Review Article
Volume 7:3, 2022

Journal of Inflammatory Bowel Diseases & Disorders

ISSN: 2476-1958 Open Access

Anaerobic Digestion and Membrane Technology for Energy and Nutrient Recovery from Apple Waste

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Introduction

Food waste is increasing globally, necessitating creative management strategies that are in line with sustainability, energy and food security. An intriguing strategy would be anaerobic digestion followed by nutrient recovery. In order to investigate the effects of different AP proportions (0, 7.5, 15 and 30%, on a volatile solids basis) on the methane production and the stability of the process, this study proposed a co-digestion of apple pomace (AP) with swine manure (SM). After that, the digestives made after the AD of 7.5% of AP and SM and SM alone, the gas-permeable membrane technology was used to recover nitrogen (N) as ammonium sulphate (bio-based fertilizer).

Description

In 2020, there were 86.44 million tonnes of apples produced worldwide, 11.48 million tonnes of which came from the European Union. Cider, jelly and juice are the primary items that the food industry makes with about 20% of this production. After processing, 25% of the fresh apple is wasted as apple pomace (AP), which is often disposed of in landfills, burned, or composted. Apple pomace is made up of the skin, seeds and pulp of the apple. These disposal methods cause problems with the environment and with health since they emit greenhouse gases.

Over the past few years, a number of works have investigated the co-digestion of various food wastes and manure. For instance, Labatut et al. co-digested a variety of co-substrates with dairy manure, including cheese whey, plain pasta, used vegetable oil, cabbage and raw potatoes [1]. By co-digesting poultry manure with fruit and vegetable waste, Bres et al. tested the performance of semi-continuous AD, while Riao et al. investigated the co-digestion of pepper waste and swine manure (SM). However, only few studies most of which looked at the AD process in batch settings have examined the utilization of apple residues as co-substrates [10].

The addition of nitrogen-rich materials to agricultural fields could result in nitrate emissions and nutrient losses if the digestate is used as organic fertilizer. These issues with storage and transportation could also arise. These problems can be solved and nutrient losses prevented by the use of nutrient recovery technology, which is why over the past few years, interest in and incentives for nutrient recovery and reuse of AD effluents have grown. The most popular technologies for recovering N from a digestate include air stripping, ion exchange, ultrafiltration, reverse osmosis and gas-permeable membrane technology (GPM). In particular, the GPM technique, which addresses both economic and energetic aspects, is regarded as one of the most valuable innovative methods to recover nitrogen [2].

As far as we are aware, no study has ever been done on the effectiveness of the AD process with various ratios of AP as the co-substrate and the subsequent recovery of N from the resulting digestate. The current study's objective was to evaluate the effects of adding various ratios of AP from the cider industry to SM in the AD process, under semi-continuous operation and mesophilic conditions, followed by the application of the GPM technology for the recovery of nitrogen from the digestate in the form of a valuable ammonium salt solution and to ascertain whether using AP as a co-substrate could affect the N recovery process [2,3].

The Regional Research and Development Service of Asturias (SERIDA) provided the AP (Asturias, Spain). The AP was a solid, recent waste product acquired from pressing apples for cider. Plastic containers were used to transfer it to the ITACyL, where it was preserved frozen for later use. The SM used was centrate obtained from a pig farm in Narros de Cuéllar following on-farm centrifugation (Segovia, Spain). The collected manure was placed in plastic containers, shipped to the ITACyL facility in Valladolid, Spain and kept there for future use at 4°C [3].

Two identical continuously stirred tank reactors (CSTRs) with a combined volume of 7 L and a working volume of 5 L, designated R1 and R2, were used to perform semi-continuous co-digestion. The reactors were kept at a 38 °C temperature using a water bath (mesophilic conditions). Separately mounted reactors were used and constant stirring was used to homogenise the liquid (37 rpm). Each reactor has outlets that can be used to feed in influent, remove effluent and collect biogas [5,6]. These outlets are located on top of each reactor. Daily water displacement measurements were used to calculate the volume of biogas produced.

It was determined how well GPM technology performed in recovering TAN from the digestates produced by the trials reported in Section 2.2.1. As a result, two experiments—D-R1 (anaerobically digested SM alone) and D-R2—were conducted using the digestate produced in period I in R1 and R2. D-R2 was chosen as the digestate with the highest AP ratio in the feed mix with SM, providing the best performance in the co-digestion in terms of stability and methane generation. D-R1 was chosen as the reference (SM) for the N capture. This made it possible to determine whether the inclusion of AP during the co-digestion of SM could affect the subsequent N recovery process [4].

According to APHA, analyses of TCOD, SCOD, TS, VS, TKN and TAN were carried out in duplicate. A closed reflux colorimetric approach was employed for the determination of TCOD and SCOD. By drying the material to a constant weight at 103-105 °C, the TS concentration was determined [7]. The weight loss during ignition corresponded to the VS concentration since the TS residue was burnt at 550 °C to constant weight. The Kjeldahl digestion, distillation and titration method was used to calculate the TKN. The distillation and titration procedure was used to calculate TAN levels. The pH was measured using a Crison Basic 20 pH-meter.

Additionally, a rise in the IA/PA ratios was seen beginning on day 6. The IA/PA ratio functions to enable a quick reaction to unstable anaerobic digestion process stages. The anaerobic process is therefore said to be performing well if the IA/PA ratio is less than 0.3 [8]. In this work, high initial IA/PA ratios and low methane outputs pointed to unstable anaerobic process functioning under the two experimental conditions. Given that feeds containing fibre or celluloses may require relatively alone HRT, a short HRT may be the source of the instability. This led to a reduction in the OLR applied in both reactors to 0.78 g VS L-1 d-1 and an increase in the HRT to 33 days in periods I and II [5,9,10].

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Date of submission: 02 May, 2022, Manuscript No. jibdd-22-75072; **Editor assigned:** 09 May, 2022, PreQC No. P-75072; **Reviewed:** 16 May, 2022, QC No. Q-75072; **Revised:** 23 May, 2022, Manuscript No. R-75072; **Published:** 30 May, 2022, DOI: 10.37421/2476-1958.2022.7.163

Conclusion

The outcomes demonstrated that anaerobic digestion may successfully valorize fresh AP from the cider sector. A methane yield of 381.8 134.1 mL CH4 g VS day 1 was reached with up to 15% of AP in the feed mix with SM (on a VS basis), but larger percentages may result in lower methane yields. In order to avoid using mineral fertilisers, this method uses a bio-based fertiliser that can be conveniently stored, transported and sprayed directly to crops. As a result, the anaerobic digestion and membrane technology used to handle organic waste can be seen as an effective method of waste valorization for the production of nutrients and energy.

Conflict of Interest

None.

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How to cite this article: Blum, Jonas. "Anaerobic Digestion and Membrane Technology for Energy and Nutrient Recovery from Apple Waste." J Inflam Bowel Dis Disorder 7 (2022): 163.