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# Need for improvements in physical pretreatment of source-separated household food waste

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ABSTRACT

The aim of the present study was to investigate the efficiency in physical pretreatment processes of source-separated solid organic household waste. The investigation of seventeen Swedish full-scale pretreatment facilities, currently receiving separately collected food waste from household for subsequent anaerobic digestion, shows that problems with the quality of produced biomass and high maintenance costs are common. Four full-scale physical pretreatment plants, three using screwpress technology and one using dispergation technology, were compared in relation to resource efficiency, losses of nitrogen and potential methane production from biodegradable matter as well as the ratio of unwanted materials in produced biomass intended for wet anaerobic digestion. Refuse generated in the processes represent 13–39% of TS in incoming wet waste. The methane yield from these fractions corresponds to 14–36 $Nm^3$/ton separately collected solid organic household waste. Also, 13–32% of N-tot in incoming food waste is found in refuse. Losses of both biodegradable material and nutrients were larger in the three facilities using screwpress technology compared to the facility using dispersion technology.[1] Thus, there are large potentials for increase of both the methane yield and nutrient recovery from separately collected solid organic household waste through increased efficiency in facilities for physical pretreatment. Improved pretreatment processes could thereby increase the overall environmental benefits from anaerobic digestion as a treatment alternative for solid organic household waste.



## 1. Introduction

The revised EU Waste Framework Directive (WFD) encourages separate collection and recycling of bio-waste amongst EU member states (European parliament, 2008). It also stipulates that for bio-waste that cannot be prevented, member states should choose the best management options in view of their specific conditions. Food waste from households is an important fraction of European bio-waste. A recent study suggests a generation rate for food waste from households in Sweden in the range of 100 kg per capita and year (Konsumentföreningen Stockholm, 2009). Separate collection of household food waste was in place or planned in 153 of 290 Swedish municipalities in 2009. The trend has in recent years been a stronger interest in anaerobic digestion (AD) with biogas production, at the expense of the interest in composting (Swedish Waste Management Association, 2010). Thus, the potential collection is in the range of 900 000 ton per year in Sweden, which according to previous methane production batch tests can result in a production of 80–110 million $Nm^3$ $CH_4$ per year, using mesophil anaerobic digestion (AD) (Davidsson et al., 2007). However, in order to realize this potential, an efficient system for collection of food waste must be followed by efficiency also in the subsequent treatment chain. The most common system for collection of household food waste in Sweden is use of paper, plastic or bio-plastic bags for later disposal in designated waste bins (Swedish Waste Management Association, 2010). Bags are generally removed before the waste enters the digestion reactor, as they might otherwise cause mechanical problems at the plant. Also, separate collection of food waste from households is not always well understood or respected, resulting in certain amounts of non-wanted materials in the separated food waste fraction. Previous studies have shown that the ratio of miss-sorting in separately collected household food waste from multi-family dwelling areas in Sweden commonly is in the level of 1–5% mass (not taking the weight of used collection bags into consideration) (Bernstad, 2010). Thus, the collection system in itself as well as the potential miss-sorting from the side of households' calls for some kind of physical pretreatment of the food waste before the food waste can enter a wet process AD facility – currently the most commonly used type of AD-treatment in Sweden. Pretreatment methods can, based on Kumar et al. (2009) roughly be categorized into:

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[1] Dispergator technology is a powerful milling equipment, commonly used in the paper recycling industry when recycled papers are atomizes into fibers for mixing with virgin fibers and production of new paper.

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- Physical pretreatment, such as milling and grinding.
- Physicochemical pretreatment, such as steam, thermal, hydrothermolysis and wet oxidation.
- Chemical pretreatment, such as alkali, acid and oxidizing agents.
- Biological and electrical pretreatment.
- Combination of some of the above methods can also be applied.

The common purpose of all methods is to improve the AD process and increase biogas yields. Physical pretreatment has several purposes; separation of non-wanted objects (miss-sorted materials, bags used for collection of food waste, packaging in the case of food waste from supermarkets, etc.), reduction of particle size (normally to <12 mm, required by the EU regulation on animal by-products (EU, 2009), meeting standards for hygienization, mixing of different organic substrates for later co-digestion and changing the dry matter substance and C/N-ratio in the substrate (Mata-Alvarez et al., 2000; Tsao, 1987; Mshandete et al., 2006).

Although physical pretreatment is an important part of the anaerobic treatment of food waste, and there is an increased interest in AD as a treatment method for food waste in Europe, little can be found in the academic literature related to such processes. Hansen et al. (2007) conclude that up to 44.5% of incoming source-separated household food waste (wet weight) was rejected in the physical pretreatment processes in Danish AD-plants. The same study states that rejected material to a large extent consisted of organic material and that the ratio of refused material to a large extent is depending on the chosen pretreatment technology. In a mass-balance of a Spanish combined anaerobic/aerobic municipal source-separated waste treatment plant, Pognani et al. (2012) showed that 32.2% of incoming waste (wet weight) was rejected in the physical pretreatment processes consisting of bag-opener and a ballistic separator where lighter/larger material was separated and screened for metals before landfilled. Also in the Spanish case, the amount of biodegradable material (including paper, cartoon and textiles) represented 44% of the wet weight of the rejected material. These examples both highlight the importance of further investigation of the efficiency in physical pretreatment processes also elsewhere.

The aim of the present study was to make an assessment of the current state-of-the-art of physical pretreatment of food waste in Sweden, with a special focus on processing of separately collected household food waste. The assessment is based on interviews with all seventeen Swedish pretreatment facilities currently receiving separately collected food waste from households and a more thorough investigation of four of these plants.

## 2. Method

### 2.1. Interview study

Seventeen Swedish AD-plants, including one pretreatment facility that currently delivers pretreated food waste for further AD in other plants, were identified as receivers of separately collected food waste from households. A questionnaire containing six questions was sent to each plant. Facilities were asked about (1) the type of bags used for the separate collection of food waste, (2) energy and resource consumption in the facility, (3) the amount of refused material as percent of total incoming food waste, (4) the further treatment of refused material. Also, each facility was asked if they (5) experience any problems with the quality of processed food waste (biomass for further AD-treatment) and (6) experience problems or have high maintenance costs in the plant which can be related to food waste. The last two questions were answered on a scale with three levels, where the plant referred to such problems as being *high*, *medium* or *low*.

### 2.2. Case studies

Four facilities in the southern part of Sweden were chosen for the case studies. Two of the facilities (A and B) where chosen as they were recently constructed and therefore can be assumed to represent the best available technology within the field. Facility C was chosen as it represents a simple and low cost mobile pretreatment alternative and facility D as this facility is based on a different separation technique compared to the others, developed within the pulp and paper industry. The treatment steps and technologies used in the four plants are described in Table 1. The study was focused on energy and resource consumption in the plants, the quality of the product (biomass aimed for further treatment through AD), the mass-flow of nitrogen and biodegradable organic material and the overall energy balance over the pretreatment process. Data from facility A is partly based on Bohn et al. (2010), but complementary data was gained through the work presented in the present study.

Separately collected household food waste is a heterogenic material. Thus, the sampling process is vital to avoid skewing of the results. A specific sampling method has previously been developed to ensure representative and homogeneous samples from this type of material (la Cour Jansen et al., 2004). However, due to practical constraints, the application of this method was not always possible in the present study. Samples from the following fractions were collected from each facility: untreated input waste (*input*), material rejected during the pretreatment process (*refuse*) and resulting bio-substrate aimed for further biological treatment (*biomass*). Due to practical reasons, the possibilities for sampling differed between the four facilities and samples were collected from each facility at 2–6 occasions. At each occasion, several subsamples were made with an interval of 1 h in the three static facilities (A, B and D) and 15 min interval in the mobile facility (C) (where the process was run batch-wise and over a shorter period of the day). Each subsample had a size of 2.5–6 kg (2.5 kg samples were used for biomass, as this fraction is more homogeneous compared to other fractions), resulting in a total sample size from each fraction of between 20 and 175 kg. Total number of sampling occasions, subsamples and size of subsamples used in the evaluation is indicated in Table 1.

All samples were stored in cold environments (4 °C) until prepared for analyses, which was in all cases done within 24 h, as analyses were performed after each sampling occasion separately. Physical characterization of the particle size in biomass and refuse was performed through sieving of non-homogenized samples. Subsamples of the biomass and refuse (500 g in each case) were sieved (8 and 2 mm perforation). Sieves were rinsed with tap water and dried (24 h, 105 °C) after which the dry weight was recorded as triplicates. Thus, a total amount of 1.5 kg sample from each facility was used in these analyses). The residual parts of the samples were prepared for analyses through homogenization using a household mixer. When needed, a known amount of distilled water was added to reach a more homogenized material. Subsamples of 1 kg were collected from the larger samples. From this sample, suitable amounts were collected for determination of total solids (TSs) and volatile solids (VSs), determined according to standard methods (2540 Solids G, APHA, 2005) as triplicates. TOC and N-tot were determined in dried samples (generated from the same subsample) (24 h, 50 °C) with TOC-analyser TOC-VCPH with additional nitrogen analyser TNM-1 from Shimadzu. The energetic value of each fraction was analyzed as potential methane production using anaerobic degradation mesophil batch-test method (Hansen et al., 2004) in triplicates. These tests were performed separately for each facility. Homogenized subsamples were frozen at −20 °C and thawed in room temperature before subsamples of approximately 5–10 g were collected for methane potential analyses. Also, the higher heating value in refused material was investigated using bomb calorimetry.