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The effect of temperature, storage time and collection method on biomethane potential of source separated household food waste

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ABSTRACT

The aim of this study was to mimic real conditions for storage and transport and to evaluate how much of the biomethane potential is lost before the organic fraction of municipal solid waste (OFMSW) from households in Sweden reaches the biogas plant. The laboratory biomethane potential (BMP) experiments was carried out with respect to the storage time, collection method (paper or plastic bag) and storage temperature (22 °C and 6 °C) in order to evaluate the effect of these factors on the biomethane potential.

A recipe representative for OFMSW from households in Sweden was designed with the help of literature and modification of recipes from technical reports and scientific literature. Laboratory experiments showed that the difference in the BMP of OFMSW stored in plastic- compared to paper bags were obvious at 22 °C with a lower biomethane potential for paper bags, but there was no difference at 6 °C. Provided that the loss of organic matter during pre-treatment is equivalent for both paper and plastic bags it is possible to get more biomethane from OFMSW collected in plastic bags during the warmest part of the year, since they have a more preservative effect on OFMSW than paper bags.

This could be explained by the plastic bags being denser than paper and therefore maintain the volatile organic compounds inside the bag and promote a pre-hydrolysis of the material rather than aerobic degradation.

1. Introduction

In Sweden and Europe, food waste from households or organic fraction of municipal solid waste (OFMSW) is a common substrate used for biogas production.

The OFMSW from households is normally source separated and collected in the households by (1) a separate bin for OFMSW or (2) a coloured plastic bag (preferably green) which is left in a single bin together with all the household waste and subsequently the coloured bags are then separated by optical reading. The Swedish Waste Management and Recycling association, Avfall Sverige collects and compiles annual data over the waste treatment system in Sweden. In August 2016 212 of Sweden's 290 municipalities had separate collection of OFMSW from households. For villas the most common system was separate bins for OFMSW (64% of the municipalities), followed by coloured plastic bags (16%), bins with several compartments in the same bin (10%) and other systems for collection (10%) (Avfall Sverige, 2016). Compared with data from 2014, the only system with a clear increase in use by the Swedish municipalities was optical sorting (Avfall Sverige, 2015a). The municipality of Linköping is the fifth biggest municipality in Sweden with about 150,000 inhabitants and is one of the leading Swedish areas for biogas production and research with Sweden's biggest co-digestion biogas plant in operation since 1997 and a national centre for biogas research called BRC, Biogas Research Center (Fallde and Eklund, 2015).

Regardless which collection method used, the OFMSW is being pre-treated to a slurry prior to digestion at the biogas plant. Collection of OFMSW has gained increasing importance as a substrate in the biogas industry and treated volumes are expected to continue to increase in the coming years as more and more municipalities in Sweden start to sort and treat OFMSW separately. This is in line with the Swedish environmental quality objectives and the target for increased resource efficiency in the food area, which state that by 2018 at least 40 percent of OFMSW should be biologically treated, in order to utilize the nutrients and energy. Approximately 27% of the OFMSW in Sweden was treated biologically with utilization of both nutrients and energy during 2014 according to the annual follow-up of the targets made by Swedish environmental protection agency (Swedish Environmental Protection Agency, 2016).

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The European commission also has ongoing projects with focus on reducing the amount of food waste and finding more sustainable ways for treatment of unavoidable food waste which is an integral part of the Commissions circular economy package (European Commission, 2015).

From the time that OFMSW from households is placed in the bin in the household until the OFMSW reaches the biogas plant, water evaporates and the material begin to degrade. During degradation of the organic material, carbon dioxide is formed which is emitted into the atmosphere and volatile hydrocarbons such as VFA (fatty acids) may diffuse before the OFMSW reaches the biogas plant. For the society and the environment, it is important that as much as possible of the produced OFMSW can be converted to renewable energy in the form of biogas and nutrients in a biogas plant. The choice and management of collection system for OFMSW can affect how much renewable energy that is produced, but so far there are just a few studies which has investigated what happens with the methane potential and nutrient content during storage and transport.

1.1. Characterisation of food waste

One key parameter to be able to perform reliable labscale studies about how the storage and collection system affects the biogas potential is to use a representative sample of fresh food waste. There have been several studies made about composition of food waste or OFMSW from households in preferably Northern Europe, e.g. Sweden (Smedlund and Ternald, 2009), Denmark (Kromann et al., 2004; Hansen et al., 2007; Edjabou et al., 2016; Naroznova et al., 2016), Norway (Sundt, 2010; Hanssen et al., 2016), UK, (Quested et al., 2013), Italy (Alibardi and Cossu, 2015) and Campuzano and González-Martínez (2016) (review about food waste from the whole world including Denmark and Finland). The methods used for classification of household food waste is often different between different studies which results in a challenge if the studies are to be compared. In a review by Dahlén and Lagerkvist (2008) 20 different methods for household composition studies are described but no working international standard. The challenge of trying to compare different studies is further discussed by Lebersorger and Schneider (2011) where one conclusion is that many studies are not really comparable due to different classifications, definitions and methods used, and in addition, these are mostly insufficiently described and not reproducible by a third party.

To be able to conduct storage experiments with OFMSW it is necessary to have quite detailed information about different categories of OFMSW and therefore five studies from Northern Europe was used as basis for design of the recipe used in this study. The studies made by Smedlund and Ternald (2009), Quested et al. (2013) and Sundt (2010) have used different categories of food waste (dairy, fruits/vegetables, meat/fish, etc.) and the proportion of the total weight for each food waste category. Kromann et al. (2004) and Hansen et al. (2007) have instead used nutritional content (fat, carbohydrates and protein).

1.2. Systems for collection of OFMSW

In Sweden, the responsibility for collecting municipal solid waste is at the municipal level. The system for collection of municipal solid waste is up to each municipality to decide. As a result, collection method, and collection intervals vary from municipality to municipality.

A general picture of the chain for management of OFMSW from households in Sweden from it arises until it arrives to a biogas plant is that OFMSW waste is placed in a paper or plastic bag inside the living house. When the bag is full it is placed in a ventilated or non ventialted bin close to the living house, a ventilated brown bin for OFMSW in paper bags is showed in Fig. 1. The household waste is collected by a garbage truck and either reloaded once or twice or transported directly to a pre-treatment plant for OFMSW which is often situated close to a biogas plant. After pre-treatment, where the OFMSW is diluted and made pumpable and unwanted materials like plastics, metal and glass is separated from the food waste, it is digested where renewable energy and liquid fertiliser is produced.

Although statistics of volumes and type of separation systems for Swedish food waste are annually compiled by the Swedish waste management and recycling assosication (Avfall Sverige, 2015b) there is limited information about the time that passes from the OFMSW is placed in the bin in the household until it reaches a biogas plant and how the time affect the biomethane potential (BMP) of the OFMSW.

2. Material and methods

2.1. Characterisation and recipe

A realistic standard recipe for OFMSW from households in Sweden was designed on the basis of a survey from Sweden where a proposal for a standardised for fresh food waste was presented (Smedlund and Ternald, 2009) which also has been used in a Swedish study for storage of OFMSW (Ternald, 2010), both published by the Swedish waste management and recycling assosication, Avfall Sverige. The results from this study has been compared with similar studies from Denmark (Hansen et al., 2007; Kromann et al., 2004), Norway (Sundt, 2010) and Great Britain (Quested et al., 2013). Own field studies have not been carried out. Values from The Swedish Food Composition Database were used for calculation of nutrient content from different categories of food waste (Livsmedelsverket, 2015).

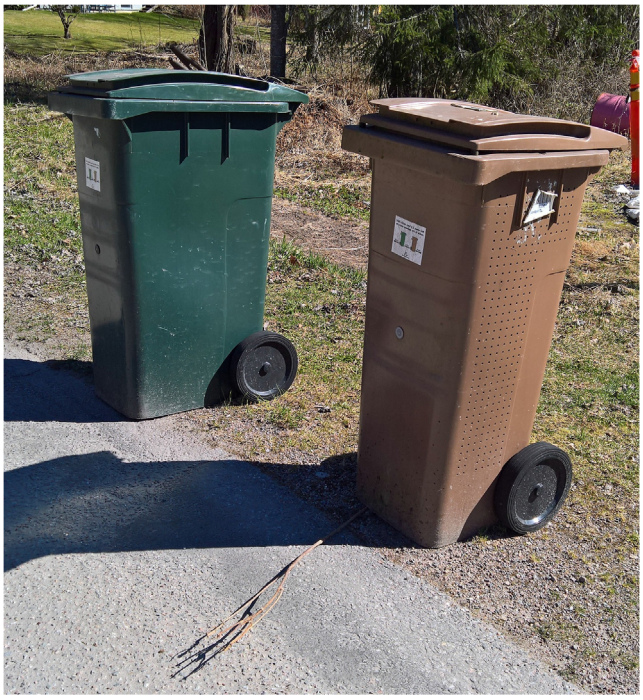

Fig. 1. Bins for collection of municipal solid waste in Gävle municipality, Sweden. The green bin to the left is used for combustible waste and the aerated brown bin to the right is used for OFMSW in paper bags. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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