Life cycle assessment of low-cost technologies for digestate treatment and reuse in small-scale farms in Colombia

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Introduction

Anaerobic digestion (AD) is a practice that is mainly carried out to give treatment to different kinds of organic residues (e.g. food waste, manure, agricultural residues) in order to obtain biogas and produce bioenergy. Because of its nature, the generated biogas is considered to be a renewable energy source, henceforth an important strategy in the fight against climate change. Anaerobic digesters carry out the AD process under specific conditions to allow microbial communities to develop and decompose organic matter (OM) into the desired biogas. In addition to biogas, the degradation of organic waste in the digester also produces a liquid effluent (digestate) (U.S. EPA, 2021).

This exiting digestate is a combination of solid and liquid fractions from the AD process, rich in nutrients and OM. Because of its characteristics, digestate is a valuable effluent, as it can be used as organic fertilizer and spread on agricultural lands (Panuccio, et al., 2018). The use of digestate as fertilizer has several benefits, such as boosting crop growth and quality, acting as soil amender, or mitigating greenhouse gas (GHG) emissions (Wang & Lee, 2021). Nonetheless, depending on the characteristics of the feedstock and on the further use of the digestate, it has to undergo treatment and/or stabilization to avoid the spreading of pathogens, toxic metals or other pollutants that might be present in it (Cucina et al., 2021; Wang & Lee, 2021).

For this study, this rationale has been implemented in Colombian low-income small-scale farms. Colombia is a country with a great agricultural tradition, considering that by 2017 more than 15% of the domestic extraction of the country was related to the agricultural industry (Material Flows, 2019). Nevertheless, even though Colombia has expected a considerable growth throughout the past 30 years, up to 50% of its population is considered to live in poverty (Garfí, et al., 2019). Consequently, low income populations have to rely on self-sufficient farming and traditional fuels such as firewood and dry dung for cooking and house warming. For these reasons, low-cost digesters have been implemented in several Colombian communities to cope with homely energy demands and substitute the risky traditional fuels that end up affecting both people and the local environment (Garfí, et al., 2011).

It is in this context that several studies have been carried out to analyze the environmental performance of anaerobic digesters in rural conditions in the Andes (Garfí, et al., 2012; Garfí, et al., 2019; Mendieta, et al., 2021). However, these studies have focused on the implementation of the digester and the biogas use, but have not deepened in the treatment and use of the digestate. Even though these studies have considered a direct use of digestate, other authors have stated that, despite the benefits of this practice, it might have associated risks if no further treatment of the digestate is carried out prior to its application on land (Cucina, et al., 2021). Therefore, the main objective of this study is to analyze the environmental impacts of three alternative scenarios for the digestate treatment and reuse from a low-cost anaerobic digester: 1) digestate treatment with a sand filter and its reuse as biofertilizer 2) digestate treatment with a vermifilter and its reuse as biofertilizer; 3) a baseline scenario without digestate treatment (direct use on land).

Materials and methods

A cradle-to-grave Life Cycle Assessment (LCA) is to be carried out to assess the potential environmental impacts of the treatment and agricultural reuse of digestate generated by a low-cost tubular anaerobic digester implemented in a small-scale farm in the Colombian Andes. For this, a functional unit of 1 m^3 of treated digestate has been selected. The system boundaries considered for this study include the acquisition of raw materials, the construction and operation of the filters, and the use on land of the digestate. LCA modelling is carried out in the SimaPro 9.3 software, having primary information acquired on-site and secondary information primarily obtained from the Ecoinvent 3.8 database. With regards to the impact assessment methods, for the impact category of climate change, the IPCC 2013 method will be used, while the ReCiPe 2016 method will be applied for the remaining impact categories.

The digester and the agricultural lands subject to this study are located in the surroundings of the population of Cachira (*Norte de Santander* region), in the northeastern area of the Colombian Andes (*Cordillera Oriental*). This zone has an average altitude of between 1800 and 2000 m.a.s.l., and an average ambient temperature of 17 ± 3 ºC (Cucina, et al., 2021). The scenario that will go under analysis in this study is based on a co-digestion scenario considered by Cucina and other colleagues in a previous study that explored the benefits and risks of plastic tubular digester digestate reuse in agriculture (Cucina, et al., 2021). In particular, in the case of the present study, the three scenarios under analysis will be focused on a psychrophilic tubular digester with a feedstock composed by cattle manure and cheese whey, shown in Figure 1.

Figure 1: Psychrophilic tubular low-cost digester implemented in Colombia. Source: Personal archive.

Results and discussion

Results obtained from this study are expected to show lower impacts in categories related to energetic and material consumption for the baseline scenario, mainly due to lower material inputs because of the lack of treatment. However, this scenario is also expected to have higher impacts in water and soil related categories (i.e. eutrophication, acidification, toxicity). With regards to the vermifilter and sand filter, the former is contemplated to have lower overall impacts, as it has lower material and energetic inputs throughout its life cycle, has a longer lifetime, and has fewer maintenance requirements. Both sand filtration and vermifiltration are foreseen to perform considerably better from an environmental point of view while considering water and soil quality implications, therefore evidencing the benefits of digestate filtration prior to its application on land.

Conclusions

The implementation of filtering technologies after anaerobic digestion systems is a process that can gain relevance in low-income communities, as these can improve their life-quality. Main results will show benefits from the application of the filtering technologies to the digestate in comparison to its direct application on land. The strong points of these filters in low-income rural communities shows not only environmental benefits, but also improvements in the quality of the crops, health of the inhabitants of the community, and consequently economic benefits. The proper application of these technologies can empower farmers and lead them into sustainable farming.

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