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Start-up, steady state performance and kinetic evaluation of a thermophilic integrated anaerobic–aerobic bioreactor (IAAB)

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HIGHLIGHTS

- Kinetic analysis of IAAB under thermophilic condition was conducted for the first time.
- Maximum applicable OLR of IAAB was at 28.0 g COD/L day.
- Monod and Grau second-order model are best-suited for thermophilic IAAB.

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ABSTRACT

Thermophilic treatment of palm oil mill effluent (POME) was studied in a novel integrated anaerobic–aerobic bioreactor (IAAB). The IAAB was subjected to a program of steady-state operation over a range of organic loading rate (OLR)s, up to 30 g COD/L day in order to evaluate its treatment capacity. The thermophilic IAAB achieved high chemical oxygen demand (COD), biochemical oxygen demand (BOD) and total suspended solids (TSS) removal efficiencies of more than 99% for OLR up to 18.5 g COD/L day. High methane yield of 0.32 LCH_4 (STP)/g $COD_{removed}$ with compliance of the final treated effluent to the discharge limit were achieved. This is higher than that of the mesophilic system due to the higher maximum specific growth rate (μ_{max}) of the thermophilic microorganisms. Besides, coupling the model of Grau second order model (anaerobic system) with the model of Monod (aerobic system) will completely define the IAAB system.

1. Introduction

Palm oil mill effluent (POME) has been identified to be one of the major sources of water pollution, not only because of the large quantity generated, but more significantly due to its high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) concentrations. Based on the extent of pollution, POME was among the first waste types to be singled out for statutory control (Ma, 1993). Presently, anaerobic digestion by ponding system is the most common treatment method adopted in Malaysia to treat the highly polluting POME (Ma, 1993). Subsequent aerobic post treatment is vital to bring the anaerobically treated POME to within the effluent discharge standard. In general, the anaerobic–aerobic systems were carried out in two separate reactors connected in series. These systems necessitate large land requirement and high construction costs. Therefore, a high rate integrated anaerobic–aerobic bioreactor (IAAB) which combines the aerobic and anaerobic processes in a single bioreactor and capable of treating POME within a short period of time at reduced space utility was utilized in this study.

In the palm oil mill processing system, POME is discharged at relatively high temperatures (75–85 °C) (Bhatia et al., 2007), and therefore making it possible to be treated at thermophilic (45–60 °C) temperatures. Nevertheless, biological treatment of anaerobic–aerobic under mesophilic conditions is still being employed widely in Malaysia and large ponds are required for pre-cooling. In fact, by treating the POME at thermophilic conditions, the heat contained in the raw POME could be recovered to facilitate the requirement of elevated operating temperatures, therefore obviating the need for large cooling ponds and reducing the operating costs. For that reason, the anaerobic–aerobic treatment of POME under thermophilic condition could be a cost effective alternative as the cooling facility is eliminated (Abeynayaka and Visvanathan, 2011). The thermophilic digestion process intrinsically will have a higher substrate degradation rate due to faster reaction kinetics and higher specific biomass growth rates (Simstich et al., 2012) but the process does have the reputation of being more sensitive to environmental changes than mesophilic processes. However, it has been shown that thermophilic bioreactors can be operated for prolonged periods at high loading rates (van Lier et al., 1996).

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