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Life cycle assessment of anaerobic digestion of pig manure coupled with different digestate treatment technologies

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ABSTRACT

The direct use of digestate on farmlands as soil amendment is becoming an uneconomic option for farmers. Moreover, there are serious environmental concerns about its oversupply in regions with intensive biogas plants. Downstream technologies, offering innovative upcycling methods to handle huge amounts of digestate, have absorbed great interest in this context. In this study, three digestate treatment technologies were compared from a life cycle assessment perspective to combine the environmental impacts from pig manure transportation to biogas plants, biogas production, different digestate treatment technologies, and the use of final products. The results showed that scenario including digestate fractionation into solid and liquid, and their use for compost production and microalgae cultivation, respectively, would be a suitable downstream strategy with lower impacts on human health, ecosystem quality, and climate change damage categories, however future improvements still required. The results showed that sealed storage system or fast-continuous downstream processes as well as shorter distances between biogas plants and farms can significantly enhance the environmental performance of coupled anaerobic digestion and microalgae production. The high energy payback also signified that co-digestion of pig manure and microalgae would be energetically favorable in this context. However, having compared the results with a baseline scenario demonstrated that the direct use of digestate on farmlands, under controlled conditions to avoid its over application, is still the most environmentally favorable option, despite being a costly option for farmers. The results achieved in the present study suffered some uncertainties because technologies under consideration are at their infancy stage, thus further research still is required to find the most sustainable solutions.

1. Introduction

China is the largest pig producer in the world with an average pig rearing amount of 449 million heads per year (FAOSTST, 2019). The number of large-scale and intensive pig farms has drastically increased in China while most of them are not supplemented by adequate manure management strategies to handle the large amounts of manure produced (Duan et al., 2019; Jiang et al., 2011). To address the concerns over pig manure (PM) mismanagement and prevent associated environmental pollutions such as CH_4 and NH_3 emissions as well as the related damages like eutrophication and soil acidification, a series of incentive policies and regulations have been implemented (Zhang et al., 2013). In this context, anaerobic digestion (AD) of manure has been introduced as the most environmentally-friendly solution which aims at mitigating the above-mentioned problems while simultaneously producing bioenergy (biogas) and high-quality bio-fertilizers (Khoshnevisan and Angelidaki, 2018; Li et al., 2017).

The development of medium and large-scale biogas plants has accelerated thanks to the implemented incentive policies, the increased environmental awareness of farm owners, and the improved profitability of AD plants (Hu et al., 2017; Yang et al., 2012). Consequently, a large amount of digestate is generated which is regarded as a valuable soil amendment because it is rich in readily available macro- and micronutrients (Khoshnevisan et al., 2018b; Vaneeckhaute et al., 2013). However, the storage of such huge amount of digestate for a period of 3–6 months before field application would be problematic. Moreover,

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