Mechanical pre-treatments of cattle manure before anaerobic digestion.

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Introduction

Anaerobic digestion (AD) is a very attractive and efficient technology to convert biomass feedstocks because of its economical and green energy recovery benefits (Mata-Alvarez et al., 2000). It consists in a complex decomposition process of organic substrate by anaerobic microorganisms under oxygen-free conditions. European full-scale plants are meanly treating agricultural organic waste including organic residues from vegetal production, and residues from breeding in particular livestock manures (Moller *et al.*, 2004ab; Tsapekos et al., 2016). Cattle manure is a major input to produce green energy by AD, in particular from countries in Northern and Western Europe. In France, nearly 87 Mt of cattle manure are generated annually (Degueurce et al., 2016). However, there are several challenges to optimize the AD. This includes the short or long storage requirements to operate continuously farm-scale digesters, the seasonal fluctuation of their generation (Teixeira Franco et al., 2018), and pre-treatments (Ward et al., 2008). Animal species, breeding conditions, growth stage of the animals, feeding and amount are factors that contribute to the methane potential of manures (Moller et al., 2004).

Mechanical pre-treatments of cattle manure are used to facilitate feeding operations and mixing, to reduce solid particle size, to increase solubilisation of fermentable organic substrates and, consequently, to increase biogas production rate and biogas yields. Mechanical operations can significantly increase the methane yield because organic compounds become more available to enzymatic hydrolysis (Vavilin et al., 1996). Many experimental works have been done to optimize AD of solid substrates, considering that biomass conversion strongly depends on the accessibility of organic compounds to external enzymes produced by anaerobic microorganisms under oxygen-free conditions. Even if many reviews have been published with full description of pre-treatment technologies including agricultural waste containing plant fibres (Mshandete et al., 2006; Taherzadeh et Karimi, 2008; Ward et al., 2008; Hendriks & Zeeman, 2009; Chandra et al. 2012; Paudel et al., 2017), feedbacks on the mechanical operation of preparing agricultural substrate are scarce, either at lab-scale or full-scale. Moreover, it is also difficult to optimize pre-treatment methods due to the diversity and variability of the feedstocks (Paudel et al., 2017). For these authors, the discrepancies between the published results is due to different conditions for evaluating the pre-treatment performance.

Considering this challenge, a multi-partner project named PAM has been launched in 2018 to evaluate the efficiency of mechanical pre-treatment devices developed for farm digester plants, with financial support of the French Environmental Protection Agency, ADEME. In the present work, lab-scale experiments have been performed to investigate the effect of mechanical pre-treatment on cattle manures. Several mechanical operations have been tested, including grinding, blending and crushing.

Material and methods

A set of analytical procedures has been developed, before and after the pre-treatments to assess physical, chemical and biological characteristics of the manure.

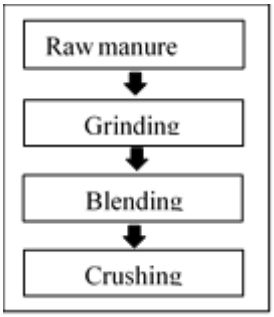

Figure 1. Simplified setup of pre-treatments.

Cattle manure was collected from an agricultural AD plant in the Auvergne-Rhône-Alpes Region, France. Different pre-treatments were successively applied, as shown in Fig. 1, in order to figure out their effects on the biomass properties. Pre-treatments were applied from the softest to the harsh one: first biomass was grinded, then blended and finally crushed.

Biomass characterization was based on previous works carried out in our laboratory (Teixeira Franco *et al*., 2019). It consists in a fractionation over a water extraction of the raw sample. This procedure enables to evaluate the water-soluble and particulate phase contribution to the main biochemical characteristics, especially the Biochemical Methane Potential (BMP), chemical oxygen demand (COD), total Kjeldahl nitrogen, volatile fatty acids, water-soluble carbohydrates (WSC) and pH.
Physical properties have been also evaluated. Particle size distribution was determined by wet sieving, with water recirculation and using sieves ranged of 0.25-31.5 mm. Moisture distribution was evaluated through drying tests (García-Bernet *et al*., 2011) and water holding capacity. Rheological properties were estimated from slump test (AFNOR, 2017) (for yield stress) and v-funnel (AFNOR, 2010) (viscosity indicator). Measurements were performed in triplicate.

Results and discussions

The biomass characterization enabled to evaluate the mechanical pre-treatments effects on cattle manure. Pre-treatments increased the soluble fraction of COD and BMP. This had an impact on the kinetics of methane production. Indeed, BMP tests showed higher kinetic constants for pre-treated samples (Table 1). This was also observed for the level of the pre-treatment, since harsher mechanical treatments improved kinetics of biomass degradation.

Table 1. Kinetics constants for pre-treated cattle manure $k=j^{-1}$

Raw cattle manure	Grinded manure	Blended manure	Crushed manure
0.068±0.004	0.083±0.011	0.080±0.002	0.103±0.002

Besides BMP, mechanical pre-treatments had an impact on other biochemical and physical properties. Detailed results and discussion will be presented in the full paper.

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