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How exothermic characteristics of rice straw during anaerobic digestion affects net energy production

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ABSTRACT

The self-heating of lignocellulosic biomass, when degraded under anaerobic conditions, has been reportedly observed. Such a phenomenon would cause substrate to show exothermic characteristics which are in contrast to the current thermodynamic or microbiological knowledge. Rice straw (RS), when undergone anaerobic digestion, is prone to self-heating which can increase the reactor temperature according to heat-releasing characteristics, thus improve the net energy production. In the present study, the relationship of biogas production and self-heating release as well as the synergistic effects of two energy production pathways was investigated. Moreover, the optimal process for maximizing the biogas production under self-heating phenomenon was scrutinized. Compared to control assays, a 0.48 °C increase in average temperature was noticed among experimental trials due to RS self-heating phenomenon. The results showed that the self-heating was even improved simultaneous with increased methane production rate. Hydrolysis rate and total solid content were found to be possible promising options to control the self-heating release.

1. Introduction

Rice is the most important staple food for over half of the world's human population, thus a huge amount of land, especially in Southeast Asia, is dedicated to rice cultivation [1]. Such farming activities, a part from rice production, lead to the production of rice straw (RS) with multiple agro-industrial applications [2]. However, open burning is still a common management practice in many Asian countries [3]. The anaerobic digestion (AD) of RS is considered to be a viable option for producing clean and renewable energy as well as mitigating greenhouse gas emissions, emitted from other straw management practices [4–6]. With the growing economic and legislative advancements in the application of AD technology, numerous biogas plants are using RS as a co-substrate [7].

As for most biogas plants, a large amount of thermal energy is required to maintain the temperature of the digesters at optimal condition (35–40 °C) [8–10]. Even in tropical zones, the heat demand of biogas plants, required to keep fixed-thermal conditions in digesters, accounts for almost 20% of the total energy produced in form of biogas [11–13]. Such an energy demand would even increase when the mechanical process or chemical materials are employed to pretreat crop straw [14,15]. Hence, particular attention must be given to the optimization of AD operation in terms of thermal energy to decrease self-energy demand in biogas plants and therefore enhance the economic efficiency of the overall process.

The type of substrate used for AD process in agricultural digesters can also affect the thermodynamics of the process. The feedstock used for AD can show, in some cases, exothermic characteristics, which are in contrast to the current thermodynamic knowledge. Lindorfer et al. [16], reported that the AD of some energy crops (i.e., corn/maize and wheat including the silage of whole plant and grains) showed exothermic behaviour, so that the tempreture curve rose leading to biological process failures. Although the energy crops employed by Lindorfer et al. [16], were carbohydrate-rich substrates, especially with high starch content,

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