Waste Management xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

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

What is the effect of mandatory pasteurisation on the biogas transformation of solid slaughterhouse wastes?

Aidan Ware, Niamh Power *

Department of Civil, Structural and Environmental Engineering, Cork Institute of Technology, Cork, Ireland

ARTICLE INFO

Article history:
Received 29 April 2015
Revised 8 October 2015
Accepted 9 October 2015
Available online xxxx

Keywords:
Anaerobic digestion
Slaughterhouse waste
Biochemical methane potential
Pasteurisation
Biogas

ABSTRACT

The effect of mandatory pasteurisation on Category 3 offals, according to the Animal By-Products Regulation (ABPR 1069/2009/EC), was determined using Biochemical Methane Potential (BMP) assays as well as kinetic and statistical analysis. Pasteurised and unpasteurised offals sampled from cattle, pig and chicken slaughterhouses were characterised and their specific methane yields (SMYs) and their bioavailability was assessed. The resultant SMYs were high (465–650 $mLCH_4\ gVS^{-1}$) with no statistically significant increase in methane production identified due to pasteurisation. However, the kinetics of the biogas transformation processes highlighted increased bioavailability of the organics due to pasteurisation. This was brought to light by the change in maximum daily SMY from day 22 to day 1 for the cattle offal ($p = 0.001$), day 17 to day 1 for chicken offal ($p = 0.025$) and an increase of 18.8% in the maximum daily SMY of the pig offal on day 1 ($p = 0.003$). The increased bioavailability of the offals manifested itself in two ways with the determining factor being identified as the physical characteristics of the fats i.e. particle size. Firstly reducing the hydrolytic lag phase for the cattle offal, $\lambda = 7.46–1.52$ days ($p = 0.013$). Secondly, causing increased accumulation of Long Chain Fatty Acids to acute inhibitory levels in the chicken and pig offal indicated by increased lag phases $\lambda = 5.05–21.91$ days ($p = 0.012$), $\lambda = 15.54–23.04$ days ($p = 0.007$) respectively.

1. Introduction

The slaughtering industry is a major facet of the agri-food sector in Ireland. More than 1.6, 2.9 and 84.8 million cattle, pigs and chickens respectively are slaughtered annually in Ireland (Central Statistics Office, 2012). Approximately 46%, 26% and 32% (cattle, pig and chicken) of the total animal weight slaughtered is not used for food consumption and is considered process by-products of varying value (Central Statistics Office, 2012; Edström et al., 2003; Verheijen et al., 1996). Traditionally these waste streams were treated through the rendering process (Bayer et al., 2012). The enforcement of the ABPR in 2002 (1774/2002/EC repealed by 1069/2009/EC) to prevent the outbreak and spread of disease, dictated the need for higher hygiene regulations, tighter process controls and exclusion of the use of some animal by-products in traditional uses (European Commission, 2009). The implementation of these regulations reduced the economic value of these materials for rendering and in many cases they have to be disposed of through incineration. The regulations regard biogas transformation as a suitable treatment method for a variety of animal by-products, provided approved pre-treatments are applied (European Commission, 2005; Palatsi et al., 2011). Legislation dictates slaughterhouse wastes must be treated by different thermal pre-treatments prior to use in biogas transformation according to its category (European Commission, 2009). Three categories are defined (Kirchmayer et al., 2003; Braun and Kirchmayr, 2003; Hejnfelt and Angelidaki, 2009):

- Category 1, high risk material (material presenting the highest risk of containing animal diseases), is not permitted to be treated through biogas transformation under any circumstances.
- Category 2, high risk animal by-products (perished animals and/or animals slaughtered but not intended for human consumption), must be sterilised to 133 °C under 3 bars for 20 mins.
- Category 3, low risk material (meat containing wastes from food industry and slaughterhouse waste of animals fit for human consumption), must be treated to a minimum of 70 °C for 60 mins.

Slaughterhouse waste streams are considered as model substrates for biogas transformation due to their high fat and protein content. However, they are also regarded as difficult substrates for the very same reasoning, primarily the high fat content (Palatsi

* Corresponding author.
E-mail address: niamh.power@cit.ie (N. Power).

http://dx.doi.org/10.1016/j.wasman.2015.10.013
0956-053X/© 2015 Published by Elsevier Ltd.

et al., 2011). The simplified biogas transformation of fats is outlined in Fig. 1. This process depends on the syntrophic nature of the acetogenic and methanogenic bacterial populations (Palatsi et al., 2011). The hydrolysis rates of fats are dependent both on their chemical characteristics as well as physical characteristics such as the available surface area (particle size). Sayed et al. (1988) found the liquefaction of fats to be rate limiting in slaughterhouse wastewater when high amounts of suspended solids were present due to their low bioavailability as a result of their lower surface area and insolubility. The most common reasons for the instability of the biogas transformation process, especially with regards to the treatment of substrates with a high fat content, are the production of inhibitory compounds known as intermediate fermenters such as Volatile Fatty Acids (VFAs) and Long Chain Fatty Acids (LCFAs), produced during acidogensis and acetogensis (Palatsi et al., 2011). Palatsi et al. (2010, 2011) along with Cirne et al. (2007) observed rapid accumulation of VFAs during the initial stages of the biogas transformation of substrates with high fat contents, indicating that the hydrolytic-acidogenic bacteria did not inhibit the substrate degradation and that the process was held at the acetogenic and methanogenic stages, shaded grey in Fig. 1. LCFAs can only be degraded through syntrophic interactions of acetogenic and methanogenic bacterial communities and as such the inhibition of the acetogensis stage results in methane production reducing or ceasing during the initial lag phase of LCFAs acetogensis (Bayer et al., 2012; Palatsi et al., 2011; Cirne et al., 2007; Sousa et al., 2007, 2009). The inhibitory effect of LCFAs is a recoverable phenomenon, related to the physical adsorption of LCFA which can hinder the solubility of the substrate through microbial cell walls along with the slow growth rate of LCFA consuming bacteria (Palatsi et al., 2011; Hejnfelt and Angelidaki, 2009; Salminen and Rintala, 2002). Consequently, when LCFA inhibition occurs it can be monitored as an initial delay in methane production or as a long lag phase before complete degradation of the substrate occurs (Palatsi et al., 2011; Hejnfelt and Angelidaki, 2009).

The pasteurisation of offals prior to use as a substrate for biogas transformation is required to meet regulations set out by the

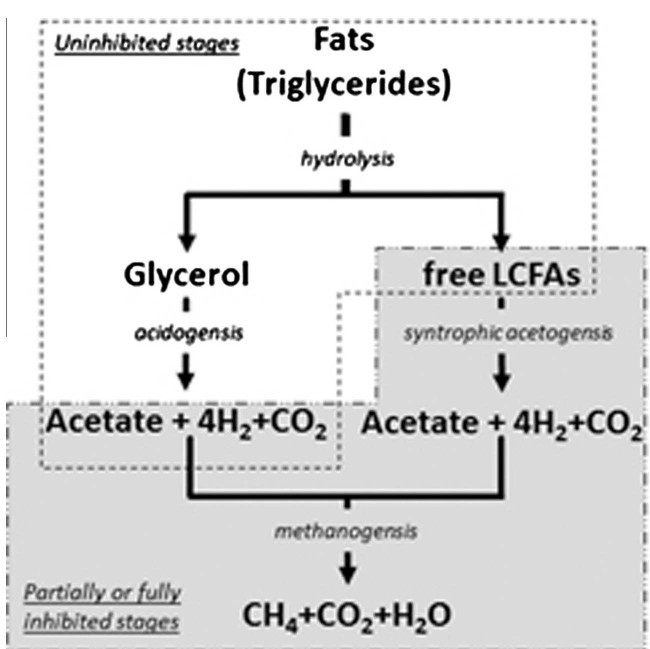

Fig. 1. Biodegradation stages of fats to biogas outlining stages affected by high levels of LCFA accumulation, derived from Palatsi et al. (2010, 2011) and Cirne et al. (2007).

European Commission to avoid potential risks to humans and animals under the ABPR. However it could potentially influence higher performance of the biogas transformation process also, in terms of the bioavailability of organics increasing methane production rate as well as increasing Specific Methane Yield (SMY). In terms of raising performance, the goal of the pre-treatment is to make the components of the waste stream more bioavailable, which means that the proteins and fats of the waste stream are more readily available to the bacterial populations thus reducing the hydrolysis period. However increasing bioavailability may also have negative connotations; by increasing the rate at which intermediate fermenters are produced, inhibition may occur through rapid accumulation of compounds such as LCFAs and VFAs. Conflicting effects of thermal pre-treatments such as sterilisation (133 °C and 3 bars for 20 min) or the more common pasteurisation (70 °C for 60 min), on the methane yield of slaughterhouse wastes have been reported.

Edström et al. (2003) compared the potential gas yield from Pasteurised (P) and Un-pasteurised (UP) mixtures of slaughterhouse waste, food waste and liquid manure. They concluded that the P mixture resulted in a fourfold increase in biogas production in comparison to the UP mixture. The biogas yield increased from 0.31l Lbiogas gVS^{-1} to 1.14 Lbiogas gVS^{-1}. Hejnfelt and Angelidaki (2009) investigated the effects of both sterilisation and pasteurisation on the methane yield from mixed pork waste and reported that neither pre-treatments had an effect on achieved methane yields. Cuetos et al. (2010) assessed the effects of sterilisation on the methane yield of poultry slaughterhouse waste and its co-digestion with the organic fraction of municipal solid waste (OFMSW). The attempt of increasing methane yield by means of application of sterilisation was not successful for either mixes tested due to the instability of the digesters. The methane yields observed were in fact reduced after pre-treatment was applied, with a reduction of between 10% and 34%. Rodríguez-Abalde et al. (2011) evaluated effects of thermal pre-treatments on the methane yield of two solid slaughterhouse wastes, poultry and pig slaughterhouse by-products. Pasteurisation was applied to both wastes and the pig waste stream was also sterilised to observe the effects. Varied results were reported; pasteurisation and sterilisation had a significant effect on the methane yield of the pig waste, over 50% increase for both pre-treatment methods. This increment was not observed with the chicken waste with only a 2.6% increase observed indicating pre-treatment had no significant benefits to the process.

It is clear that the effect of thermal pre-treatment on the methane yield of slaughterhouse waste is extremely varied and a categorical statement as to the increase or decrease on the methane/biogas yield cannot be made. The focus of this work is to study the anaerobic biodegradability and methane potential of solid slaughterhouse waste streams, under standardised conditions, in order to determine the effect of mandatory pasteurisation imposed by the ABPR.

2. Materials and methods

2.1. Substrates

Solid slaughterhouse wastes were gathered from cattle, pig and chicken slaughtering facilities. The selected solid waste fractions were Category 3 soft offals produced during the evisceration process. The general consistency of the offals in their sampled state was as a heterogeneous solid waste, consisting of large identifiable individual components of animal entrails and fat trimmings. Both the chicken and pig offal contained the digestive tract contents of the animals. The digestive tract contents of the cattle are removed