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Research Paper

Composition and biogas yield of a novel source segregation system for pig excreta

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The performance of a novel source segregation method for pig excreta (a V-shaped conveyor belt underneath the slatted pen floor) was compared to conventional separation methods for pig slurry (screw press, centrifugation, flocculation with/without centrifugation). For the source segregation system, a larger amount of organic matter accumulated in the solid fraction (96%) than for conventional separation systems (34–93%). Also the dry matter content, nutrient content (total N and P), and methane production of this solid was higher than for the other systems. Furthermore the volumetric methane yield was much higher than for the solid fraction from the other separation systems (1.6 vs 0.8–1.0 m^3 [CH_4]·m^{-3} [reactor]·day^{-1} for a CSTR). Due to the high methane yield, digestion of the solid from source segregation is expected to require a considerable smaller reactor than for slurry digestion, which would increase the economic feasibility of mono-digestion systems for animal manure.

1. Introduction

In industrialized livestock production in Europe, regulations limit the amount of manure that may be applied on arable land mainly to prevent over application of the nutrients nitrogen (N) and phosphorous (P), e.g. the Nitrate Directive for the EU-27 (EC, 1991) and the Minerals Policy Act for the Netherlands (RVO, 2005). These regulations strongly affect regions with high animal density and limited arable land, such as areas with intensive pig and poultry farms in densely populated areas. In this situation, surplus nutrients or surplus manure that may not be applied must be treated or exported. A common first treatment step is to separate pig slurry into a solid fraction and a liquid fraction. This facilitates transport of the solid fraction and may also be necessary for further processing of the solid or liquid fraction. The solid fraction is sometimes used for production of value-added products such as compost or fertilizers. The liquid fraction may be treated further, e.g. by anaerobic digestion ("biogas plant").

However, it is often not economically feasible (without subsidies) for biogas plants to digest pig slurry alone ("mono-digestion") due to its low biogas yield per ton of substrate (Angelidaki & Ellegaard, 2003). In order to increase the biogas yield often high-energy co-substrates, e.g. maize, glycerine or food waste, are added to the slurry ("co-digestion"). Because of

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prevailing regulations, a disadvantage of co-digestion is sometimes that the total volume of digestate and the amount of minerals in the digestate increases as compared to original manure. This could mean that the mineral surplus of a farmer increases, as the nutrients from the co-substrates are added to the manure. Furthermore, co-substrate must be available at acceptable cost; in recent years prices of many co-substrates have increased. Finally, from an Life Cycle Analysis perspective mono-digestion is preferable as it has a lower environmental impact than co-digestion according to De Vries, Vinken, Hamelin, and De Boer (2012). An alternative way to increase the biogas yield of mono-digestion systems could be the use of the solid fraction from slurry separation as substrate, instead of the slurry. It is expected that such a reactor would require less volume and have lower investment costs. Digesting the solid fraction might overcome the economic constraint of biogas plants with mono-digestion of slurry. In this study, the possibility of separating pig excreta and using the separated solid fractions for biogas production is explored.

Many solid–liquid separation systems for slurry have been investigated, including mechanical and chemical separation (e.g. Hjorth, Christensen, Christensen, & Sommer, 2010). Separation efficiencies vary between techniques and adding chemicals prior to mechanical separation often leads to significant improval of separation efficiency with regard to dry matter (DM), total phosphorus (TP) and total nitrogen (TN), i.e. the accumulation of the specific component in the solid fraction is increased. However, techniques with a high separation efficiency are often complex and expensive for farmers to use. Beside these conventional solid–liquid separation techniques, in recent years researchers have introduced a new separation system using a conveyor belt that is located underneath the slatted floor of a pig house. The belt is either transversally sloped or V-shaped with perforations at the centre along the length of the belt (Aarnink & Ogink, 2007; Koger et al., 2014; De Vries, Aarnink, Groot Koerkamp, & De Boer, 2013). The liquid ('urine') flows off continuously either to the lower side of the sloped belt or to the perforations at the centre of the V-shaped belt, where it is collected in a drain pipe; the solids ('faeces') remain on the belt. The belt operates along the length of the house and periodically carries the solids to the end of the building where the solids are collected. This system is called a *source segregation* system because it keeps faeces and urine segregated after excretion, instead of mixing them to slurry first followed by separation. In practice, the conveyor belt system is not widely used, yet it has proven to be beneficial for animal welfare and environmental performance, including the reduction of ammonia and methane emissions. The solid fraction obtained from this type of conveyor belt system contains 80–90% of all DM, 60–70% of all TN, and >90% of all TP; the remainder is present in the liquid fraction (Aarnink & Ogink, 2007; Koger et al., 2014; De Vries et al., 2013). These separation efficiencies are comparable to the best results that can be obtained using conventional slurry separation techniques (reported ranges by (Hjorth et al., 2010): 11–95% for DM, 3–51% for TN, 7–90% for TP).

Many studies were done on biogas production from pig slurry, however, few studies focus on the use of the solid fraction from pig excreta ("solids") for biogas production. From the known studies on solids, most report values for the solid fraction obtained only after separation of slurry (Møller, Sommer, & Ahring, 2004, 2007; González-Fernández, Nieto-Diez, León-Cofreces, & García-Encina, 2008; Thygesen, Triolo, & Sommer, 2014); only two studies are known that report values for faeces that were directly collected from pigs (Jarret, Martinez, & Dourmad, 2011, 2012). No data is currently available on biogas production from solids obtained from a source segregation system. Furthermore, between these studies on solids there is a large variation of methane yield in terms of ml CH_4 per gram organic matter of solid derived, even when the same separation method is used. No information has been published on hydrolysis rate constants of solid fractions from pig slurry separation, although such information is important for system design of biogas plants in practice.

The physical and chemical characteristics of pig slurries vary between farms, animal breeds, feed types etc. and also depend on storage time and conditions (Jarret et al., 2012; Møller et al., 2004; Massé, Masse, Claveau, Benchaar, & Thomas, 2008). These variations might not only influence the measured efficiency of a separation technique but also the methane yield of the solids. In most studies where efficiencies are compared, or when efficiencies between studies are compared, different starting materials were used: the separation techniques are operated on manure from a different source with different characteristics. This will explain part of the broad ranges that are reported for separation efficiencies and methane yield, even if the same technique is applied. In our study we tried to circumvent this problem by evaluating all techniques using pig's excreta from the same batch, i.e. having equal characteristics.

The objective of this study was to evaluate the influence of source segregation and conventional separation systems on biogas yield and composition of solids and liquids derived from pig manure. First of all, the source segregation and the conventional systems (screw press, centrifugation, flocculation, and flocculation combined with centrifugation) were evaluated with regard to separation efficiency and composition of the solids and liquids. Then the biogas yield, biodegradability, and hydrolysis rate constants of the solids and liquids were determined and compared. All tests were performed with manure from the same batch, thus guaranteeing equal characteristics and enabling a valid comparison of separation methods.

2. Materials and methods

2.1. *Manure sampling and slurry preparation*

Freshly source segregated solid (SSS) and source segregated liquid (LSS) were collected during a period of 24 h from a V-shaped conveyor belt system (De Vries et al., 2013) underneath a pig house (138 full-grown fattening pigs in 12 pens, age of 27 weeks) at the Swine Innovation Centre (VIC), a research farm in Sterksel, The Netherlands. This conveyor belt system is a source segregation system which means urine and faeces are collected as separate fractions. The belt ran automatically every 8 h. The collected materials were homogenized by mixing and samples of about 220 L of solids and 220 L of liquid