Maximum organic loading rate for the single-stage wet anaerobic digestion of food waste

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HIGHLIGHTS

\begin{itemize}
\item Anaerobic digestion (AD) of food waste (FD) was conducted at high OLR for 225 days.
\item High CH\textsubscript{4} yield and high VS reduction were achieved at high OLR simultaneously.
\item The cell density in the sludge increased to 15 times that in the original seed sludge.
\item The cell density increased during the periods when there was no organic loading.
\item The maximum OLR was estimated around 10.5 kg-VS m\textsuperscript{-3} day\textsuperscript{-1} in a single-stage wet AD of FD.
\end{itemize}

ABSTRACT

Anaerobic digestion of food waste was conducted at high OLR from 3.7 to 12.9 kg-VS m\textsuperscript{-3} day\textsuperscript{-1} for 225 days. Periods without organic loading were arranged between each loading period. Stable operation at an OLR of 9.2 kg-VS (15.0 kg-COD) m\textsuperscript{-3} day\textsuperscript{-1} was achieved with a high VS reduction (91.8%) and high methane yield (455 mL g-VS\textsuperscript{-1}). The cell density increased in the periods without organic loading, and reached to 10.9\texttimes10\textsuperscript{10} cells mL\textsuperscript{-1} on day 187, which was around 15 times higher than that of the seed sludge. There was a significant correlation between OLR and saturated TSS in the sludge (\(y = 17.3e^{0.1679x}, r^2 = 0.996, P < 0.05\)). A theoretical maximum OLR of 10.5 kg-VS (17.0 kg-COD) m\textsuperscript{-3} day\textsuperscript{-1} was obtained for mesophilic single-stage wet anaerobic digestion that is able to maintain a stable operation with high methane yield and VS reduction.

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\section{1. Introduction}

Food waste constitutes one of the largest components of the waste stream around the world (HKEPD, 2010; MOE, 2010). In Japan, demand for the reduction or effective utilization of food waste has increased in recent years, following the 2007 revision of the Food Recycling Law that aimed to build a “recycling society”. Food waste is generally incinerated in Japan and the remaining ash is placed in landfills. However, alternative treatment methods are highly desirable, since food waste comprises 30–40% of municipal solid waste, and because it typically has a water content greater than 80%, it requires high amounts of energy to incinerate this waste (MOE, 2010; Sawayama et al., 1997). Anaerobic digestion is a spontaneous process mediated by microorganisms that convert biomass into biogas (a mixture of mainly methane and carbon dioxide) without requiring advanced dewatering or further chemical extraction. In addition, the effluent sludge can be used for a solid soil conditioner or a liquid fertilizer (Dong et al., 2010; Kim et al., 2006). Thus, this treatment represents an attractive alternative to incineration.

In recent years, a number of novel reactor designs, such as two-stage or multiple-stage reactors, with semi-dry and dry sub-types, have been adapted and developed for stable treatment of waste under high organic loading rates (OLRs) (Bolzonella et al., 2003; Dong et al., 2010; Fernández et al., 2008; Forster-Carneiro et al., 2008; Verrier et al., 1987). However, the anaerobic digestion of organic waste generally relies on single-stage systems, which account for more than 95% of Europe’s full-scale plants (Baere et al., 2011; Forster-Carneiro et al., 2008). In the single-stage system, all of the reactions (hydrolysis, acidogenesis, acetogenesis, ...