Nutrient Recovery from Anaerobic Digestate Using a Natural Polymer and Mechanical Separation

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Anaerobic digestion (AD) is considered as one of the most prominent sustainable technologies for bioenergy production. AD of agricultural/livestock by-products, food waste, municipal organic waste, energy crops, waste from agro-industries, and residues from biofuel industries is increasingly used to recover energy from wastes and to promote circular economy.

Besides biogas, AD digesters produce digestate, which is more than 90% (mass basis) of the feedstocks. Digestate represents the effluent or digested substrate which is removed from an AD reactor after the production and recovery of biogas. It is considered as an excellent fertilizer which is rich in nutrients necessary for crops, such as nitrogen (N), potassium (K), and phosphorous (P). During the AD process, the nutrients are mobilized from the organically bound form in the feedstock as ammonium and free potassium and phosphorus so that they can be returned into the food chain.

Finding ways to partially upgrade digestate and create markets for all of its elements could improve the profitability of AD systems. Hallbar Consulting estimated $10/tonne revenues for nutrient rich cake from digestate (AAFC, 2018). Furthermore, the need for efficient nutrient management, required by environmental regulations, along with depletion of the global natural reserves of phosphorous and potassium, make recovery and recycling of the nutrients from digestate increasingly important (Drosg et al., 2015).

The nutrients contained in digestate can be extracted and concentrated through the application of a range of technologies and processes. Digestate processing can be partial, primarily for the purpose of volume reduction, or it can be complete, refining digestate to pure water, a solid bio-fertilizer fraction and fertilizer concentrates. While partial processing uses relatively simple and inexpensive technologies, for complete processing, complex methods and technologies are currently available with various degrees of technical maturity, higher energy input, and higher investment and operating costs (Drosg et al., 2015).

Due to the low dry matter content and high volume, digestate is often separated into a liquid and solid fraction at the first stage to save costs related to transport and storage capacities. To this end, screw press and centrifuge are most commonly used technologies for solid–liquid separation. Separation using these techniques can be enhanced by addition of biodegradable flocculants (Luo et al., 2018).

In this study, a natural biodegradable polymer was used to enhance the nutrient recovery from anaerobic digestates. Following the application of the polymer, solid-liquid separation was performed using mechanical separation techniques including centrifuge, compressed filtration, and horizontal screen. Three different digestates from farm-based biogas plants in Ontario and British Columbia in Canada were tested in this work. The polymer used in this research was bionanocoil (BNC) that was obtained from the manufacturer and patent holder, Biopolynet Inc.

Effects of polymer concentration, mechanical separation technique at different operating conditions (such as centrifugation time and speed) on solid-liquid separation and nutrient removal efficiency were investigated in this work. Polymer dosages varied between 7, 14, 21 and 42 mL/ L of digestate. Centrifugation time was changed between 5 and 10 min at 3500 rpm.

According to the results, centrifugation time did not affect P recovery in solid phase and a recovery of more than 99.8% was obtained using centrifuge at 3500 rpm. P recovery increased in the presence of the polymer (14 mL BNC/ L digestate) no matter what type of mechanical separation used in this study. A phosphorous recovery of more than 99.4% in solid phase was achieved once BNC polymer was applied before mechanical separation step.

The application of centrifuge even in the absence of BNC caused a P recovery of more than 97%, however, phosphorous recovery increased to almost 99.9% upon the addition of the polymer before solid-liquid separation. Addition of polymer resulted in 3-9% increase in P recovery once compressed filtration was used, however, this increase was almost 19% in the case of horizontal screen (14 mL BNC in 1 L digestate).

It should be noted that effect of polymer concentration on the phosphorous recovery in solid phase was not significant and a P recovery of more than 99% was observed when BNC concentration changed from 7 mL to 42 mL/ L digestate.

In terms of nitrogen recovery, highest N recovery was obtained when centrifugation was done for 7 min (speed was constant at 3500 rpm during the tests and a recovery of almost 72% was achieved). The addition of BNC resulted in 10% and 102% increase in N recovery in solid phase once compressed filtration and centrifuge were used for mechanical separation, respectively (14 mL BNC in 1 L digestate). After the addition of BNC, a nitrogen recovery of 84% was obtained through compressed filtration, however, N recovery was almost 72% in the case of centrifuge. Furthermore, highest N recovery using horizontal screen was obtained when 14 mL BNC was used in 1 L digestate (almost 48%).

However, BNC addition led to a slight decrease in potassium recovery due to the fact that the potassium compounds are dissolved and remain mostly in the liquid phase. Potassium recovery was varied between 10% and 70% depending on the digestate, polymer dosage, and separation method. Moreover, centrifugation time did not change the K recovery when it was varied between 5 and 10 min, and a recovery of almost 30% was observed.

Considering the results, simplicity, and energy required for centrifugation, it is concluded that using BNC polymer at a concentration of 14 mL/ L digestate together with horizontal screen to separate solid from liquid for the purpose of nutrient recovery was the best option in this work.

Table 1. NPK recovery from digestate in the presence and absence of BNC, solid-liquid separation took place by horizontal screen, BNC concentration was 14 mL in 1 L digestate.

Solid-Liquid Separation	P Recovery (%)	N Recovery (%)	K Recovery (%)
Without BNC	83.9	4.5	48.0
With BNC	99.6	75.7	30.8

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