# Optimization of the thermophilic anaerobic co-digestion of pig manure, agriculture waste and inorganic additive through specific methanogenic activity

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## ABSTRACT

The anaerobic co-digestion of three wastes (manure, rice straw and clay residue, an inorganic additive) at different concentration levels and their interactive effects on methanogenic activity were investigated in this work at thermophilic conditions in order to enhance hydrolytic activity and methane production. A central composite design and the response surface methodology were applied for the optimization of specific methanogenic activity (SMA) by assessing their interaction effects with a reduced number of experiments. The results showed a significant interaction among the wastes on the SMA and confirmed that co-digestion enhances methane production. Rice straw apparently did not supply a significant amount of substrate to make a difference in SMA or methane yield. On the other hand, clay residue had a positive effect as an inorganic additive for stimulating the anaerobic process, based on its mineral content and its adsorbent properties for ammonia. Finally, the optimal conditions for achieving a thermophilic SMA value close to 1.4 g $CH_4$-COD/g VSS · $d^{-1}$ were 20.3 gVSS/L of manure, 9.8 gVSS/L of rice straw and 3.3 gTSS/L of clay.

**Key words** | methanogenic activity, optimization, response surface methodology, thermophilic co-digestion

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## INTRODUCTION

The anaerobic digestion of manure could be enhanced using organic agriculture wastes as co-substrate, due to improvement of the C/N balance (Campos 2001). Agriculture wastes such as rice straw could be a promising feedstock biomass as co-substrate for pig manure anaerobic digestion, due to their availability and low cost (Wang *et al.* 2009) and their high carbon and other nutrients content. However, rice straw contains lignocellulose compounds that would limit its anaerobic biodegradation (Mussatto *et al.* 2008). In order to partly overcome this limitation, a thermophilic anaerobic process may be applied, since at this operational temperature the digestibility of straw increases (Zhang & Zhang 1999).

On the other hand, other factors contribute to hinder methane production from manures, namely high ammonia concentration, which may be inhibitory to anaerobic digestion (Sung & Liu 2003; Rajagopal *et al.* 2013). To solve this problem, several inorganic additives, such as heavy metals, zeolites and clay can improve the drawback of process instability caused by ammonia inhibition (Angelidaki & Ahring 1993; Hansen *et al.* 1998; Montalvo *et al.* 2005). This is of great importance because methanogens are the microorganisms least tolerant to high ammonia concentration (Kayhanian 1994; Karakashev *et al.* 2005; Nettmann *et al.* 2010). In this sense, the anaerobic digestion of swine manure (ammonia rich substrate) has been improved using clay and zeolite as inorganic additives, e.g. glauconite, natural zeolite (clinoptilolite, mordenite) and montmorillonite (Hansen *et al.* 1999; Milán *et al.* 2001; Duran-Barrantes *et al.* 2008; Kotsopoulos *et al.* 2008; Rajagopal *et al.* 2013).

Many environmental factors also affect methane yield, including substrate concentration, temperature, etc. In this multi-component system, response surface methodology

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