Overcoming sodium toxicity by utilizing grass leaves as co-substrate during the start-up of batch thermophilic anaerobic digestion

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HIGHLIGHTS

► Sodium toxicity in anaerobic digestion can be overcome by adding grass clippings as co-substrate.
► Different grass turf species can be used as co-substrate to decrease sodium toxicity.
► Betaine could be a significant compound in grass causing reduction in sodium inhibition.

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ABSTRACT

Sodium toxicity is a common problem causing inhibition of anaerobic digestion, and digesters treating highly concentrated wastes, such as food and municipal solid waste, and concentrated animal manure, are likely to suffer from partial or complete inhibition of methane-producing consortia, including methanogens. When grass clippings were added at the onset of anaerobic digestion of acetate containing a sodium concentration of 7.8 g Na+/L, a total methane production about 8 L/L was obtained, whereas no methane was produced in the absence of grass leaves. In an attempt to narrow down which components of grass leaves caused decrease of sodium toxicity, different hypotheses were tested. Results revealed that betaine could be a significant compound in grass leaves causing reduction to sodium inhibition.

1. Introduction

Anaerobic digestion of wastes, in particular solid wastes, results in the solubilization of organic and inorganic salts. The inhibitory effect of accumulating salts on the methanogenic microbiota in the anaerobic digester is a problem that is not well understood. One of the ions that always accumulates and that has been shown to be toxic to methanogenic Archaea is sodium.

Although sodium is essential for bacterial growth (Dimroth and Thomer, 1989), high sodium concentrations increase osmotic stress that can result in decreased cell activity and cell plasmolysis (Uygur, 2006). The occurrence of high sodium concentrations in an anaerobic reactor can generally be attributed to a high sodium concentration in the influent waste stream or sodium addition during operation of the digestion process. Industries, such as the seafood processing industries, utilize raw materials containing high sodium salts resulting in the generation of a salty wastewater. High sodium concentrations in an anaerobic digester can also arise from the addition of alkaline solution in the form of sodium hydroxide (NaOH), sodium carbonate (Na2CO3) or sodium bi-carbonate (NaHCO3) to neutralize acidity during start-up and operation.

Although anaerobic digestion of saline wastewaters such as effluents from tannery industries (Lefebvre et al., 2006), seafood-processing (Omil et al., 1995) and oil and gas production (Ji et al., 2009) have been studied, solutions to the problem of inhibitory high sodium salts are still limited. One way of tackling the sodium salts problem, is by allowing the anaerobic sludge to acclimate to high sodium concentrations (Vyrides and Stuckey, 2009), but this technique requires time for the methanogens to adapt to the saline conditions which in turn results in a prolonged period before the anaerobic reactor can achieve its full-loading capacity. Mendez et al. (1995) stated that a start-up period of 9 months was required for the adaptation of anaerobic sludge to effectively treat saline seafood-processing wastewater. The use of halophilic methanogens as an inoculum has also been reported as an approach to deal with high sodium salts problems (Riffat and Krongthamchat, 2007). However, in a practical sense, it may be difficult to obtain halophilic methanogens for anaerobic reactors located far from the sea. One possible organic compound, which can cause