Bioresource Technology 150 (2013) 187–194

Contents lists available at ScienceDirect

Bioresource Technology

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

Feasibility of grass co-digestion in an agricultural digester, influence on process parameters and residue composition

S. De Moor [a,*], F. Velghe [b], I. Wierinck [b], E. Michels [a], B. Ryckaert [c], A. De Vocht [d], W. Verbeke [e], E. Meers [a,f,g]

[a] Department of Applied Analytical and Physical Chemistry, Laboratory of Analytical Chemistry and Applied Ecochemistry, Ghent University, Coupure Links 653, B-9000 Ghent, Belgium
[b] Organic Waste Systems, Dok Noord 5, B-9000 Ghent, Belgium
[c] Inagro vzw, Ieperseweg 87, B-8800 Rumbeke-Beitem, Belgium
[d] PHL-bio, Agoralaan, Gebouw E, B-3590 Diepenbeek, Belgium
[e] Inverde, Koning Albert II-laan 20, B-1000 Brussel, Belgium
[f] Faculty of Business Economics, University of Hasselt, Campus Diepenbeek, Agoralaan Gebouw D, B-3590 Diepenbeek, Belgium
[g] Biogas-E, Graaf Karel de Goedelaan 34, B-8500 Kortrijk, Belgium

HIGHLIGHTS

- Up to 20% of the input mixture of an agro-digester was replaced by grass clippings.
- Viscosity increased, but all other process parameters were unaffected.
- The addition of an enzyme mixture (MethaPlus L100) again decreased the viscosity.
- Grass can be a low-impact co-input for an agro-digester.

ARTICLE INFO

Article history:
Received 11 June 2013
Received in revised form 30 September 2013
Accepted 3 October 2013
Available online 11 October 2013

Keywords:
Anaerobic digestion
Grass clippings
Semi-continuous system
Mesophilic co-digestion
Agro-digester

ABSTRACT

This study investigated the potential of co-digestion of grass clippings in a typical Flemish agro-digester characterized by an input of 30% manure, 30% maize silage and 40% side streams. No significant adverse effects in the microbiological functioning of the reactors were detected when part of the maize input was replaced by 10–20% grass. However at the highest dosage of grass input, dry matter content and the viscosity of the reactor content increased substantially. These parameters could be reduced again by enzyme addition in the form of MethaPlus L100. It can be concluded that co-digestion of 20% grass in an agricultural digester would not pose any problem if dry matter content and viscosity are improved by the use of an enzyme mixture.

1. Introduction

In response to the global climate change debate and a growing awareness of environmental issues, the European Union has set an ambitious goal to achieve a 20% share of renewable energy and a 10% share of biofuels in the transport energy consumption by 2020. This led to the development of a whole range of different techniques to produce energy from biomass. First generation biofuels were produced from food crops such as maize, sugarcane, soybeans, sunflowers and rapeseed. This raised ethical concerns since their production competes with food production. The food vs energy debate intensified when the price of food on the world market increased significantly (Müller et al., 2008; Timilsina et al., 2011). The discussion eventually resulted in a shift towards second generation biofuels, which are produced from non-food biomass. This can for instance be non-food energy crops, post-harvest biomass, organic wastes or unused biomass such as greenery cuts and grass. However, the ethical concern persisted in the case of energy crops, as they still compete with food crops for agricultural land and are therefore considered as non-sustainable (Thompson and Meyer, 2013). To assess the sustainability of crops for bio-fuels and more generally bio-energy, it is however important to take into account more factors than only the competition for land use with food crops. Sustainability is a broad term which should also include environmental impacts such as greenhouse gas mitigation, soil erosion, water shortage, pollution from pesticides or fertilizers, biodiversity, damage to ecosystems… (European Biofuels, 2013).

---

* Corresponding author. Tel.: +32 92646131.
E-mail address: sofie.demoor@ugent.be (S. De Moor).

0960-8524/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2013.10.011

The European Environment Agency states that Belgium is a country with a low environmentally-compatible bioenergy potential (EEA, 2007). This means that the scope for extra agricultural land to become available for biomass crop production is limited. The main factors determining this low potential for Belgium are the high population density as well as the highly competitive agricultural sector. This will obviously limit the options for the production of biomass for bioenergy in Belgium. In this regard, grass could be an interesting low-impact biomass resource for the production of bioenergy. On the one hand the grass can come from permanent grasslands, where the harvest of this biomass can have a beneficial impact on biodiversity conservation (Peeters, 2009). Biomass and energy potentials of grasslands have been observed before (Tilman et al., 2006). On the other hand a second supply of grass can come from roadsides, where it is not only unused but also a waste product that is in need of disposal.

The production of bioenergy from grass can be done in various ways such as for example combustion, anaerobic digestion (Prochnow et al., 2009; Orozco et al., 2013) or a combination of different techniques (Hensgen et al., 2012). During the process of anaerobic digestion methane is produced. Methane is an excellent fuel, for which pipeline transport infrastructure already exists and that has good conversion efficiencies. Energy efficiency is higher for anaerobic digestion compared to combustion. In comparison to the production of bio-ethanol, which is a fermentation process, anaerobic digestion needs much less pretreatment of the feedstock biomass (Chynoweth et al., 2001) and requires no energy intensive distillation of the reaction products as the gaseous methane escapes spontaneously. Currently, in some Northern European countries, grass is used in practice for anaerobic digestion to produce biogas (Prochnow et al., 2009; Thamsiriroj and Murphy, 2010). Gerin et al. (2008) report that grass, although unquantified, could be a relevant feedstock for anaerobic digestion in Belgium.

Biogas yield and energy efficiency in the process of anaerobic digestion depend greatly on the anaerobic biodegradability of the biomass feed. Factors influencing this biodegradability are relative lignin content, relative (hemi)cellulose content and crystallization, proportion of (non)structural carbohydrates, degree of association between lignin and carbohydrates, the presence of toxic components, ash content and nutrient status (Gunaseelan, 2007, 2009; Schievano et al., 2008). These factors can even vary among plants of the same species according to cultivation method, plant part, harvest time/plant age/growth stage and genotype (Deren and Snyder, 1991; Lehtomäki et al., 2008; Schittenhelm, 2008). Different strategies can be followed to enhance the biodegradability of biomass. A commonly used method is size reduction before feeding to the reactor. This will increase the specific surface of the grass particles and thus speed up the process (Sharma et al., 1988; Chynoweth et al., 1993; Moorhead and Nordstedt, 1993; Mshandete et al., 2006; Nopharatana et al., 2007). A second beneficial effect of size reduction is that the biomass will be easier to stir in the reactor ensuring good mass transfer. In practice, the reactor will need a (semi)continuous feed, while grass is harvested only periodically. Ensiling is a commonly used conservation method used to avoid aerobic deterioration. First the grass is shredded and piled up, subsequently the stack is packed to exclude oxygen so that the microbiology can uniformly heat and partially break down the biomass. The microorganisms anaerobically ferment the water-soluble carbohydrates to lactic acid and (to a lesser extent) acetic acid, thereby increasing acidity beyond a critical pH value so that further subsequent bacterial (methanogenic) conversion of the acids become inhibited and the biomass is effectively conserved. If done properly, this conservation process can also have a significantly positive effect on the biogas production during the subsequent anaerobic digestion (Prochnow et al., 2009). Herrmann et al. (2011) state that this can be attributed to increases in organic acids and alcohols during ensiling, as these products are important precursors in the production of methane during anaerobic digestion.

There are several technical options that should be considered for the anaerobic digestion of grass. Firstly, if grass is the only input material of the digester, the process is called monodigestion. On the contrary, co-digestion entails the use of different types of input materials that form an input mix together, for example a combination of grass with manure and organic wastes. Co-digestion of grass will avoid a number of problems that are associated with monodigestion. Thamsiriroj et al. (2012) state that long term monodigestion of grass will fail without the addition of trace elements to the reactor. The minimal level of slurry required in co-digestion to alleviate inhibition remains to be investigated (Thamsiriroj et al., 2012). Xie et al. (2011) conclude that for successful anaerobic digestion of grass silage it is necessary to add a source of external alkalinity to increase buffering capacity, which they achieve by co-digestion of pig manure. An additional argument to choose co-digestion over monodigestion is that the environmental performance (as assessed by De Vries et al. (2012) by an LCA study) is best when manure and grass are digested together.

Another problem with grass however is that it tends to cause mixing problems due to increased viscosity, floats at the liquor surface and blocks pipes and pumps (Thamsiriroj and Murphy, 2010). Romano et al. (2009) propose the use of enzymes to overcome this obstacle. Enzymes are biologically active protein molecules that target specific substrates and can be isolated from microbial, plant or animal cells. They can perform all sorts of reactions such as for instance hydrolytic, synthetic, redox or transfer reactions. Romano et al. (2009) saw a better solubilization of wheat grass if enzyme products containing cellulase, hemicellulase, and β-glucosidase were added to the reactor, without significant effect on biogas/methane yields and volatile solids reduction.

The aim of this study is to investigate whether it is feasible to mesophilically co-digest grass in a typical Flemish agricultural digester. For this purpose a semi-continuous digestion test was conducted as the impact of a specific substrate on the digestion process cannot always be predicted from its chemical composition. As some effects will only be measurable after a longer period of testing, the experiment was continued for 17 weeks. The effect of dosing 10% and 20% grass was looked into, as well as the impact of two different types of grass feedstocks: roadside grasses and grassland. Also the effect of enzyme addition to the reactor was investigated to see which process parameters were affected.

2. Methods

2.1. Experimental setup

To investigate the feasibility of mesophilic co-digestion of grass in a typical Flemish agricultural digester, 5 test reactors were run in parallel. The input streams will be discussed in detail in Section 2.2.

- Reactor 1 (R1): ‘blank’, no grass addition
- Reactor 2 (R2): roadside grass 1 (stopped after 5 test weeks)
- Reactor 3 (R3): roadside grass 2
- Reactor 4 (R4): grass from grassland
- Reactor 5 (R5): grass from grassland + MethaPlus L100 (started in test week 6)

Each reactor had a total volume of 50 L with an active content of 20–25 kg. Temperature was kept constant at 37 ± 2 °C to maintain