Influence of Unlike Proportions of Preliminary and Activated Sludge on Methane Generation During Anaerobic Co-digestion

Md. Nurul Islam Siddique[1, *], Mohd Zamri Bin Ibrahim[1], Mohd Mokhlesur Rahman[2]

[1]Faculty of Ocean Engineering Technology and Informatics, University Malaysia Terengganu (UMT), Terengganu, Malaysia

[2]East Coast Environmental Research Institute, Universiti Sultan Zainal Abidin, Terengganu, Malaysia

Email address:

m.nurul@umt.edu.my (Md. N. I. Siddique)

[*]Corresponding author

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Abstract: The aim of this study was to look into methane generation using different amounts of initial sludge (IS) and activated sludge (AS) for anaerobic transformation. To compare the best combination in analysis with a benchmark combination, C0, three experimental ratios (IS: AS) (v/v) were used: C1 (60: 40), C2 (80: 20), and C3 (100: 00). (40: 60). Anaerobic digestion was carried out at 37°C in mesophilic conditions with a 12 day HRT and a loading rate of 1.63 0.06 kg TVS/m3 day. In comparison to C0, biogas generation for ratios C1 and C2 increased from 25% to 38%. The maximum amount generated by combination C3, which was 52.44 percent more than that of C0, showed a clear improvement in specific methane generation. C1, which involves using less initial sludge and increasing activated sludge condensing, is the most realistic combination to use on a large scale. IS has a C/N proportion that is 2 times more than AS because of the higher organic compounds in IS. The obtained proportion of IS that ought to be added to AS to achieve the greatest methane production were 60 and 80% (combination C1 and C2), separately than the reference conditions, C0. Nevertheless, the influent ought to be deliberately arranged with a gradual increment to the ideal influent proportion to acclimatization of the microorganisms and avoid over-loading. 3.72 years are found to be the time needed to recover expenses.

Keywords: Methane, Anaerobic Co-digestion, IS: AS Ratio, Sludge

1. Introduction

The increasing population and industrialization have caused exceptional changes in water resources and reliable treatment techniques have turned into the significant focal point of research throughout the globe [15]. Scarcity of power sources turned into the primary objective in trend-setting innovations to beat vitality costs related to water and wastewater purification [16].

The abundance and deficient utilization of non-renewable energy sources have quickened the consumption of worldwide nonrenewable assets and environmental change [17]. Around the world, the activated sludge process is the most widely recognized organic treatment applied on wastewater treatment plants (WWTP) and is a compelling and effective treatment innovation just as large consumer of bio-energy, utilizing 40% of the electricity [18].

The expanding applications of treatment plants in ongoing decades caused a continuous increment in the quantity of sludge generation and in energy utilization [8, 9]. Creating feasible technologies has become significantly important because of the rising energy requirements, to limit worldwide energy utilization regardless of the nature of treated wastewater [10, 11]. This methodology might be applied by redesigning the various units of treatment plants, to improve the anaerobic treatment of sewage sludge [6]. Sludge treatment and minimization have turned into a first issue, as sludge generation will be increasing because of stringent ecological guidelines [18].

Anaerobic digestion is broadly utilized for the

adjustment of blended sludge, a combination of initial sludge (IS) and activated sludge (AS) [2, 13]. IS is produced during physical treatment of preliminary sedimentation, while AS is created in the organic treatment system of treatment plants [19].

Besides, sludge handling expenses are around sixty percent of the total operating expenses of treatment plants. This implies that the challenge is to propose new arrangements which may be adjusted to traditional commercial-scale treatment plants, utilizing anaerobic digestion of blended sludge as a bio-process innovation, improving the energy stability [7].

Blended sludge as a solitary substrate is described by a lower C/N proportion (below ten) and generally lower anaerobic bio-digestibility, as the refractory materials present in sludge require longer retention time [20, 21]. Although anaerobic technology is considered an economic and naturally benevolent innovation, carries certain constraints which might be overcome by novel techniques [22-24].

As indicated by the previous studies in the field of the anaerobic digestion of sewage, two main concerns had been mentioned: improvement in biodegradability and methane generation in the anaerobic system [25-27].

Yet, little data can be found in the previous studies on the adjustments of sludge to improve methane generation to confront the imperatives in a traditional medium [28-30]. For this reason, the research work was started to overcome the few limitations of anaerobic digesters. The objective of this manuscript is to fill this gap by considering a few different ways of obtaining higher energy productions from IS and AS by their chemical structure and energy contents. In Europe, the most widely recognized sustaining blend of IS and AS utilized in treatment plants is 40: 60 (v/v), complying with different investigations. Subsequently, the objective of this work is to study the usefulness of a variation on this proportion to improve methane generation and waste minimization.

This study offers the advancement of sustainable power source generation, considering various properties of substrate blends and by the assessment of the IS and AS bioconversion into bio-methane. This methodology gives the likelihood of applying basic adjustments in feed substrates without disturbing the normal functions of the water treatment plants.

2. Materials and Methods

2.1. Substrates and Inoculum

The sludge utilized in this investigation was initial sludge (IS) and activated sludge (AS) and was collected from a full-scale wastewater treatment plant named Quantum Hydromech Sdn. Bhd., Kuantan, Pahang, Malaysia. Analysis was performed on IS and AS samples two times every month and transferred to Laboratory where they were kept at 4°C for further examinations. The fundamental properties of IS and AS utilized in this examination are listed in Table 1.

Table 1. Properties of Feed wastewater (Average±SD).

Parameters	Primary sludge	Waste activated sludge
TCOD (g/ L)	65±4	24±4
SCOD (g/ L)	5±0.05	0.3±0.15
SCOD/TCOD (%)	7	2
pH	5.7±0.3	6.5±0.2
EC (mS/ cm)	17±1	5±0.04
TS (g/ L)	55±3	24±1.5
TVS (g/ L)	37±4	19±3
TVS/TS (%)	67	79
TVSS (g/ L)	33±12	18±3
TVSS/TVS (%)	88	95
TKN (g/ L)	1.25±0.3	1.5±0.5
NH_4^+-N (g/ L)	0.3±0.03	0.4±0.05
TOC (g/ L)	22±5	11±1
TP (g/ L)	0.3±0.08	0.4±0.1
C/N	19	8

2.2. Batch Tests

To achieve the commercial-scale anaerobic degradation, a benchmark combination was prepared with a similar proportion of IS and AS (40: 60, v/v) and characterized as preliminary combination 0 (C0), after the acclimatization was established. To examine various combinations to improve the sustaining blend usually utilized in a treatment plant and to enhance the methane yield, three combinations of IS: AS (v/v) were utilized: combination 1 (C1), 60: 40; combination 2 (C2), 80: 20; and combination 3 (C3), 100: 0. Besides, to keep up the loading rate of 1.63±0.06 kg TVS/m³ day related to the commercial scale, sustaining blends were diluted (Table 1) as per [3, 4] methods.

2.3. Fermentation

Anaerobic digestion was performed in a continuous stirred tank reactor comprised of stirrer, pumps, and temperature control panels. Biogas was collected in a gas collection bag by water displacement method. The parts of the anaerobic reactor were shown in Figure 1.

Figure 1. Photograph of experimental set up.

Initially, 65% nitrogen gas was used for 2 minutes to ensure anaerobic condition in the CSTR. The CSTR was seeded with 3 L of sludge from Quantum Hydromech Sdn.

Bhd., Kuantan, Pahang, Malaysia wastewater treatment plant. To keep away from the retention of the activated biomass in the reactor the stirrer works two additional times each day. The start-up was achieved after 2 months until acclimatization was established. Substrate blends were prepared as per the reference combination (C0).

Mesophilic (37°C) state with an HRT of 12 days were chosen for the experiments according to [31], and were continued for 4 months, separated into four combinations (C0, C1, C2, and C3).

2.4. Analysis

All the water quality parameters were analyzed by standard methods of [1]. The biogas produced by the CSTR 0was assessed by OMEGA® building gas meters. Biogas synthesis and VFAs were estimated by (Siddique et al., 2014). Standard techniques [1] were applied for pH, electrical conductivity (EC), TS, TVS, TSS, TVSS, TCOD, SCOD, TOC, TKN, NH_4 - N, and TP. The characteristics of the blends and effluents generated in each trial are listed in Table 2.

Table 2. Digester output for after operation (Average±SD).

Parameters	C0 (40: 60), V/V		C1 (60: 40), V/V		C2 (80: 20), V/V		C3 (100: 0), V/V	
	Feed	Effluent	Feed	Effluent	Feed	Effluent	Feed	Effluent
TCOD (g/ L)	41±0.4	23±0.2	39±1.5	21±8	40±2	22±5	38±4	18±0.4
SCOD (g/ L)	4.5±0.05	3.6±0.1	3±0.09	3.7±0.1	3.2±1.5	5.4±1.2	2.8±0.2	3.5±1
pH	5.9±0.3	7.2±0.3	5.7±0.2	7.5±0.2	5.6±0.2	7.4±0.2	5.4±0.2	7.3±0.4
EC (mS/ cm)	14.4±0.3	13±0.3	15.2±2	13.6±0.4	17±1.5	14±0.4	17.3±3	14.6±0.2
TS (g/ L)	32.6±0.7	26.4±0.7	33.7±1.7	25.3±2.5	34.6±0.5	25.8±2	33±4	20.6±7
TVS (g/ L)	24.9±0.9	15±0.5	22.7±1.3	13±3	25.9±0.9	11.5±8.5	22.6±2.3	9.7±1.9
TVS/TS (%)	76.5	57	67.5±0.2	51.4±0.2	73.4±0.1	69±0.4	68.5±0.2	46.8±0.3
TVSS (g/ L)	23±0.9	13±0.07	19±0.3	10.5±2	21.4±0.5	8.4±0.7	19±6	7.9±0.2
TKN (g/ L)	1.8±0.2	1.6±0.08	1±0.2	1±0.2	1.2±0.3	1.2±0.3	0.9±0.1	0.7±0.3
NH_4^+-N (g/ L)	0.4±0.2	0.7±0.05	0.3±0.02	0.6±0.02	0.3±0.02	0.6±0.02	0.3±0.04	0.3±0.03
TOC (g/ L)	14.4±1.5	8.7±0.04	13.2±1.2	7.5±1.3	14±0.06	10.3±2	13.3±2.6	5.6±0.3
TP (g/ L)	0.6±0.05	0.6±0.03	0.4±0.02	0.4±0.02	0.4±0.08	0.3±0.02	0.3±0.04	0.2±0.03
C/N	10	7	15	9	16	8	18	10

3. Results and Discussion

3.1. Characterization

The principle qualities of IS and AS utilized amid the test measures are demonstrated in Table 1.

Evaluating the properties of IS and AS, their contribution to the improvement of the anaerobic digestion system can be observed. Concerning C/N proportion of the IS and AS, we can observe that the increase of IS ratio in the mixture can improve the methane yield due to its C/N proportion approximately 2 times higher than that of AS. This complies with the study of [5, 6]. Another significant parameter to show the dependability of an anaerobic system is pH [11, 12]. Moreover, the pH of influents demonstrated a declining trend: 5.9 (C0), 5.7 (C1), 5.6 (C2), 5.4 (C3), showing that utilizing the C3 might make it progressively hard to accomplish stable states [13, 14]. In any case, investigating the effluent properties the pH was observed to be 7.2 (C0), 7.5 (C1), 7.4 (C2), 7.3 (C3) demonstrated that the response of the CSTR showed a sensible buffering capacity.

The various combinations of IS and AS in every experiment clarified the distinctions seen in the physicochemical properties examined, as listed in Table 2. The response of the sustaining blend properties demonstrated the synergetic impact of enhanced IS ratios in the CSTR influents to improve methane productions [32, 33].

3.2. Co-digestion Operation

In Table 3, the most extreme Ground-penetrating radar,

GPR attained by combination C3 with an enhancement of around 37% compared to that of C0. An obvious enhancement was seen in specific methane production (SGP) produced by the combination, C3, which was 52.44% greater than that of C0. While examining specific methane generation utilizing an alternate parameter (SGP Methane, mL g/ TVS), we can see an identical trend ranged between 59.24% and 87%. The best outcome produced from the combination, C3 in terms of C/N proportion [12, 13]. The impact of this ratio among IS and AS, as mentioned between combinations C1 and C3, resulted in an improvement of the C/N proportion. This is suggested for the anaerobic system by [4]. Another fascinating viewpoint is the impact on CSTR performance while enhancing the ratio among IS and AS, as observed from the combination, C0 to C3, which appeared by an increment in TVS removal productivity of 42.85%.

The specific methanogenic capacity was steadily below 0.38 per day. Therefore, the activity of the methanogens was never surpassed indicating the likelihood of enhancing the OLR without the danger of digester instability that is as per past investigations of [34- 36]. Table 4 shows the day-by-day biogas generation during various experiments, with a mean of 8, 9, 10, and 11 NL /day for combinations C0, C1, C2, and C3 respectively. In comparison with C0 and the accompanying combinations achieved increments of 13, 25, and 38% individually, demonstrating an enhancement in the day-by-day biogas generation with the higher ratios of IS applied in blends. The properties of IS and AS could explain this enhancement as IS contains the more effectively biodegradable compound. Likewise, Figure 2 shows the specific methane generation that is as per the biogas

generation profile, affirming the outcomes that appeared in Table 3. The specific methane generation enhanced from 59.24% to 87%. This synergistic impact was determined by the difference between the methane production from C0 and the methane production from combination C1, C2and C3 enhancing the ratio of IS in the substrate combination, which is as per the study of [37-39].

***Table 3.** Operating parameters during experimental runs (Average±SD).*

Runs	C0	C1	C2	C3
Temperature °C	37±0.6	37±0.6	36±0.6	37±0.6
Substrate ratio (v/ v)	40: 60	60: 40	80: 20	100: 0
HRT (days)	17	17	17	17
GPR (NmL/L. day)	581	689	760	796
Methane (%)	64	71	69	72
SGPMethane (NmL g/TVS)	246 220	355 318	389 304	418 374
SGPMethane (NmL g/TCOD)	164 136	210 189	215 198	250 224
SGPMethane (NmL g/TVSS)	265 237	422 378	462 308	496 443
TVS removal,%	42	45	56	60
TCOD removal,%	46	47	50	54
TVSS removal,%	46	49	61	62
Specific methanogenic capacity (per day)	0.22	0.27	0.34	0.36

***Table 4.** Daily Biogas production in different substrate ratios (C0-C3) (Average±SD).*

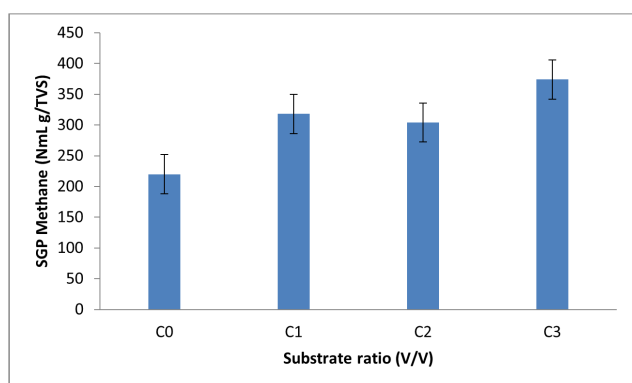|	C0	C1	C2	C3
Daily Biogas production (NL/day)	7±0.5	9±0.6	10±0.6	11±0.6

***Figure 2.** Methane productions for different substrate (v/v) proportion.*

These increments might be clarified once the organic compounds (in TVS) are two times higher for IS than that of AS [40, 41, 42]. This conduct is likewise valid for the SCOD/TCOD proportion that was five times higher when comparing IS and AS [43-45]. It indicates an improvement in methane generation; these outcomes are as per the study of [46-48].

4. Conclusions

The findings that can be concluded from this study are listed below:

(1) IS has a C/N proportion that is 2 times more than AS because of the higher organic compounds in IS;

(2) An obvious enhancement was seen in specific methane generation with the maximum amount produced by combination C3, which was 52.44% more than that of C0;

(3) Assuming C0 as a kind of benchmark combination, with the higher ratio of IS, methane generation (SGP Methane, mL g/ TVS) enhanced from 59.24% and 87%;

(4) The obtained proportion of IS that ought to be added to AS to achieve the greatest methane production were 60 and 80% (combination C1 and C2), separately than the reference conditions, C0. Nevertheless, the influent ought to be deliberately arranged with a gradual increment to the ideal influent proportion to acclimatization of the microorganisms and avoid over-loading;

(5) Thus, C1 is the best choice as it may be applied at a commercial-scale waste treatment plant with little adjustments.

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