Comparative environmental analysis of anaerobic mono-digestion and co-digestion of organic waste

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The anaerobic digestion of organic waste is considered a well proven technology not only for sustainable waste management, but also for the reduction of the high dependency on fossil fuels. Food waste is an available organic substrate that needs to be managed. The way food waste streams are collected and managed can lead to valuable products finding their way back into the economy (i.e. circular economy) or to an inefficient system where it ends in landfills, with potentially harmful environmental impacts and significant economic losses (European Commission, 2015). Furthermore, the anaerobic co-digestion of food waste with other organic streams has benefits, increasing biogas yield and outweighing constraints associated with the variability of food waste (Fitamo et al., 2016; Koch et al., 2015). However it is important to remark that the anaerobic digestion of food waste is limited by the optimisation of separate collection scheme. Sewage sludge is an organic substrate available in urban areas and it is frequently treated through anaerobic digestion in wastewater treatment plants (WWTPs). Moreover, digesters in WWTP are usually oversized; the potential utilisation of the spare capacity through using food waste as a co-substrate can provide waste management at a local level while improving WWTP economy (Fitamo et al., 2016).

The aim of this study is to determine the technical and environmental feasibility of food waste and sewage sludge co-digestion by comparing its performance with the mono-digestion scheme. For this purpose, three schemes were developed including the separated digestion of waste streams and their co-digestion in different integration rates within a WWTP. More specifically, Scheme 1 includes the mono-digestion of sewage sludge and food waste in different facilities. Scheme 2 includes the partial integration of food waste in the WWTP by using it as a co-substrate in the sewage sludge digestion, according to the spare capacity of the digester. Scheme 3 considers the total integration of the food waste within the WWTP; in order to allow total co-digestion of both waste streams, the construction of another digester is required. The environmental analysis was performed following the Life Cycle Assessment (LCA) methodology (ISO 14040, 2006). The selected functional unit (FU) was the treatment of the total food waste and sewage sludge produced by a community of 150,000 people equivalent (PE) each day. The involved processes in the treatment schemes (system boundaries) are shown in Figure 1.

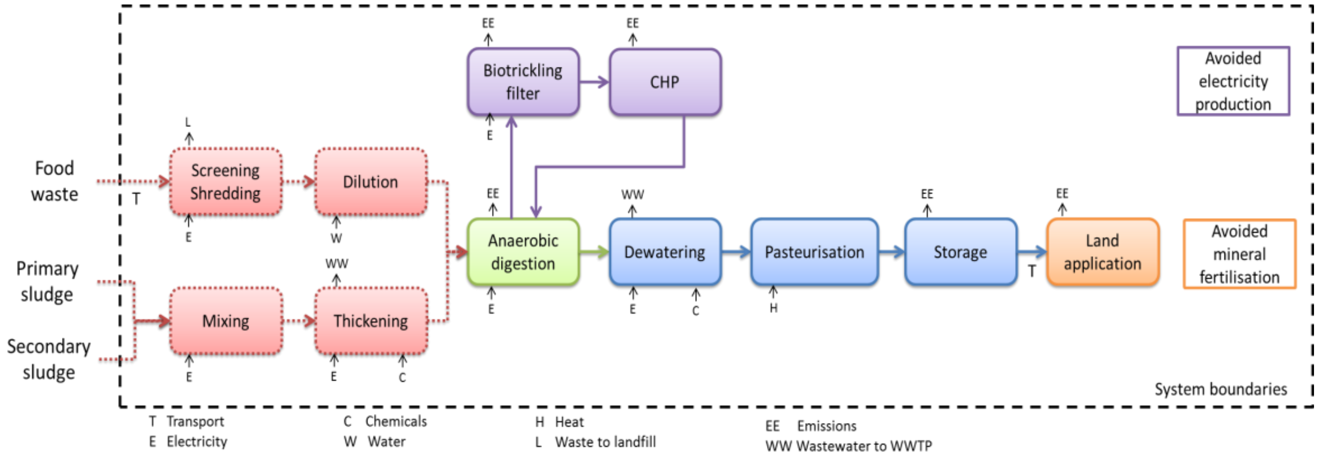

Figure 1. Flow-diagram for separated digestion of waste streams and their co-digestion (system boundaries for the treatment scheme). Note that dotted boxes and harrows appear depending on the scheme analysed.

The potential impacts of the examined schemes were determined using characterisation factors proposed in the ReCiPe Midpoint methodology (Goedkoop et al., 2009) for the following impact categories: climate change (CC), terrestrial acidification (TA), freshwater eutrophication (FE) and marine eutrophication (ME). The results obtained are depicted in Figure 2.

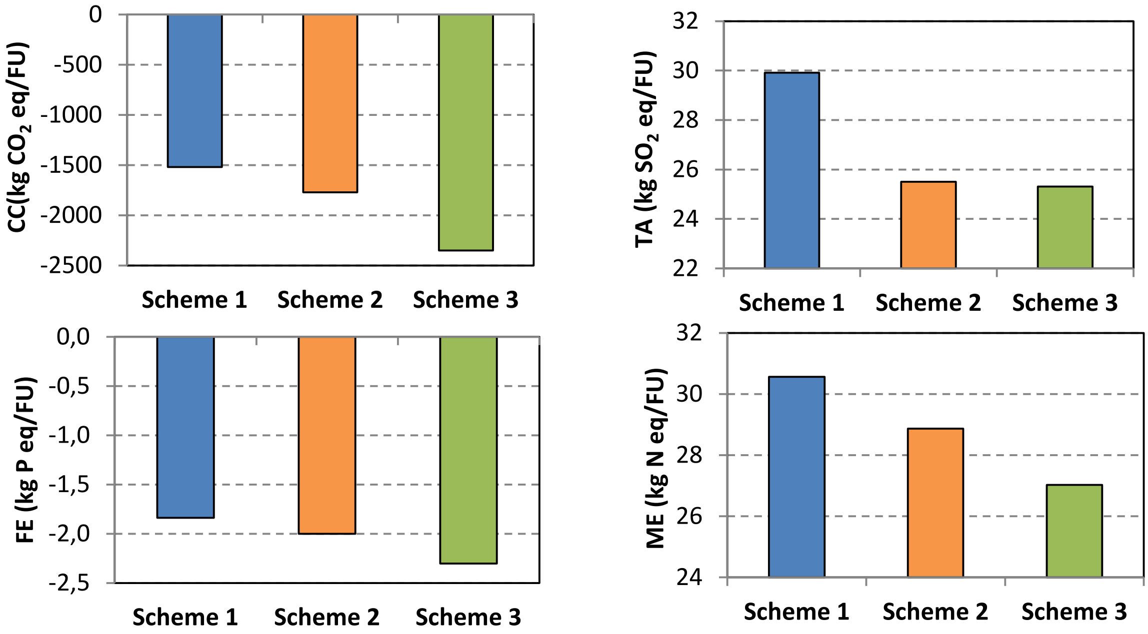

Figure 2. Environmental results of the three scenarios for CC, TA, FE and ME.

The mixture of both substrates in Scheme 2 and 3 achieved higher biogas yields due to the positive synergetic effects. In more detail, despite the total volatile solids (TVS) digested in all schemes is the same, the specific biogas production (SGP) change among schemes. Specifically, SGP of sewage sludge is 0.35 m^3/kg TVS; while the SGP of food waste is 0.7 m^3/kg TVS. The mixture of both substrates in Scheme 2 and 3 ended up in a SGP of 0.40 and 0.54 m^3/kg TVS, respectively. As a result, the use of food waste as feedstock in the anaerobic digester of a sewage treatment plant involves different environmental advantages. Scheme 2 decreases GHG emissions of 252 kg CO_2 eq/FU compared to Scheme 1. Moreover, Scenario 3, which includes the full integration of food waste in the WWTP, entails reductions of GHG emissions of 833 kg of CO_2 eq/FU. The latter is attributed to increased electricity generation in Scenario 2 and 3 due to higher biogas production derived from the positive synergies of co-digestion (Koch et al., 2015; Nielfa et al., 2015). Moreover, increased biogas production leads to smaller digestate production, since a greater proportion of the organic matter is degraded. Therefore, in Scenarios 2 and 3, the amount of digestate stored and applied is lower. Regarding TA, the impacts are mainly attributed to ammonia emissions that occur when digestate is applied in land. Thus, Scenarios 2 and 3 resulted in less environmental impacts considering TA. Likewise, emissions of eutrophying substances derived from the agricultural application of digested are lower (i.e. phosphate and nitrate), obtaining better results Scenarios 2 and 3 in FE and ME compared with Scenario 1. The integration of the management of different organic waste streams within a WWTP can contribute to the reduction of the environmental impacts mainly through the optimisation of biogas production from positive synergetic effects. However, legislative framework in some countries such as UK prevents the implementation of these waste streams. In more detail, sewage sludge and food waste fall into very different regulatory norms, and the legislation where co-digestion falls is not clear.

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