ARTICLE IN PRESS

Waste Management xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Review

The challenges of anaerobic digestion and the role of biochar in optimizing anaerobic digestion

Michael O. Fagbohungbe [a,*], Ben M.J. Herbert [b], Lois Hurst [b], Cynthia N. Ibeto [c], Hong Li [a], Shams Q. Usmani [d], Kirk T. Semple [a]

[a] Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ, United Kingdom
[b] Stopford Energy and Environment, Merseyton Road, Ellesmere Port, Chester CH65 3AD, United Kingdom
[c] National Centre for Energy Research and Development, University of Nigeria Nsukka, Enugu State, Nigeria
[d] Ariva Technology, The Heath Business and Technical Park, Runcorn, Cheshire WA7 4EB, United Kingdom

ARTICLE INFO

Article history:
Received 4 August 2016
Revised 6 November 2016
Accepted 19 November 2016
Available online xxxx

Keywords:
Biochar
Inhibition
Nutrient leaching
Digestate
Anaerobic digestion

ABSTRACT

Biochar, like most other adsorbents, is a carbonaceous material, which is formed from the combustion of plant materials, in low-zero oxygen conditions and results in a material, which has the capacity to sorb chemicals onto its surfaces. Currently, research is being carried out to investigate the relevance of biochar in improving the soil ecosystem, digestate quality and most recently the anaerobic digestion process. Anaerobic digestion (AD) of organic substrates provides both a sustainable source of energy and a digestate with the potential to enhance plant growth and soil health. In order to ensure that these benefits are realised, the anaerobic digestion system must be optimized for process stability and high nutrient retention capacity in the digestate produced. Substrate-induced inhibition is a major issue, which can disrupt the stable functioning of the AD system reducing microbial breakdown of the organic waste and formation of methane, which in turn reduces energy output. Likewise, the spreading of digestate on land can often result in nutrient loss, surface runoff and leaching. This review will examine substrate inhibition and their impact on anaerobic digestion, nutrient leaching and their environmental implications, the properties and functionality of biochar material in counteracting these challenges.

© 2016 Elsevier Ltd. All rights reserved.

Contents

1. Introduction . . . 00
2. The challenges with anaerobic digestion of organic susbtrate . . . 00
   2.1. Direct inhibition . . . 00
   2.2. Indirect inhibition . . . 00
   2.3. Acclimation of microbial cells to inhibition . . . 00
3. Nutrient loss and environmental pollution . . . 00
4. Optimizing the AD process: the use of adsorbent . . . 00
   4.1. Mechanisms of biochar adsorption . . . 00
   4.2. Controls on biochar adsorption processes . . . 00
      4.2.1. Structure and pore size . . . 00
      4.2.2. Surface chemistry and pH . . . 00
      4.2.3. Hydrophobicity . . . 00
   4.3. Mechanisms of desorption or regeneration . . . 00
5. The role of biochar in anaerobic digestion . . . 00
   5.1. Biochar . . . 00
   5.2. Adsorption of inhibitors . . . 00
   5.3. Increasing buffering capacity . . . 00

* Corresponding author.
E-mail address: m.fagbohungbe@lancaster.ac.uk (M.O. Fagbohungbe).

http://dx.doi.org/10.1016/j.wasman.2016.11.028
0956-053X/© 2016 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Fagbohungbe, M.O., et al. The challenges of anaerobic digestion and the role of biochar in optimizing anaerobic digestion. Waste Management (2016), http://dx.doi.org/10.1016/j.wasman.2016.11.028

5.4. Immobilization of microbial cell . . . 00
5.5. Nutrient retention . . . 00
6. Conclusions . . . 00
Acknowledgements . . . 00
References . . . 00

1. Introduction

The number of anaerobic digestion (AD) systems has increased rapidly because of various factors including financial incentives for renewable energy facilities, governmental policies on climate change, landfill and an increasing energy need (Zglobisz et al., 2010; Klavon et al., 2013). Currently, in Europe and Asia, there are over 30 million large and small-scale anaerobic digesters for both commercial and domestic applications (Chen et al., 2010; De Baere et al., 2010; Donoso-Bravo et al., 2011; Ferrer et al., 2011). AD is the stepwise breakdown of an organic substrate by a consortium of mutually dependent groups of microorganisms (Fig 1). If the correct conditions are maintained, the AD process will be stable with high energy recovery (Dechrugsa et al., 2013). However, the technology still faces two major challenges: (i) operational instability and (ii) the quality of the digestate produced (Holm-Nielsen et al., 2009; Appels et al., 2011).

Organic substrate selection plays an important role in the stability of an AD system as some feedstocks can have inhibitory effects on AD processes. Substrate-induced inhibition (SII) in AD can occur when the constituent fraction(s) or metabolic intermediate product(s) from organic substrates inhibit microbial activity. These forms of inhibition have been reported for organic substrates containing high amounts of protein, lipids, limonene, furans, metals, pesticides, antibiotics and other organic compounds (El-Gohary et al., 1986; Palmqvist and Hahn-Hagerdal, 2000; Lallai et al., 2002; Wilkins et al., 2007; Alvarez et al., 2010; Sousa et al., 2013; Yangin-Gomec and Ozturk, 2013). SII is either through the direct addition of inhibitory compounds, such as limonene, or indirectly through the production of inhibitory intermediates, such as ammonium and hydrogen sulphide from protein (Table 1). Microbial adaptation to potential inhibitors and co-digestion with two or more substrates are commonly used to reduce inhibition (El-Mashad and Zhang, 2010; Zhang and Jahng, 2012). During microbial adaptation, the inhibitor can be transformed into metabolites with a similar or lower level of toxicity while the application of co-digestion reduces the concentration of the inhibitor by increasing the ratio of the co-substrate (Athanasoulia et al., 2014). In most cases, AD operators prefer co-digestion of two or more substrates in order to reduce possible inhibition that might result from the treatment of individual feed-stocks (Cheng and Zhong, 2014). However, an alternative approach to reducing inhibition in AD is to remove or reduce the mobility/bioavailability of the inhibitors without affecting with the AD process.

Another major concern with AD is how to retain the nutritive value of the digestate before and after application to land (Mihoubi, 2004; Mangwandi et al., 2013). In most cases, digestate has a high moisture content and in an attempt to reduce this, phase separating equipment is utilized. According to Vaneeckhaute et al. (2013), 43% of the total nitrogen (N) and 25% of the total phosphorus (P) will be lost if the liquid fraction of pig slurry digestate is separated. Further nutrient and metal losses can occur during and after the spreading of the digestate on farmland via transfer to the surrounding watercourses or to the atmosphere. The volatilization of ammonium, leading to ammonia emission, and the leaching of heavy metal as diffuse pollution, are examples of losses that have a negative impact on the environment and crops

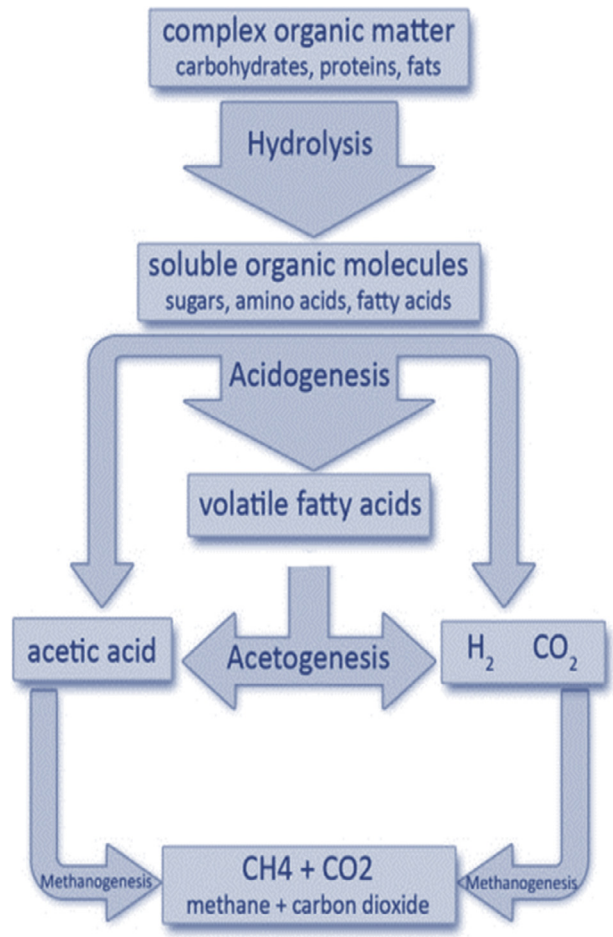

Fig. 1. Schematic representation of the anaerobic digestion process (Amaya et al., 2013).

(Svoboda et al., 2013; Page et al., 2014). Nutrient recovery from digestate has been considered as an option to reduce the nutrient loss from the digestate. However, this approach might reduce the economic value of the digestate (Verstraete et al., 2009; Batstone et al., 2015).

A better approach may be to focus on increasing the nutrient retention capacity of the digestate material. There is a growing interest in the use of biochar in AD to both increase the recovery rate of the process during SII and decrease the nutrient loss before and after land application (Mumme et al., 2014; Dicke et al., 2015; Cai et al., 2016; Lü et al., 2016; Sunyoto et al., 2016). This will potentially increase the operation of mono-substrate AD, which is often used by single substrate onsite AD operators, increase nutrient availability during digestate application to land and reduce the environmental implications of diffuse pollution and nutrient leaching. This review examines substrate-induced inhibition and its impact on anaerobic digestion, nutrient leaching and its environmental implications, and the properties and functionality of biochar material in counteracting these challenges.

Please cite this article in press as: Fagbohungbe, M.O., et al. The challenges of anaerobic digestion and the role of biochar in optimizing anaerobic digestion. Waste Management (2016), http://dx.doi.org/10.1016/j.wasman.2016.11.028

Download English Version:

https://daneshyari.com/en/article/5756958

Download Persian Version:

https://daneshyari.com/article/5756958

Daneshyari.com