Low-field nuclear magnetic resonance as a predictive tool for efficient industrial anaerobic digestate solid-liquid separation

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Abstract

With increasing human development waste management from industrial processes has become an ever-increasing problem. In addition to the logistic and financial impact, the environmental impact has recently received heightened attention, with new strategies being developed to turn waste-into-value through the adoption of circular economies. To this end sources of organic waste are increasingly used as feedstock for further processing. For example, the solid's waste from anaerobic digestion (AD) is further processed into bio-based fertilizers. In that process the anaerobic digestate must be de-watered, which is commonly done using coagulation/flocculation treatment followed by mechanical de-watering.

In this study solid-liquid separation of anaerobic digestate (AD) from a red meat processing plant was assessed during flocculation and mechanical de-watering using low field NMR relaxometry. NMR was used as it allows for non-invasive monitoring of the solids layer during the de-watering process and can be used to monitor changes in the structure of the solids layer as function of flocculant dosing. In the study industrial anaerobic digestate samples in triplicate were flocculated using a commercial flocculant with dosing range of 0 to 5.25 wt.%. The samples were monitored to assess changes in water/solid structure. The samples were analysed using CPMG T_2 relaxometry which showed that increasing flocculant concentration

correlated with increasing free water signal, indicative of good solids-liquid separation. Figure 1 shows the T_2 relaxation distributions as a function of flocculant dosing with a notable increase in longest T_2 peak, signal from free water, with increasing addition of flocculant.

After mechanical de-watering the three highest flocculant concentrations tested (3.75, 4.5 and 5.25 wt.%) were observed to possess a desirable solid's cake structure. Figure 2 shows photographs of flocculated samples and solid's cakes formed after mechanical de-watering. The T_2 relaxation results for three samples (0, 2.25 and 5.25 wt. %) before (T_{2f}) and after (T_{2s}) application of mechanical de-watering are shown in Fig 3. It was observed that the shortest T_2 peak (Peak 3 – in the flocculated samples) remained after de-watering (Peak 1 – for de-watered sample). This peak is due to surface water which remains after de-watering. It was additionally observed that for the highest flocculant dosed samples, there was a shift of T_2 to lower values which is due to enhanced water drainage, and is consistent with literature observations of the dewatering of similar sludge systems.

To examine the useability of the NMR technique to predict de-watering performance a $T_{2,cutoff}$ of 1s and signal fraction (SF) of 0.4 were used to assess the samples during the flocculation step. This was to be used as a predictor a suitable solid cake structure formation during the subsequent mechanical de-watering step. Figure 4 shows results of this analysis whereby using these criteria it was possible to predict that the three highest flocculant dosed samples (3.75, 4.50 and 5.25 wt %) would produce the best de-watered solids during the mechanical de-watering step. The quality of the solids de-watering was confirmed by industry experts using visual assessment of the cake formed relative to usual practice and by monitoring the weight of the solid's cake formed.

The initial research work presented here has been shown the capacity of low field NMR relaxometry to predict whether anaerobic digestate will produce good solid's cakes during mechanical de-watering. Further studies are therefore proposed based on these results. It is proposed that a larger sample of industrial AD be monitored to assess the technique as function of commonly encountered AD sample variability. If sufficiently high confidence is achieved, this can motivate the development of an inline sensor technology installed as part of a continuous AD control scheme to manage and optimise flocculant dosing. It is proposed that this technology may have significant impact on de-watering applications where monitoring of the solid's layer structure can be used to enhance industrial de-watering performance. It is also proposed that this NMR based technique may be a useful complement to commonly used optical techniques where sampling-window fouling can be a significant source of error.

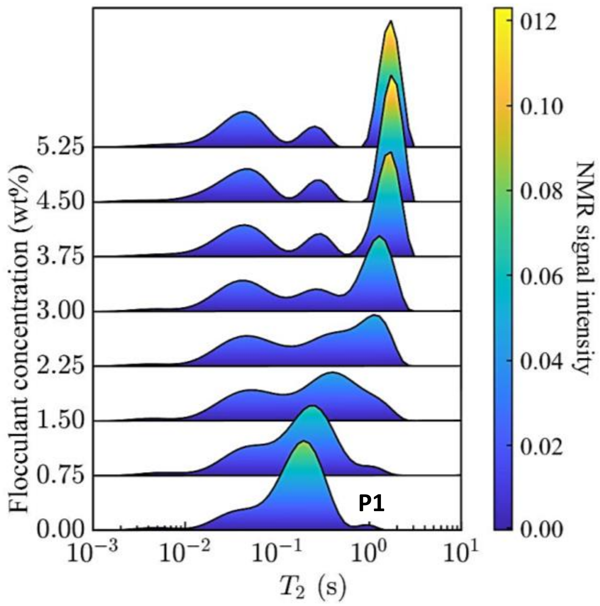

Fig. 1. T_2 distributions of flocculated samples showing an increase in T_2 value of the longest T_2 peak (P1) with increasing flocculant dosing.

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

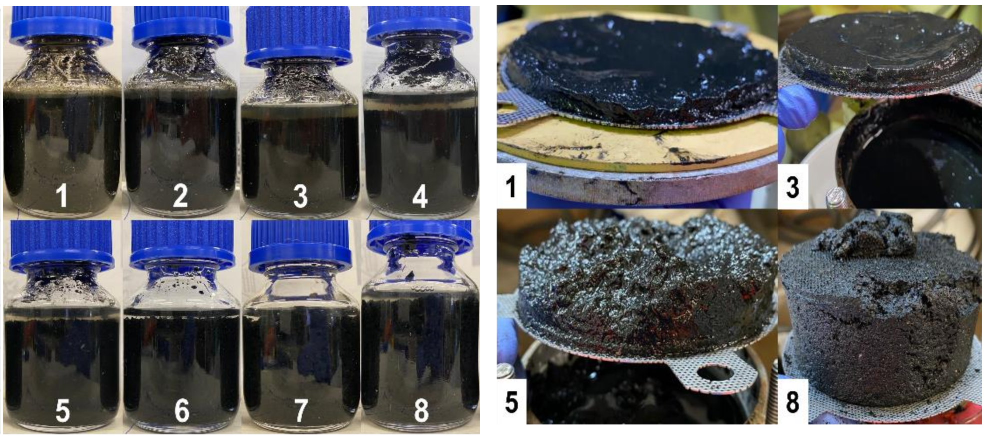

Fig. 2. Shows the dosing range used in the experiments and a collage of the flocculated samples, with four of the resulting solid's cake highlighted after being pressed.

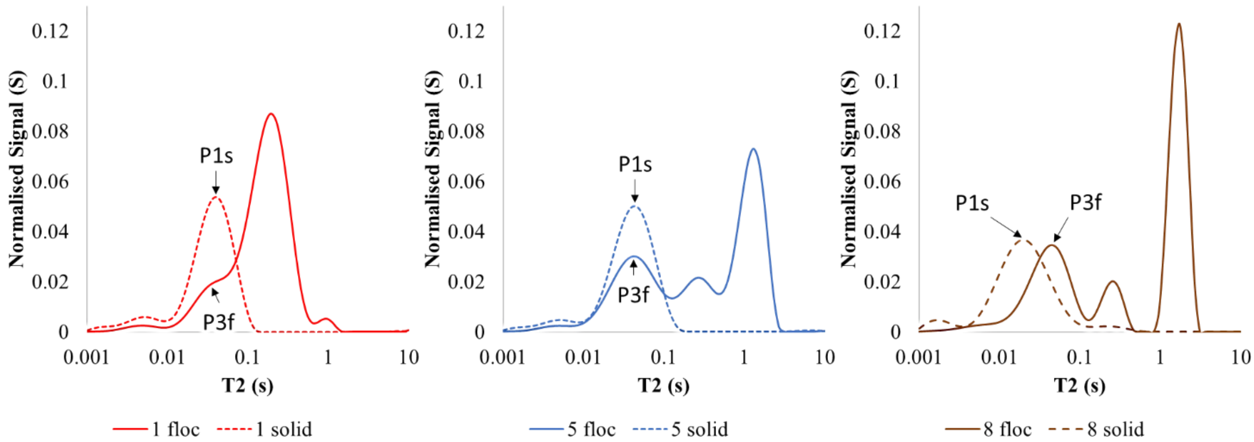

Fig. 3. Sample 1 (L), 5 (C) and 8 (R) T_2 distributions of flocculated sample (floc) and finals solids (solid) after passing through the cylinder press overlayed.

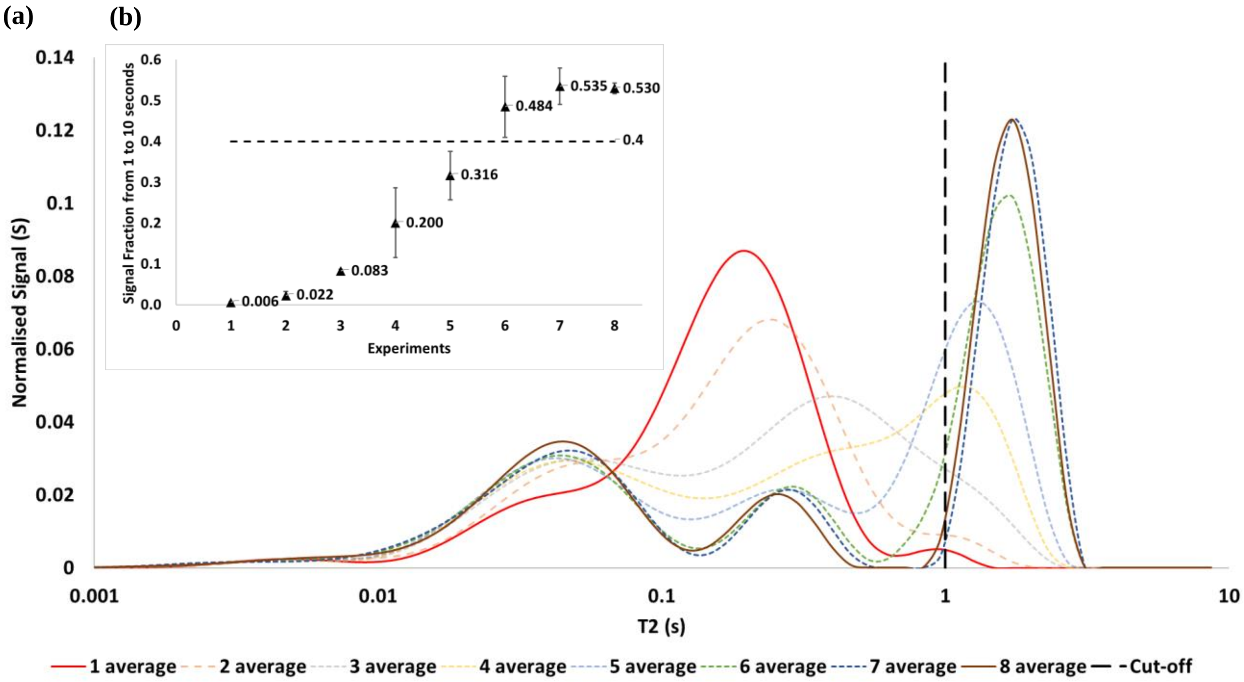

Fig. 4. **(a)** Shows T_2 distribution of flocculated samples and the proposed T_2 cut-off of 1 second. Inset plot **(b)** provides visual evidence of the signal fraction from 1 to 10 seconds in each sample and the proposed cut-off of 0.4.