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LAB-SCALE STUDY ON CO-DIGESTION OF KITCHEN WASTE, SLUDGE AND SEWAGE

Son Minh Tran[1], Hang Thanh Vo[1, *], Lam Uy Tran Huynh[1], Kiet Quoc Tran[1], Dan Cong Bach[1], Linh Hoang Nguyen[1], Tuc Quoc Dinh[1], Ludo Diels[2], Heleen De Wever[2]

[1]*University of Technology, Vietnam National University Ho Chi Minh City, 268 Ly Thuong Kiet, District 10, Ho Chi Minh City, Vietnam*

[2]*VITO (Flemish Institute for Technology Research), Boeretang 200, 2400, Mol, Flanders, Belgium*

[*]Email: *hang_vothanh2003@yahoo.com*

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ABSTRACT

Anaerobic digestion is widely used for biodegradable solid organic wastes in order to recover bio-energy in the form of biogas. Some previous studies presented that co-digestion of various substrates can improve biogas yields as well as enhanceperformance of organic wastes digestion, in comparison with digestion of sole solid waste. This study aimed to evaluate the performance of anaerobic mono-digestion and anaerobic co-digestion of the following mixtures: (a) sole kitchen waste (KW), (b) KW and sewage (SW), (c) sole sludge (SL)and (d) KW and SL. This study was conductedby four lab-scale anaerobic complete mixing reactors (numbered MH1 – MH4) in 4,5 liters working volume atorganic loading rate (OLR) 2,0 g(VS).$L^{-1}.d^{-1}$. The KW was collected from canteen B4 and SW was collected from effluent from septic tank C6 Building in Ho Chi Minh University of Technology (HCMUT). The results show that the reactor of sole KW obtained average total chemical oxygen demand (tCOD), soluble chemical oxygen demand (sCOD), total solid (TS), volatile solid (VS), total phosphorus (TP) and total Kjeldahl nitrogen (TKN) of 62 %, 62 %, 71 %, 72 %, 73 % and 45 %, respectively, whereas reactor of KW and SW co-digestion had were tCOD, sCOD, TS, VS, TP and TKN removal of 73 %, 78 %, 75 %, 79 %, 59 % and 57 %, respectively. Thus co-digestion of KW and SW revealed an efficient enhancement of digestion, instead of sole KW digestion. Similarly, TS (74 %) and VS removals (75 %) of co-digesting mixtures of SL and KW were higher than those of sole SL digestion (67 %). Furthermore, co-digestion of SL and KW obtained better performance in tCOD and sCOD removals (70 % and 76 %, respectively).

Keywords: Co-digestion, kitchen waste, sludge, sewage and anaerobic complete mixing reactor.

1. INTRODUCTION

According to statistical analysis of Viet Nam Centre for Economic and Policy Research (VEPR) during 2008-2015, solid waste generation is increasing 10 - 16 %/year due to population explosion and urbanization, and 50 –60 % municipal solid wastes is easily biodegradable organic wastes [9]. Additionally, the rapidly rising costs associated with exploitation of fossil fuels lead to a high demand for renewable energy. Anaerobic digestion is a technical solution for both of those problems by decreasing environmental pollution and supplying biogas as a clear energy source.

Kitchen waste (KW) is characterized by a high organic content, most of which is composed of easily biodegradable compounds such as carbohydrates, proteins, and smaller lipid molecules. As a result, an interest in anaerobic digestion has increased for the efficient management of kitchen waste [8]. Food waste (FW) has similar characteristic with KW, and it was reported that the individual anaerobic digestion of FW failed at the OLR 3,0 g $VS.L^{-1}.d^{-1}$ due to acid accumulation [3]. Moreover, the stability of anaerobic digestion process would become poor when high OLR was applied [2, 4]. These problems may potential limit the application of anaerobic digestion for treating such wastes in industrial scale.

Co-digestion of different materials may enhance the anaerobic digestion process due to better carbon and nutrient balance [6, 7]. According to Mata-Alvarez et al. (2000), digestion of more than one substrate in the same digester can establish positive synergism and the added nutrients can support microbial growth [5]. The addition of SL or SW to KW digestion processes provides the nitrogen, as well as other macro and micro nutrients that are not present at sufficient levels in KW alone. Therefore, it should be a good option to co-digest KW with SL and KW with SW to obtain a higher biogas production and digestion stability, and to conveniently treat two wastes in one facility [10].

In Viet Nam, there are 17 waste water treatment plants (WWTPs) which is operating. Thus, sewage sludge (SL), the byproduct of biological wastewater treatment processes will be increasing gradually due to increasing population connected to sewage networks, building new WWTPs and upgrading existing plants. Treatment of sewage sludge via anaerobic digestion has been conducted widely due to its renewable energy production capacity (Chen et al., 2008).

So, this study aimed to investigate the performance of anaerobic co-digestion in single phase of the following mixtures: (a) KW and sludge (SL) collected from Binh Hung sewage treatment plant and (b) KW and SW from effluent of a septic tank.

2. MATERIALS AND METHODS

2.1. Collection and preparation of substrates

A 0,5 kg of KW was collected daily from canteen B4 Building in Ho Chi Minh University of Technology (HCMUT). The collected KW mainly contained the cooked food residues, such as steamed rice, noodles, cooked vegetables, cooked meat, cooked fishes. The indigestible materials, such as plastics, bones, egg shell, and toothpicks was removed before the collected KW were crushed.

0,5 L of SW was collected daily from effluent from septic tank C6 Building in HCMUT.

0,5 L of SL from Binh Hung waste water treatment plant (Ho Chi Minh City, Viet Nam) was used daily as substrate for present study. It was stored at 4 ^{o}C.

2.1.1. Anaerobic digestion

The inoculum was anaerobic sludge collected from a pilot scale working digester treating municipal solid waste at canteen of B4 Building in HCMUT. At the beginning of the digestion test, in each reactor, bacterial inoculate was mixed with glucose at an amount determined from the initial VS content of the KW and SL. The reactor was tightly closed with a rubber septa and a screw cap. All the digesters were incubated for a time period until little if any biogas was produced. MH1 was fed with sole KW, MH2 was fed with mixed substrate of KW and SW, MH3 was fed with sole SL and MH4 was fed with mixed substrate of KW and SL.

Batch digestion tests were performed on the sole KW, sole SL, mixture of KW and SW and mixture of SL and SW at OLR 2,0 g (VS) L^{-1} d^{-1}. The initial volatile solids loadings for batch digestion of sole KW, sole SL, mixture of KW and SW and mixture of SL and SW were 18,742 mg VS/L, 17,642 mg VS/L, 22,217 mg VS/L and 18,053 mgVS/L, respectively. All the tests were conducted under ambient air temperature condition. Four reactors (numbered MH1-MH4), with liquid working volume of 4,5 L, were equipped with stirrers to provide sufficient mixing for substrate. The rotation speed was set at 1 s^{-1} with 60 min stirring and 10 min break continuously. Daily feeding was conducted by pushing substrate through the inlet of the reactor and daily draw-off by opening the discharge valve.

2.1.2. Analytical parameters

Samples were taken on working days, all collected samples were analyzed for chemical oxygen demand (COD), total solid (TS) and volatile solid (VS) contents according to the Standard Methods for the Examination of Water and Wastewater (SMEWW) and also contents of various nutrients such as total Kjeldahl nitrogen (TKN), ammonium-nitrogen (NH_4) and Total Phosphorus (TP).

3. RESULTS AND DISCUSSION

3.1. VS/TS removal efficiency

The average TS and VS concentrations of the influent from Lab-scalesMH1, MH2, MH3, MH4 were 27 mg/L and 19 mg/L, 28 mg/L and 22 mg/L, 25 mg/L and 18 mg/L, 26 mg/L and 18 mg/L (Fig. 1), respectively. The VS/TS ratios were 69 % and 81 % for MH1 and MH2, respectively, indicated that the biodegradability of mixed substrate of KW and SW of MH2 were higher than sole KW of MH1. The VS/TS ratio of MH2 was relatively high and it is suitable for anaerobic conversion. In effluent, VS/TS ratios were 66 % and 68 % for MH1 and MH2, respectively. VS/TS ratio reduction of MH1 (3 %) is lower MH2 (13 %), which indicated that the co-digestion of KW and SW released higher VS content than sole KW.

The VS/TS ratio for influents of MH3 approximateto that for MH4 (70 %). For effluent, VS/TS ratios reduction were 69 % (MH3) and 57 % (MH4) (Fig. 2).

3.1.1. Acidification rate tests

The alteration of sCOD concentration corresponded to the alteration of TS and VS content. The average sCODcontent which was consumed per day($sCOD_{prod.}$) in acidification process for MH1, MH2, MH3 and MH4 were 5 g/d, 8 g/d, 3 g/d,and 5 g/d, respectively, and the average VS of the influent (VS_{in}) were 19 mg/L, 22 mg/L, 18 mg/L, and 18 mg/L (Fig. 3), respectively. The acidification rate as analyzed based on $sCOD_{prod}/VS_{in}$ ratio of MH1, MH2, MH3 and MH4 which were 270 gCOD.L/gVS.d, 354 gCOD.L/gVS.d, 166 gCOD.L/gVS.d, 276 gCOD.L/gVS.d, respectively. The acidificationefficiency of MH2 was higher than MH1 and that of MH4 was higher than MH3.

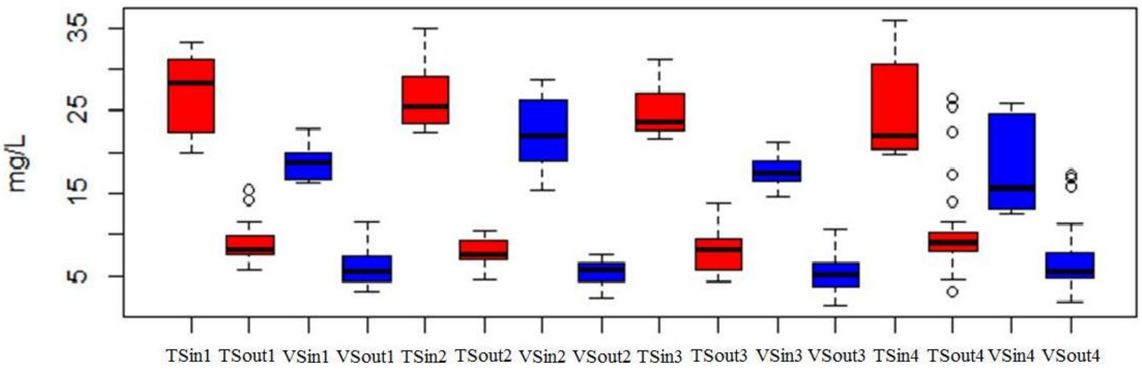

Figure 1. Comparison of influent and effluent of average TS and VS of MH1 and MH2, MH3 and MH4.

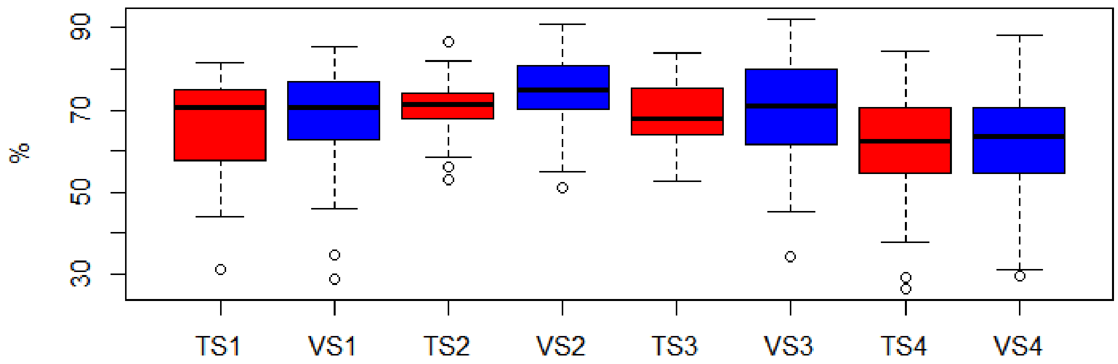

Figure 2. Comparison of TS and VS removal efficency of MH1 and MH2, MH3 and MH4.

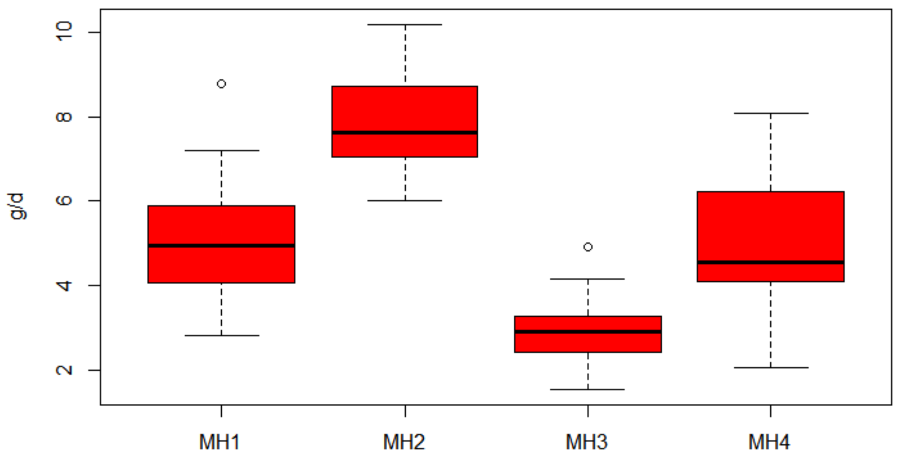

Figure 3. Comparison of average $sCOD_{prod}$ concentration of MH1 and MH2, MH3 and MH4.

3.1.2. Nutrients removal efficency

According to Figure 4, the average TKN concentration of MH1influent (1128 mg/L) was lower than that of MH2 (1443 mg/L), while the average TP concentration of MH1 influent (33 mg/L) was higher than that of MH2 (7 mg/L) (Fig. 5). The average ammonia concentration of MH1 influent and MH2 influent were 131 mg/L and 60 mg/L, this showed that organic-N of MH1 influent accounted for 88 % of TKN and that of MH2 influent accounted for 96 % of TKN. In the effluent, the average ammonia concentration of MH1 (177 mg/L) and MH2 (192 mg/L) increased compared to those of the influent, which indicated that organic nitrogen is converted to ammonia during anaerobic digestion. The average TKN and TP removal efficiency of MH1 (54 % and 60 %) is lower than that of MH2 (55 % and 68 %), respectively. Therefore, MH2 removed nutrients more effectively than MH1.

Similarly, the results show that MH4 removed nutrients more effectively than MH3.

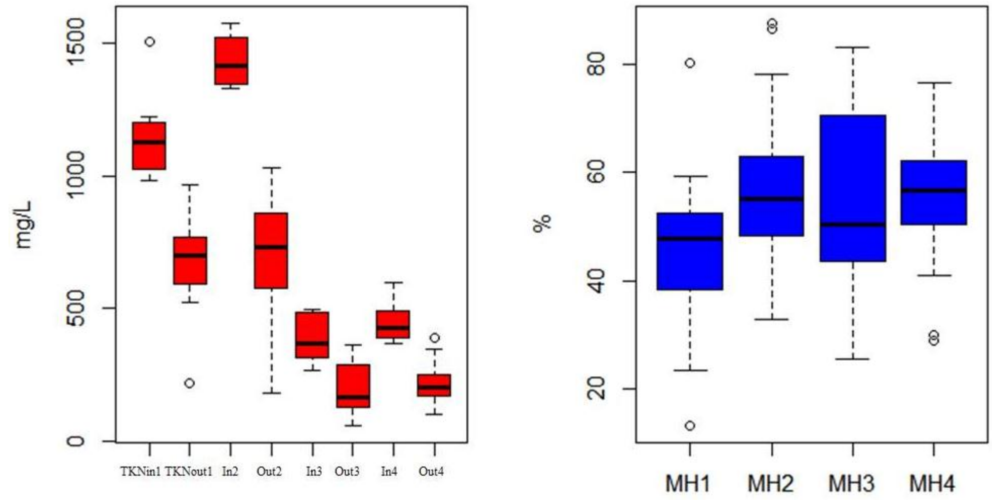

Figure 4. Comparison of average TKN concentration and TKN removal efficency of MH1 and MH2, MH3 and MH4.

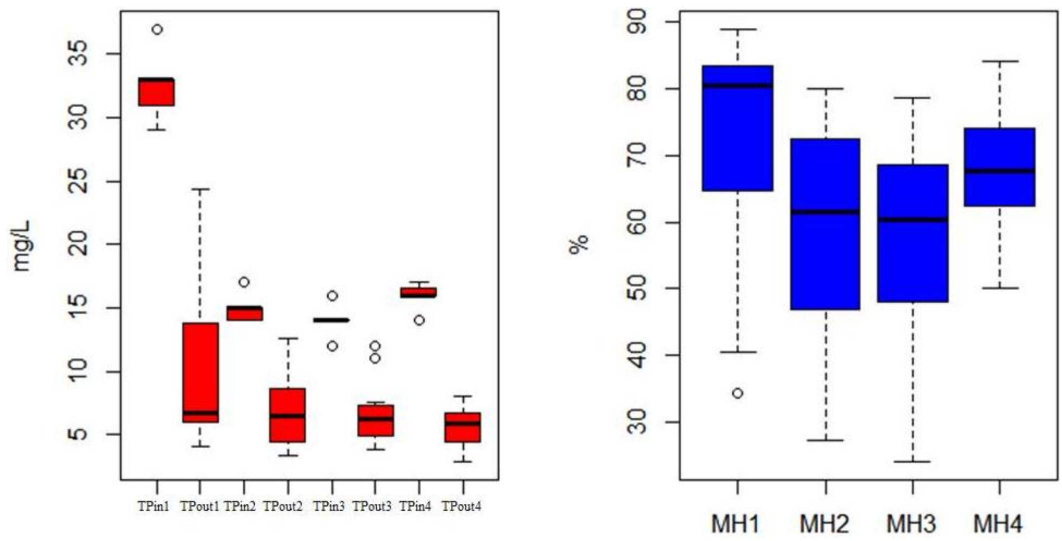

Figure 5. Comparison of average TP and TP removal efficency of MH1 and MH2, MH3 and MH4.

4. CONCLUSIONS

The results show that the co-digestion of various substrates obtained a better performance in waste treatment and energy recovery. The co-digestion of KW and SW revealed an efficient enhancement of digestion, which are suitable for developing a small-scale waste treatment system.

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