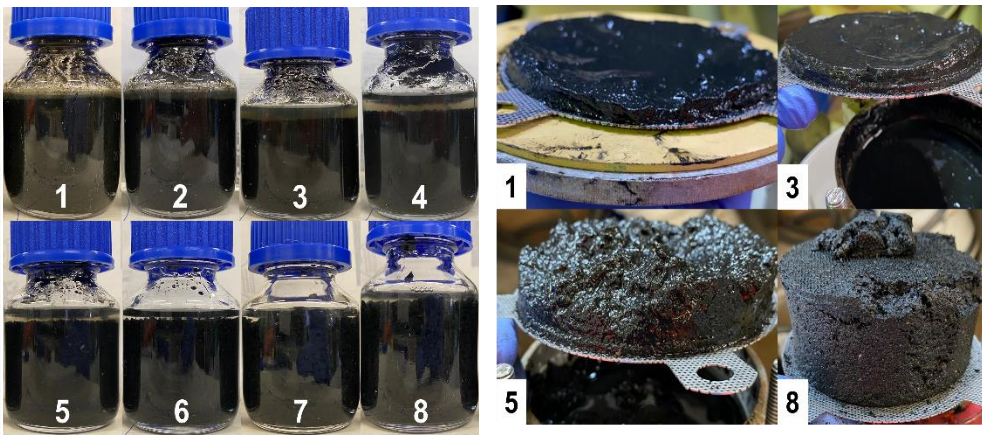

Fig. 2. Shows the dosing range used in the experiments and a collage of the flocculated samples, with four of the resulting solid's cake highlighted after being pressed.

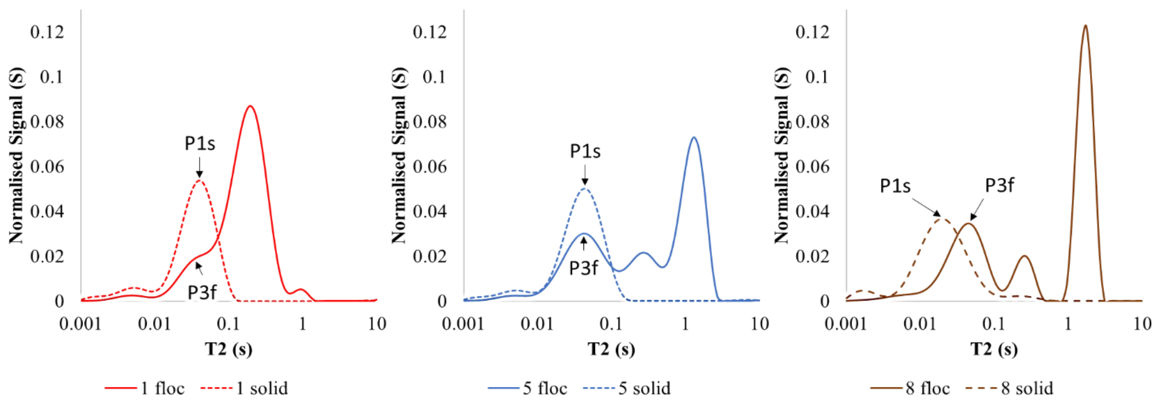

Fig. 3. Sample 1 (L), 5 (C) and 8 (R) T_2 distributions of flocculated sample (floc) and finals solids (solid) after passing through the cylinder press overlayed.

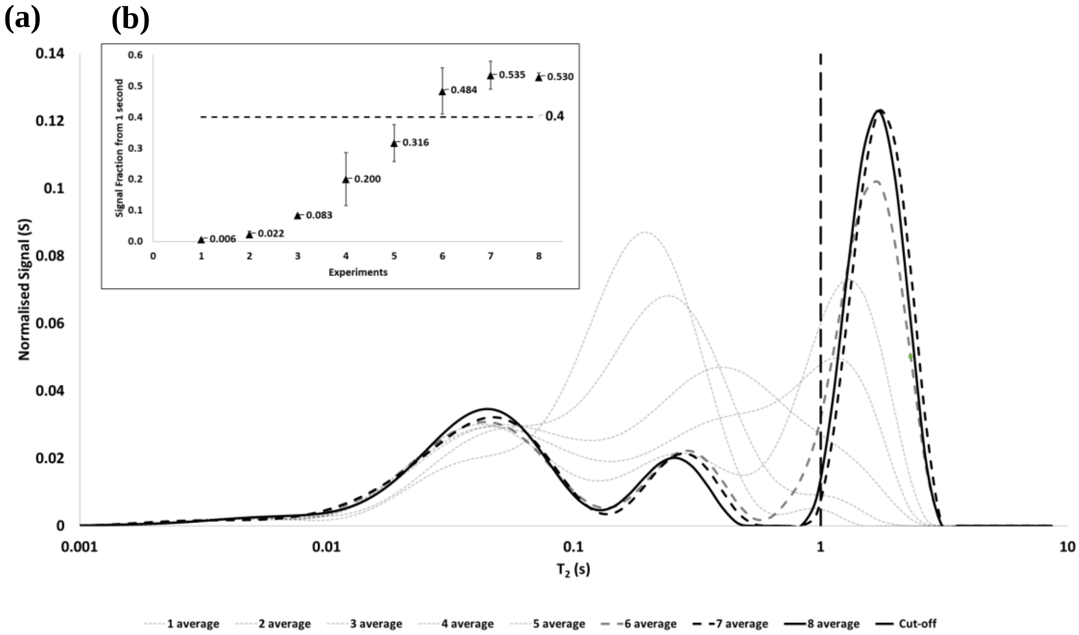

Fig. 4. **(a)** Shows T_2 distribution of flocculated samples and the proposed T_2 cut-off of 1 second. Inset plot **(b)** provides visual evidence of the signal fraction from 1 to 10 seconds in each sample and the proposed cut-off of 0.4.

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