Waste Management 56 (2016) 506–518

Contents lists available at ScienceDirect

Waste Management

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

Horse manure as feedstock for anaerobic digestion

Åsa Hadin *, Ola Eriksson

Department of Building, Energy and Environmental Engineering, Faculty of Engineering and Sustainable Development, University of Gävle, Kungsbäcksvägen 47, S-801 76 Gävle, Sweden

ARTICLE INFO

Article history:
Received 9 March 2016
Revised 14 June 2016
Accepted 14 June 2016
Available online 7 July 2016

Keywords:
Horse manure
Bedding
Anaerobic digestion
SS-AD
Methane potential
Feedstock
Operating factor
Biogas
Digestate
BMP
Co-digestion

ABSTRACT

Horse keeping is of great economic, social and environmental benefit for society, but causes environmental impacts throughout the whole chain from feed production to manure treatment. According to national statistics, the number of horses in Sweden is continually increasing and is currently approximately 360,000. This in turn leads to increasing amounts of horse manure that have to be managed and treated. Current practices could cause local and global environmental impacts due to poor performance or lack of proper management. Horse manure with its content of nutrients and organic material can however contribute to fertilisation of arable land and recovery of renewable energy following anaerobic digestion. At present anaerobic digestion of horse manure is not a common treatment. In this paper the potential for producing biogas and biofertiliser from horse manure is analysed based on a thorough literature review in combination with mathematical modelling and simulations. Anaerobic digestion was chosen as it has a high degree of resource conservation, both in terms of energy (biogas) and nutrients (digestate). Important factors regarding manure characteristics and operating factors in the biogas plant are identified. Two crucial factors are the type and amount of bedding material used, which has strong implications for feedstock characteristics, and the type of digestion method applied (dry or wet process). Straw and waste paper are identified as the best materials in an energy point of view. While the specific methane yield decreases with a high amount of bedding, the bedding material still makes a positive contribution to the energy balance. Thermophilic digestion increases the methane generation rate and yield, compared with mesophilic digestion, but the total effect is negligible.

Contents

* Corresponding author.
E-mail address: asa.hadin@hig.se (Å. Hadin).

http://dx.doi.org/10.1016/j.wasman.2016.06.023
0956-053X/

1. Introduction

Horse manure, a mixture of faeces, urine and bedding, is a dry material with a total solids (TS) content of 20% or higher (Hadin et al., in press). Horse manure is often viewed as a problem and defined as a waste, but can be used as a soil improver and fertiliser, as well as a resource for renewable energy. The increasing numbers of horses kept within or near urban areas creates environmental problems, as there is a lack of arable land for spreading manure and insufficient methods or capacity for manure storage. Factors affecting environmental impact from horse manure and amount and chemical composition of horse manure include the type and amount of feed, type and amount of bedding, mucking out regime, residence time outside, type and duration of manure storage, spreading and soil conditions, transport distance and type of fuel used (Hadin et al., in press). All these factors influence environmental impacts from horse manure such as emissions to soil, water and air.

Improved manure management can reduce the direct environmental impact from horse manure. If manure is used as a resource for renewable energy, it could also reduce the use of fossil fuels, thereby mitigating global warming. Recovery of resources from horse manure can be facilitated by different technologies for energy and nutrient recovery. Of particular interest is anaerobic digestion, a method for simultaneous energy recovery and nutrient recycling, and so far not commonly used for treatment of horse manure. By introducing horse manure as a substrate for anaerobic digestion, renewable energy could be recovered as biogas and digestate could replace mineral fertilisers and also possibly reduce the environmental impact compared with direct spreading of composted horse manure on arable land. Anaerobic digestion, a recycling method, should be chosen in favour of e.g. combustion, following the EU waste hierarchy (European Commission, 2008). However, horse manure has so far not been considered feasible for anaerobic digestion due to the high TS content in combination with the presence of bedding materials with poor process performance such as woodchips (slowly degradable) and straw (long straw). Scientific publications on the issue are scarce and deal mainly with pilot or laboratory-scale experiments (e.g. Kusch et al., 2008; Mönch-Tegeder et al., 2013; Böske et al., 2014, 2015). The aim of the present study was to identify, describe, analyse and discuss important aspects of horse manure for anaerobic treatment in terms of feedstock characteristics and biogas process parameters.

2. Method

The study focused on factors which affect quantity and quality of biogas and digestate. Factors were identified for: (1) manure characteristics and (2) digestion process parameters in relation to horse manure as a substrate. The method applied was a combination of literature review and mathematical modelling. The scope of the study is depicted in Fig. 1, which also shows the layout of the paper.

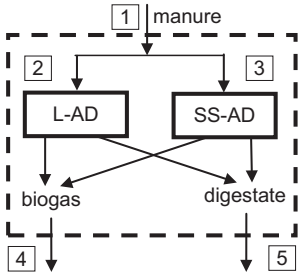

Fig. 1. Products and processes for which crucial factors were identified in this study.

Following Fig. 1, characteristics of the manure entering the system (1) can act as feedstock for liquid anaerobic digestion (L-AD) (2) and solid state anaerobic digestion (SS-AD) (3). Each digestion process includes pre-treatment, reactor (digester) and digestate storage. Products leaving the system are biogas (4), utilised by direct combustion or upgrading to vehicle gas, and digestate (5), transported for application on agricultural soil.

2.1. Literature review

Literature about horse manure characteristics and biogas technology in the form of scientific papers, representing international research in the area of horse manure biogas potential, reports from research centres, e.g. the Swedish Institute of Agricultural and Environmental Engineering, and agencies, e.g. the Swedish Board of Agriculture, primary about horse manure characteristics, were reviewed. The scope of the search was wide and included experimental tests, operational laboratory-scale processes and full-scale co-digestion. The objective was to compile information to enable comparisons of horse manure biogas potential results in different studies, even if each test or operational test in laboratory scale is unique. The literature search was made using databases such as Science Direct and Google Scholar.

2.2. Mathematical modelling

Some of the information from the literature review was used in model simulations to investigate the importance of varying numerical data on manure characteristics and biogas process parameters. The model chosen was ORWARE, a computational life cycle assessment (LCA) model for evaluating environmental impacts of waste management (Eriksson et al., 2002). The ORWARE model has been under development since the early 1990s and has led to a vast number of research papers, doctoral theses and major studies (e.g. Eriksson et al., 2005; Gentil et al., 2010). The basis for