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High solid anaerobic digestion: Operational challenges and possibilities

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HIGHLIGHTS

- The integration of two or more anaerobic digestion technologies can be employed to improve HSAD.
- Leachate pre-treatment and recirculation provide a better option for mixing during HSAD.
- Digestate quality and handling in HSAD are expected to be better.

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ABSTRACT

The process of high solid anaerobic digestions (HSAD) was developed to reduce water usage, increase organic loading rate (OLR), reduce nutrient loss in digestate and avoid or decrease the dewatering of digestate. However, the operation of HSAD is currently constrained by low rates and extents of methane production high operational costs. Several published investigations have been conducted to study the effects of inhibition, temperature, moisture, and reactor design on the efficiency of HSAD. However, low moisture and poor mixing, which are required for the dilution and diffusion of metabolites, have been reported to be the major causes of low methane yield in HSAD. In order to optimize the operation of HSAD, technological integration has to be considered, especially thermo–mesophilic digestion, co-digestion, mixing and integration of two or more reactors. This paper provides a critical review of recent research on HSAD while focusing on how these studies can be integrated to improve HSAD.

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1. Introduction

The earliest application of anaerobic digestion (AD) is thought to have commenced in 19th Century, using low solid anaerobic digestion (LSAD) systems (He, 2010; Mccarty, 2001). More recently, AD has gradually become an increasingly acceptable technology for the treatment of biodegradable organic wastes (De Baere, 2000). Between 1995 and 2010, nearly 150–200 large-scale plants were established across Europe with a capacity increase of 6 000,000 tonnes of biomass feedstock annually; 50% of these plants were developed for high solid anaerobic digestion (HSAD) (De Baere et al., 2010). HSAD is a solid state operational system with low water content; this type of AD is called a semi-dry or dry system. Recently, HSAD has been demonstrated using various AD technologies, these include the silo shaped Dranco digester and the cylindrical Valorga digester system (Li et al., 2011). The key reasons for the development of HSAD are practical, in that there is low water usage and the digester size is typically smaller than that of the other systems (as summarized in Table 1) (Garcia-Bernet et al., 2011). Apart from reducing water usage, the technology has been reported to increase organic loading rate (OLR), avoid or reduce digestate dewatering and reduce heating requirements; however, methane recovery is lower and volatile solid removal is less than 50% (Dong et al., 2010; Nagao et al., 2012). Another major concern with HSAD relates to the pumping and digestate handling devices, which add to the cost of the technology (Vandevivere et al., 2003). The difficulty in pumping the feedstock's is influenced by the total solid (TS) content; in extreme cases, e.g. 30%–40% total solid (TS) pumping and mixing would require sophisticated equipment (Vandevivere et al., 2003).

Mixing is essential during AD because it reduces sedimentation and increases contact between the microorganisms and organic fractions (Karim et al., 2005a,b). For HSAD this can be achieved without the use of internal mixing devices, however leachate recirculation has been reported to improve mixing during HSAD. The potential in leachate and biogas recirculation has been explored and noted as an option for increasing contact and reducing sedimentation (Nkemka and Murto, 2013; Sponza and Ağdağ, 2004). Nevertheless, amidst the challenges of HSAD the benefits of high quality digestate otherwise called bio-fertilizer, higher volume of treatable waste per digester size, low water usage, and avoidable cost of digestate dewatering could encourage further research for higher methane production. The potential for HSAD is high and so are the challenges, this review will critically and comparatively look at how research has approached these challenges as well as highlighting other benefits.

2. High solid anaerobic digesters

The recovery of methane through the decomposition of organic compounds by anaerobic microorganisms is usually stimulated using an enclosed system devoid of oxygen. This enclosed system is called an anaerobic digester which varies in design depending on the characteristics of the substrate and the type of the AD process. Anaerobic digestion can be categorized based on the total solid content of the feedstock as wet otherwise called LSAD, semi-dry and dry. Both semi-dry and dry AD processes have been categorized as HSAD. According to Abbassi-Guendouz et al. (2012), the HSAD process can be grouped semi-HSAD (treating 10%–20% total solid) and HSAD (treating $>$ 20% total solid). With regard to HSAD, there are