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Technical evaluation of a tank-connected food waste disposer system for biogas production and nutrient recovery

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In this study, a tank-connected food waste disposer system with the objective to optimise biogas production and nutrient recovery from food waste in Malmö was evaluated. The project investigated the source-separation ratio of food waste through waste composition analyses, determined the potential biogas production in ground food waste, analysed the organic matter content and the limiting components in ground food waste and analysed outlet samples to calculate food waste losses from the separation tank.

It can be concluded that the tank-connected food waste disposer system in Malmö can be used for energy recovery and optimisation of biogas production. The organic content of the collected waste is very high and contains a lot of energy rich fat and protein, and the methane potential is high.

The results showed that approximately 38% of the food waste dry matter is collected in the tank. The remaining food waste is either found in residual waste (34% of the dry matter) or passes the tank and goes through the outlet to the sewer (28%). The relatively high dry matter content in the collected fraction (3–5% DM) indicates that the separation tank can thicken the waste substantially.

The potential for nutrient recovery is rather limited considering the tank content. Only small fractions of the phosphorus (15%) and nitrogen (21%) are recyclable by the collected waste in the tank. The quality of the outlet indicates a satisfactory separation of particulate organic matter and fat. The organic content and nutrients, which are in dissolved form, cannot be retained in the tank and are rather led to the sewage via the outlet.

1. Introduction

According to the European Commission (2010), the estimated annual food waste generation in households in the EU27 is approximately 37 million tonnes per year. The average food waste rate per capita for developed countries was estimated to be 107 kg/year by Thi et al. (2014). This waste type makes up a valuable source for production of biogas and nutrient recycling if separated, collected and pre-treated properly. In Sweden, 31% of the food waste was recycled by biological treatment in 2013, where the current Swedish goal is to recycle 50% of the food waste by 2018 (SEPA, 2015).

Food waste separation in households is found in most Swedish municipalities. Waste bin and a type of bag is the most common system (Avfall Sverige, 2011). The outcome from this system is food waste wrapped in bags, which requires pre-treatment in the form of waste disintegration to reduce particle size and separation of undesired non-degradable matter, e.g., plastics and metals. Besides being energy demanding, the pre-treatment also leads to a significant loss of food waste because certain food waste attaches to or becomes trapped in the plastics or paper bags in the separated fraction (Bernstad et al., 2013). Furthermore, the bag system has several disadvantages for the users, such as the space requirement in kitchens, nuisance in handling the waste bags and the effort required to bring the bag to a collective container. The placement of collective containers and arrangement for collection by trucks can also be problematic in multi-apartment areas, particularly in densely populated cities.

As separation is introduced in more and more municipalities, the interest for alternative collection systems increases. A new food waste separation system including food waste disposers (FWD) connected to a separation tank (Fig. 1) was installed in 614 apartment households in a new city area of Malmö, Sweden.

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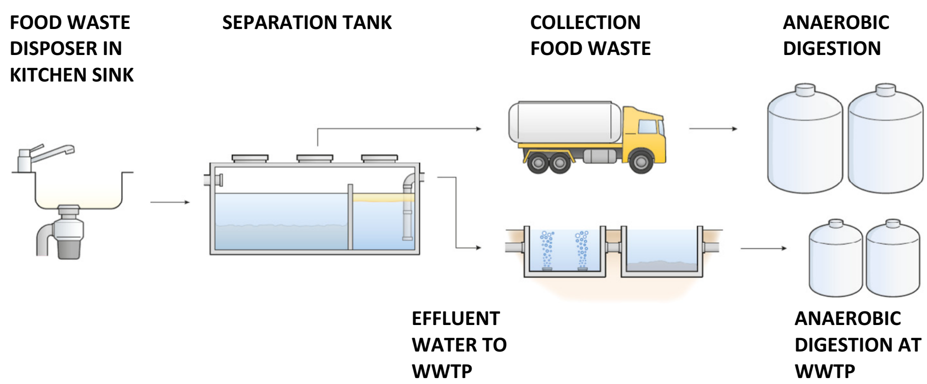

Fig. 1. System description of food waste disposers connected to a separation tank (partly modified and reprinted from Bernstad et al., 2013, with permission from Elsevier.

The goal of this system is to separate and collect food waste for biogas production. It is particularly convenient in new urban areas, where there is no space for waste bins and there is a desire for less heavy transports with collection trucks. The system has the advantage that the waste collected from the tank is already mechanically degraded, which reduces the need for further pre-treatment. The evaluated system can also be considered more comfortable for users and sanitation workers because less contact with the waste is needed.

The disposer is mounted directly to an ordinary kitchen sink. The houses were built with double drain strains, one from the bathroom that is led to the regular sewage net and one from the kitchen that is led to a local separation tank. The food waste in the tank is collected every 3–4 weeks by a traditional sludge collection truck and is then transported to the biogas plant. The separation tank is divided into two compartments. The first, larger tank allows the ground food waste to settle to the bottom of the tank. The other compartment traps the sludge and grease floating on the surface. Excess water then flows out to the ordinary sewerage.

Previous studies have shown that the disposer system is promising and could e.g. lead to a high usage of the waste in the form of biogas production (Bernstad et al., 2013). However, the success of the system in terms of both nutrient and energy recovery is dependent on a high sorting efficiency (households separating a large fraction of the generated food waste), the quantity and quality of the collected food waste and the efficiency of the tank separation. The idea of this study was to evaluate these aspects by an extensive field sampling and analysis programme of the newest area in Malmö where the system is implemented in a large number of apartments, ensuring representative data sets. The studied full-scale area is divided into two parts due to the large number of apartments, the western (341 apartments) and eastern (273 apartments) parts. These sub-areas are connected to separate tanks (a western tank and an eastern tank).

2. Materials and methods

To evaluate the possibilities for nutrient and energy recovery with at FWD system a technical evaluation was performed including waste composition analyses, flow measurements, sampling and chemical analysis of the collected waste and tank outlet as well as the methane potential determination of the collected waste. Both the western and the eastern tanks were evaluated and mass balances were set up with the help of analytical data and key figures from the literature. The methods used are described below; however, more detailed descriptions can be found in Bissmont et al. (2015)

2.1. Waste composition analysis

Waste composition analyses were done twice in the studied area (September 2013 and March 2014). For comparison with food waste separation with paper bags, an analysis was made once in the neighbourhood area (September 2014). Analyses of residual waste were made according to existing guidelines (RVF, 2005). The waste composition analyses were used to determine the source separation ratio in the system.

2.2. Flow measurements

Flow measurements were done by installing a portable instrument (Portable Mainstream 04) in the manholes on the outlet channel from the tanks. Flow measurements were obtained during a period of 4 weeks.

2.3. Analyses and sampling

Chemical analyses of samples from the tank and tank outlet were made according to standardized methods from APHA or the Swedish Standards Institute. Parameters analysed can be found in Table 1. The methods used can be found in Table 2. The samples were stored in a cold room (max + 6 °C) for up to 24 h before analysis or before preparation for later analysis. The externally analysed samples were stored in a freezer after preparation. Some of the parameters were determined by combining samples into composite samples (see Table 1). Outlet composite samples consisted of outlet samples taken out at two different occasions during one day. Sludge composite samples consisted of a mix of samples from different compartments of the tank. The amount of sludge from each compartment used in the mix was in proportion to the volume of each compartment of the tank.

2.4. Methane potential

The potential methane production from the collected food waste was determined in triplicates following the batch tests method described in Hansen et al. (2004) at an incubation temperature of 37 °C. Inoculum was collected from a full-scale mesophilic digester in Malmö. Gas production was measured by analysing the methane content in 0.2-ml samples, which were withdrawn from the reactors by a gas-tight syringe in a gas chromatograph (Agilent 6850 series with FID and an HP-1 column (30 m/0.32 mm/0.25 μm), inlet temp of 50 °C, detector temp of 200 °C). Cellulose was digested as a reference substrate to check the inoculum's function.

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