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Comparing environmental consequences of anaerobic mono- and co-digestion of pig manure to produce bio-energy – A life cycle perspective

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HIGHLIGHTS

- Production of substitutes required for initial use of co-substrates was included.
- Land use change emissions from maize, barley, and soybean production were included.
- Mono-digestion had good environmental performance, but low bio-energy production.
- Co-digestion with animal feed increased bio-energy, but also environmental impact.
- Co-digestion with roadside grass showed best environmental performance.

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ABSTRACT

The aim of this work was to assess the environmental consequences of anaerobic mono- and co-digestion of pig manure to produce bio-energy, from a life cycle perspective. This included assessing environmental impacts and land use change emissions (LUC) required to replace used co-substrates for anaerobic digestion. Environmental impact categories considered were climate change, terrestrial acidification, marine and freshwater eutrophication, particulate matter formation, land use, and fossil fuel depletion. Six scenarios were evaluated: mono-digestion of manure, co-digestion with: maize silage, maize silage and glycerin, beet tails, wheat yeast concentrate (WYC), and roadside grass. Mono-digestion reduced most impacts, but represented a limited source for bio-energy. Co-digestion with maize silage, beet tails, and WYC (competing with animal feed), and glycerin increased bio-energy production (up to 568%), but at expense of increasing climate change (through LUC), marine eutrophication, and land use. Co-digestion with wastes or residues like roadside grass gave the best environmental performance.

1. Introduction

The demand for renewable energy is rising because of increasing social awareness of consequences related to non-renewable energy use, e.g. fossil fuel depletion, energy security, and climate change (CC). Renewable energy production in the European Union, for example, is targeted to reach 20% of total energy production by 2020 (EU, 2009). This transition requires insight into environmental consequences of producing renewable energy, including CC, fossil fuel depletion, and land use changes. Life cycle assessment (LCA) is an internationally accepted method to gain insight into the environmental consequences of a product or system (ISO-14040, 2006).

Bio-energy is a form of renewable energy and is produced from biomass. Biomass can be converted by anaerobic digestion (AD) into biogas, composed of methane (CH_4), carbon dioxide (CO_2) and some trace gases (e.g., hydrogen gas), which can then be used to produce bio-energy in the form of electricity, heat, or transport fuel (De Vries et al., 2012; Hamelin et al., 2011). The remaining product after AD, i.e. digestate, can be recycled as organic fertilizer for crop cultivation to substitute mineral fertilizer (Börjesson and Berglund, 2007). Main substrates for AD include agricultural biomass in the form of animal manures and energy crops (e.g. maize), organic residues from the processing industry (e.g. glycerin, beet tails, and gut and intestines from slaughtering houses), and other residues such as, roadside grass or forest residues (Cherubini and Strømman, 2011).

Environmental LCA studies of AD of pig and cattle manure (raw or separated fraction) and energy crops, such as maize and rye grass focused on bio-energy production, greenhouse gas (GHG) emission reduction potentials, and various biogas end applications (Börjesson and Berglund, 2007; De Vries et al., 2012; Hamelin et al.,

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