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Research Article

Biogas Production and Biofertilizer Estimation from Anaerobic Co-Digestion of Blends of Wastewater and Microalgae

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The study aimed to investigate the enhancement of biogas production through anaerobic digestion from blends of wastewater and microalgae. The microalgae functioned as a co-substrate. A series of laboratory-scale batch anaerobic co-digestion of the wastewater and microalgae were carried out under mesophilic conditions for 21 days. Biogas production rates from wastewater (WW) alone and different blends of WW and microalgae (MA) were analysed. In addition, the nutrient values and reduction in the volume of the WW after digestion were determined. The results show that the quantity and quality of biogas produced with different mix ratios of WW to MA (WW only, 3 : 1, and 3 : 2) were 24 mL CH_4/g COD, 37 mL CH_4/g COD, and 44 mL CH_4/g COD, respectively. At the optimum mix ratio, the optimum methane produced was 44 mL CH_4/g COD, which is much lower than volumes of gas STP conditions, which is 350 mL CH_4/g COD. The values of TS, VS, and COD were also reduced by 43.11%, 40.09%, and 71.99% at the optimum mix ratio, respectively. The optimum mix ratio of 1732.77, 77.14, and 174.26 kg/year of urea, diammonium phosphate, and potash fertilizer, respectively, was obtained. The results indicate that biogas production can be improved through co-digestion of WW and MA as a co-substrate relatively, but to improve the production rate another substrate should be investigated. However, the result can be used as a supplementary investigation for practical application in energy production.

1. Introduction

In recent years, there has been increased interest in converting a fraction of the wastewater (WW) due to the high decomposition potential and production of CH_4 as a valuable product [1]. Anaerobic digestion (AD) has been recognized as one of the best options for treating WW since it results in two valuable final products: biogas and biofertilizer [2, 3]. In addition, AD is widely used to treat high strength wastewater and reuse of industrial effluent, which contribute to water conservation efforts [4].

Algal biomass is considered third-generation biomass, which does not require arable land for cultivation [5]. Benedetti et al. [5] identified that the interest in bulk biomass from microalgae, for the extraction of high-value nutraceuticals, bioproducts, animal feed, and as a source of renewable fuels, is high. Advantages of microalgal vs plant biomass production include higher yield, use of nonarable land, recovery of nutrients from wastewater, efficient carbon capture, and faster development of new domesticated strains [6, 7].

Anaerobic conversion of organic materials and pollutants is an established technology for environmental protection [8]. The end product is biogas, a mixture of CH_4 and CO_2, O_2, H_2S, CO_2, and other trace gases [1, 5]. AD is a technologically simple process, with a low energy requirement, used to convert organic material from a wide range of WW types, solid wastes, and biomass into biogas [9, 10] [11]. Initially, the aim was simply to generate energy in the form of heat and electricity. While electricity and heat are still the main products of biogas utilization [12], other interests in the use of biogas have steadily grown and now include utilization as a vehicle fuel and all applications that natural gas has found over the last century [13, 14]. In addition to energy, the AD process has a residue, the digestate, which contains valuable nutrients and can therefore be used as a biofertilizer [14, 15].

This summary describes the developments in the biogas sector in terms of the drivers for AD deployment, the technologies adopted, and utilization of the products, biogas, and digestate. However, locally the demand for biogas is continuously growing and the biogas substrate, such as algae, may soon become limited, and it is therefore important for biogas producers to expand the range of substrates. Much attention has been focused on the improvement of CH_4 production to prevent the limitation. An interesting option for improving CH_4 yields is co-digestion. This is a process where resource recovery can be optimized by improving the nutrient and organic content of substrates to be used in an anaerobic digester along co-digester.

Numerous feedstocks can be used in the AD process. Feedstock can include animal and human manure [16], wastewater [11, 17], food waste [18], sewage sludge [19], and brewery effluent [20]. However, biogas composition, especially the CH_4: CO_2 ratio, varies greatly depending on the type of feedstock, or feedstock (if co-digesting) [21, 22].

It has been found during anaerobic digestion that the microbial population makes use of about 25 to 30 times carbon faster than nitrogen [23]. The substrate with low C/N ratio may likely result in the production of high amount of total ammonia nitrogen (TAN) and volatile fatty acids (VFAs) [24]. These substances are important intermediate products produced during the anaerobic digestion [25]. Increased concentrations of VFAs could hinder methanogenic activities. Gradual accumulation of these intermediates could lead to total failure of the anaerobic digestion (AD) process [23, 24]. The benefits of increasing C/N ratio through co-digestion with complementary feedstock include higher biogas yield and feed loading rate as well as reduction in potentially toxic ammonia concentration [26]. Additionally, the study conducted by Tanimu et al. [27] showed us that batch AD study increased the C/N ratio of the available food waste ($C/N = 17$) through co-digestion with meat, fruits, and vegetable wastes. This study shows biogas the possibility of biogas production at low C/N.

Therefore, the mixing WW: MA and increasing the amount of co-substrate will increase the amount of biogas and will modify C/N ratio. Along this, this study was explored, under a laboratory setup, the possibility to use microalgae collected from the oxidation pond of Jimma Institute of Technology as a co-substrate to wastewater in biogas production under mesophilic conditions.

2. Materials and Methods

2.1. Sampling Area. The study focused on the WW generated from the cafeteria of Jimma Institute of Technology (JiT), Jimma University (JU), Jimma. For the co-digestion purpose, MA was collected from the oxidation pond of JiT. Jimma is far from the capital city of Ethiopia, Addis Ababa, 335 km having 1717 m altitude, 7.66 m latitude, and 36.833 m longitude. It has an average yearly temperature of 22.8°C and 125 mm yearly rainfall.

2.2. Sampling Procedure. Well-mixed representative samples of WW were collected from Jimma Institute of Technology, Jimma University, Ethiopia. The WW was collected for three consecutive days in the morning, midday, and evening to reduce sample variation. Then, the volume of WW collected during morning, midday, and evening was mixed to get one common sample of WW of that day. With the same procedure for the next two days, the samples were collected. The collected samples were preserved in the refrigerator working at 4°C temperature to prevent result variation during the experiment. For blue-green algal representative, the sample was collected for three consecutive days from oxidation pond of JiT (Figure 1) and was prepared one day representative and with the same procedure for the next two days. Then, it is filtered and preserved in the refrigerator to prevent result variation.

2.3. Methods

2.3.1. Study Variables. The study parameters are classified into independent and dependent. Independent parameters include the amount of WW and MA, carbon-to-nitrogen ratio (C/N), dilution rate, temperature, pH, retention time, total nitrogen (TN), total phosphorus (TP), total potassium (TK), and coliforms, and the dependent parameter is the amount of biogas produced.

2.3.2. Experimental Procedure. A digester, necessary fittings, and different measuring devices were prepared before collecting the samples from each site. Sample preparation, testing for different parameters and recording (pH, BOD_5, TS, VS, COD), preparation of different mixes, and homogenizing were done during the experiment, and finally, experimental results were collected. The pH of the solution (slurry) was adjusted through the production time at standard pH (5–8), at the temperature of the mesophilic range (29–40°C). The biogas produced during the digestion process was collected by a gas collector and analysed by employing a gas analyser.

2.3.3. Experimental Setup. A digester, necessary fittings, and different measuring device were prepared before collecting the samples from each site. A series of batch experiments were carried out in the experimental setup consisting of a jacketed glass reactor with controlled temperature under mesophilic condition (35°C) with a volume of 5 liters of laboratory scale of EDBON anaerobic digester as indicated in Figure 2. A magnetic stirrer was used for mixing and increasing the homogeneity of feedstock. A digestion period of 21 days was used in the laboratory for each setup. Methane, carbon dioxide, hydrogen sulphide, and oxygen in biogas were measured by a gas analyser. The temperature of the reactor was controlled by electric heating of the water bath connecting to digester, the water bath is set to 35°C, and this temperature is continuously circulating using the pump. Biogas from the digester was taken to a volumetrically calibrated collector vessel operating by water displacement.

Figure 1: Oxidation pond of JiT from where microalgae were collected.

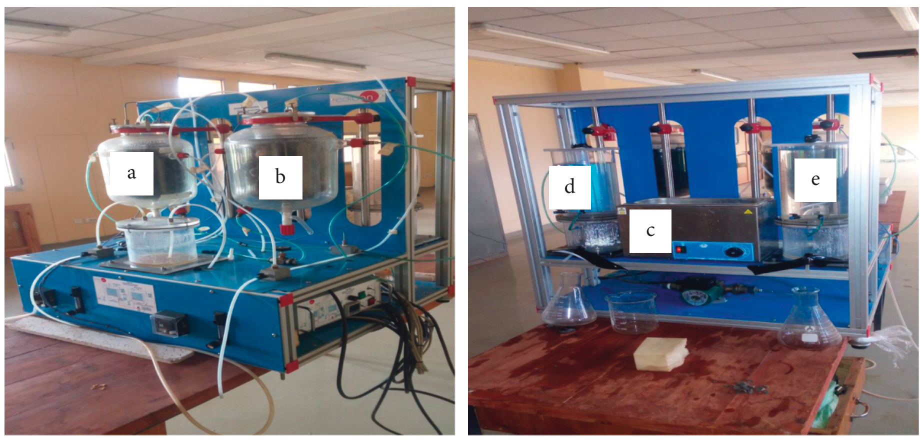

Figure 2: EDBON experimental setup (a and b are digester tanks, d and e are biogas collectors, and c is temperature regulator or water bath).

In addition, the fresh cow dung is used as inoculum for each mix ratio because it contains both methanogenic and acid-forming bacteria and is used to reduce the starting time and optimization of the decay process of digestion.

The amount of biogas produced from only wastewater and co-digestion of 3 : 1 and 3 : 2 (WW : MA) was determined through water displacement, and the gases were collected using a Tedlar gas sampling bag and subsequently analysed by a gas analyser.

In Figures 2(a) and 2(b), two packed column anaerobic digester tanks of 10 liter volume were used. Hot H_2O recycling in the shell cover of the digester was also used to maintain temperature. From 10 liters of digester, 3 liters are occupied by packed column, 1 liter is occupied by free gas generation, and only 6 liters of each are used for sample volume. Two H_2O displacers or gas collector cylinders of 3 liter capacity of plastic type were used. Gas is transported through the plastic pipe, which is connected to top free space of the digester to the H_2O displacer. The amount of gas produced is equal to H_2O displaced. H_2O bath is the temperature adjustment of the digester.

2.3.4. Sample Analysis. A series of batch anaerobic reactor under the mesophilic condition (35°C) for a digestion period of 21 days were used in the laboratory. Biogas production was determined by water displacement. OM content was estimated from weight loss upon ignition at 550°C for 3 hours in the furnace at the Laboratory of the Environmental Health Science and Technology Department, JU. Coliforms were measured using the membrane filtration method. TK, TN, and TP are measured using the kit method. pH was measured using a digital pH meter at the Environmental Engineering Laboratory of JiT, Jimma University.

Parameters such as total solids (TS), volatile solids (VS), biochemical oxygen demand (BOD5), chemical oxygen demand (COD), pathogen (total and FC), ash content, total nitrogen (TN), total phosphorus (TP), and total potassium (TK) were analysed in the Laboratory of Environmental Health Science and Technology Department of JU. The pH of feedstock under digestion was measured in the Environmental Engineering Laboratory, JiT, Jimma University. Finally, biogas was analysed at Addis Ababa Institute of Technology, Addis Ababa University.

The volume ($m^3/d/m^3$) of biogas produced was estimated using the following equation:

$$\text{gas volume}\left(m^3/d/m^3\right) = \frac{(\text{gas produced (L)/retention time (day)})}{\text{feedstock volume (L)}}. \quad (1)$$

Carbon content was estimated approximately by assuming it to be 58% of the volatile solids [23]. Therefore, it is possible to determine the approximate ratio of *C*/*N* by dividing carbon content to total nitrogen and *C*/*P* by dividing carbon content by total phosphorus. Biogas yield was calculated by comparing the actual production of CH_4 produced to the theoretical maximum (350 mL CH_4/g COD) at standard conditions of temperature and pressure (STP) [25, 28, 29]. This is very important because it can tell whether the AD process is good or not for this study.

2.3.5. Data Quality Assurance. The quality of the data was assured through triplicate analysis of samples and replication (the average plus or minus was reported) of the samples in operating procedures for quality purposes and software (Excel Software 2019, OriginPro 8) was used for data report.

3. Results and Discussion

3.1. Characterization of Raw Feedstock before Digestion. The physicochemical and bacteriological characteristics of the WW used in the study have been determined, and the experimental results are displayed in Table 1. Accordingly, the TS of the WW was 2271.87 ± 3.97 mg/l and the VS of the WW was 703.95 ± 1.40 mg/l. The mean value of COD of the WW was 1549.79 ± 2.14 mg/l.

3.2. Characterization of the Microalgae before Digestion. The physiochemical characteristics of MA used in the study were determined, and the experimental results are tabulated in Table 2. TS of the MA was 1979.48 ± 6.48 mg/l, and its VS was 720.13 ± 3.48 mg/l. The value of the COD of the MA was 61.73 ± 0.21 mg/l.

The characteristics of WW as the main substrate and the MA as co-substrate mixed in different mix ratios were analysed, and the results are displayed in Table 3. When the mixed substrates were characterized, the mean value of the TS of the 3 : 1 mix by volume was 2032.68 ± 4.72 mg/l and that of the 3 : 2 mix of WW to MA was 1711.93 ± 4.38 mg/l; the VS of the two mixes was 634.43 ± 2.68 mg/l and 564.75 ± 5.83 mg/l, respectively. The COD of the mixture was 1390.38 ± 3.35 mg/l and 1292.37 ± 4.12 mg/l for 3 : 1 and 3 : 2 mix ratios, respectively.

From Table 1, the *C*/*N* of feedstock before digestion is about 24 : 1, 15 : 1, and 12 : 1 for WW only, 3 : 1 (WW : MA), and 3 : 2 (WW : MA), respectively. From Table 2, the *C*/*N* ratio of MA is about 7 : 1, which is more than the nutrient values needed for anaerobes to carry out AD. Hence, mixing WW and MA, the *C*/*N* ratio was increased. Thus, the increase in carbon content will give rise to more carbon dioxide formation and lower pH value, which will affect biogas production by making the environment of microorganism uncomfortable [23].

While the ratio *C*/*P* is about 118 : 1, 92 : 1, and 85 : 1 for WW only, 3 : 1 (WW : MA), and 3 : 2 (WW : MA), respectively, this indicates that the concentration of phosphorus was increased as mix ratio increased. This is very important for biogas production as it stimulates the growth of microorganism by becoming their nutrients, which are further used for sufficient biogas production [30].

3.3. Characterization of the Feedstocks after Digestion. The physicochemical and bacteriological characteristics of the feedstocks after the digestion processes are expressed in Table 3. TS of 1342.33 ± 1.93 mg/l, 1161.41 ± 2.01 mg/l, and 973.91 ± 2.52 mg/l for WW, 3 : 1, and 3 : 2 mix ratios was reported, respectively. The values of VS after digestion processes were 503.97 ± 2.74 mg/l for WW alone, and 414.13 ± 2.94 mg/l and 338.33 ± 3.31 mg/l for 3 : 1 and 3 : 2 mix ratios, respectively, were recorded.

From Tables 1 and 3, the physiochemical and bacteriological characteristics of WW after and before digestion exhibit extreme variations. These variations have also been observed in several studies and are attributed to several factors such as the origin of the waste, type of on-site sanitation system, amount of ageing that has taken place, the extent of storm H_2O, temperature and infiltration, and user habit [31–33].

3.3.1. Reduction Percentage of Pollutants after Digestion. Physiochemical and bacteriological properties after digestion of feedstock analysed in this study were discussed in detail as follows.

(1) Total Solids (TS). Comparing Tables 1 and 3, reduction in TS by 40.91%, 42.86%, and 43.11% of the feedstock for WW, and 3 : 1 and 3 : 2 mix of WW to MA, was observed, respectively. This shows that there is a slight increase in the removal efficiency of TS as the mix ratio of WW and MA increases.

(2) Volatile Solids (VS). Reductions in VS are also observed with the following percentages: 28.41%, 34.72%, and 40.09% for WW alone, and 3 : 1 and 3:2 mix of WW to MA, respectively (Tables 1 and 3). From the reduction percentage of TS and VS, it can be concluded that co-digestion can reduce the area, which is covered by dry cake in the oxidation pond of JiT, Jimma University.

(3) Chemical Oxygen Demand (COD). Looking at Figure 3, considerable removal efficiencies of COD were generally observed on WW and MA digestion with an average efficiency of 62.34%, 68.84%, and 71.99% for WW, a 3 : 1 mix of WW to MA, and a 3 : 2 mix of WW to MA, respectively. The COD removal efficiencies throughout the experiment were comparable to those reported in the literature ranging from 60 to 75%. Overall, the high removal efficiencies for COD are a good indication of the fact that the AD under proper operating conditions can be used for the pretreatment of WW before the conventional WW treatment.

(4) Biological Oxygen Demand (BOD_5). The percentage reduction in BOD_5 was generally observed in WW and MA digestion with the average efficiency of 62.5%, 69.2%, and 71.5% for WW only, 3 : 1 mix of WW to MA, and 3 : 2 mix of WW to MA, respectively. The BOD_5 removal efficiencies throughout the experiment were almost justified that COD is approximately twice BOD_5 for untreated wastewater [31].

Table 1: Composition of feedstock before digestion.

Parameters	Unit	WW alone	WW : MA (3 : 1)	WW : MA (3 : 2)
Ph	x	7.80 ± 0.16	7.77 ± 0.09	7.93 ± 0.12
TS	mg/l	2271.87 ± 3.97	2032.68 ± 4.72	1711.93 ± 4.38
VS	mg/l	703.95 ± 1.40	634.43 ± 2.68	564.75 ± 5.83
BOD_5	mg/l	777.57 ± 4.58	702.94 ± 3.95	652.03 ± 2.15
COD	mg/l	1549.79 ± 2.14	1390.38 ± 3.35	1292.37 ± 4.12
DO	mg/l	1.49 ± 0.29	2.03 ± 0.08	2.30 ± 0.14
TP	mg/l	3.47 ± 0.10	3.99 ± 0.02	3.96 ± 0.06
TK	mg/l	13.40 ± 1.84	12.61 ± 1.16	11.28 ± 0.65
TN	mg/l	16.97 ± 0.88	25.44 ± 0.78	28.21 ± 1.69
TC	col/100 ml	$307^{*}10^4$	$301^{*}10^4$	$298^{*}10^4$
FC	col/100 ml	$181^{*}10^4$	$178^{*}10^4$	$171^{*}10^4$

x = no unit, col = colonies, SD = standard deviation.

Table 2: Composition of raw microalgae.

Parameters	Unit	Values (mean ± SD)
pH	x	8.20 ± 0.08
TS	mg/l	1979.48 ± 6.48
VS	mg/l	720.13 ± 3.48
BOD_5	mg/l	40.67 ± 0.85
COD	mg/l	61.73 ± 0.21
DO	mg/l	10.28 ± 0.42
TP	mg/l	4.62 ± 0.49
TN	mg/l	59.63 ± 0.70

Table 3: Characteristics of feedstock after digestion.

Parameters	Unit	WW alone	WW : MA (3 : 1)	WW : MA (3 : 2)
pH	x	5.80 ± 0.08	6.03 ± 0.09	6.00 ± 0.08
TS	mg/l	1342.33 ± 1.93	1161.41 ± 2.01	973.91 ± 2.52
VS	mg/l	503.97 ± 2.74	414.13 ± 2.94	338.33 ± 3.31
BOD_5	mg/l	291.70 ± 4.26	216.46 ± 4.30	186.43 ± 3.90
COD	mg/l	583.70 ± 2.60	433.25 ± 2.28	361.99 ± 4.18
DO	mg/l	5.57 ± 0.30	6.30 ± 0.42	6.47 ± 0.38
TP	mg/l	3.07 ± 0.12	3.58 ± 0.10	3.61 ± 0.13
TK	mg/l	10.43 ± 0.69	7.82 ± 0.46	6.85 ± 0.06
TN	mg/l	50.99 ± 0.79	55.10 ± 1.44	60.66 ± 0.61
TC	col/100 ml	$113^{*}10^4$	$68^{*}10^4$	$23^{*}10^4$
FC	col/100 ml	$64^{*}10^4$	$40^{*}10^4$	$12^{*}10^4$

3.4. Temperature, pH, and Amount of Gas Produced Measured in Volume (L). The relationship between parameters such as temperature, pH, and the amount of gas produced during the processes is expressed in Figures 4–6.

The temperature of the water bath for the anaerobic digester was set to 35°C. This temperature was continuously maintained until the retention time was completed. However, from Figures 3–5, when the pH of the feedstock being digested was checked along with the internal temperature of the digester, this temperature is changed with insignificance. This change is due to the H_2O bath being open to atmospheric temperature, which influences temperature uniformity. Also, due to the different structures of the digester system, there is temperature loss when it circulates between the digester tank and water bath. During the study, the pH value was almost with the standard range for biogas production for all the three mix ratios (Figures 4–6). For instance, in Figure 3 the pH is between 7.87 and 5.71, in Figure 4 the pH is between 8.36 and 5.71, and in Figure 6 the pH is between 8.24 and 5.78. This is because the reaction medium provides sufficient buffering capacity to neutralize acid accumulation. In the anaerobic digester, generally, the pH value is controlled by the bicarbonate buffer system, which depends on the partial pressure of the carbon dioxide and on the presence of the basic or acid components in the reaction medium [34].

Depending on the acid or base accumulation, the buffer system acts and attenuates the pH changes [34, 35].

3.5. Determination of Biogas Production for Each Mix Ratio. For the determination of maximum CH_4 in the study from digestion and co-digestion of WW and MA : WW only, and 3 : 1 and 3 : 2 mixes of WW and MA were used. The

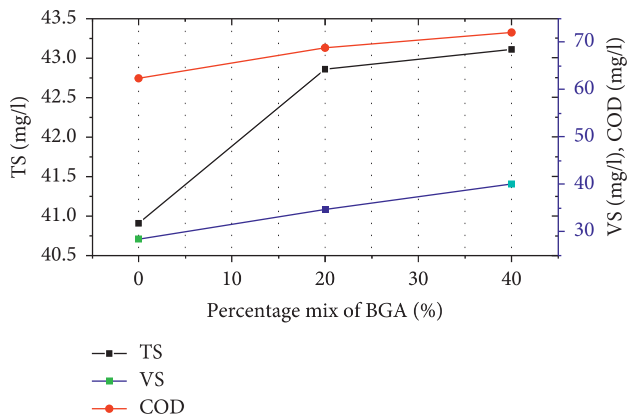

Figure 3: Removal efficiency of TS, VS, and COD at different mix ratios of MA.

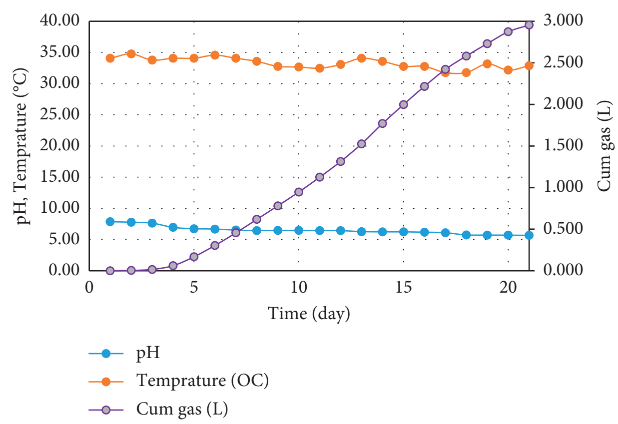

Figure 4: Relation between temperature, pH, and amount of gas produced from WW only.

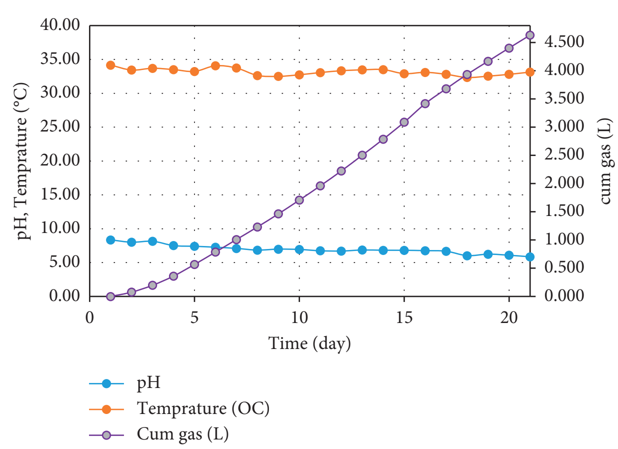

Figure 5: Relation between temperature, pH, and amount of gas produced at a 3 : 1 ratio (WW : MA).

cumulative biogases produced during the experimental period are displayed in Table 4. Gas measured in volume is increased as the mix ratio is increased, i.e., from WW only to 3 : 2 (WW : MA). The values were 2.955, 4.631, and 5.150 L for WW only, 3 : 1 (WW : MA), and 3 : 2 (WW : MA), respectively, measured at the end of 21 days.

From the digestion of WW alone: 0.028 $m^3/d/m^3$ biogas with 37.1% CH_4 (24 mL CH_4/g COD) was produced; 0.044 $m^3/d/m^3$ (37 mL CH_4/g COD) and 0.049 $m^3/d/m^3$ (44 mL CH_4/g COD) biogases with 51.1% and 57.4% CH_4 were produced from 3 : 1 and 3 : 2 mix ratio of the substrates, respectively. The estimation is obtained from equation (1).

From Figure 7, y-axis is labelled by the amount of biogas produced daily in L/day and the *x*-axis is labelled by the retention time in the day. As indicated, the amount of biogas produced is increased more up to 3 : 2 (WW : MA) mix ratios. This was because more food was available for bacteria to degrade organic compounds.

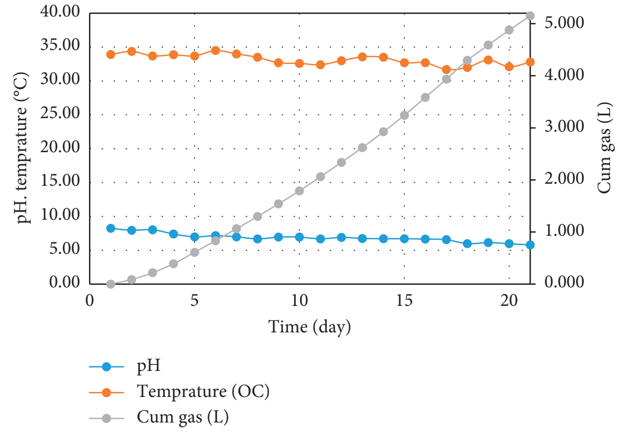

Figure 6: Relation between temperature, pH, and amount of gas produced at 3 : 2 ratio (WW : MA).

Table 4: Percentage composition of biogas produced.

Biogas content	Average volume of gas produced (L)		
	2.955 L	4.631 L	5.150 L
CH_4 (%)	37.1	51.1	57.4
CO_2 (%)	55.4	42.9	38.8
H_2S ppm	16 ppm	11 ppm	10 ppm
O_2 (%)	1.8	1.2	0.8
Others (%)	5.7	4.8	3
Parameters			
TS (mg/L)	2271.9	2032.7	1711.9
VS (mg/L)	704.0	634.4	564.8
COD (mg/L)	1549.8	1390.4	1292.4
CH_4 per parameters			
CH_4 TS (mL/g)	16	25	34
CH_4 VS (mL/g)	35	81	102
CH_4 COD (mL/g)	24	37	44

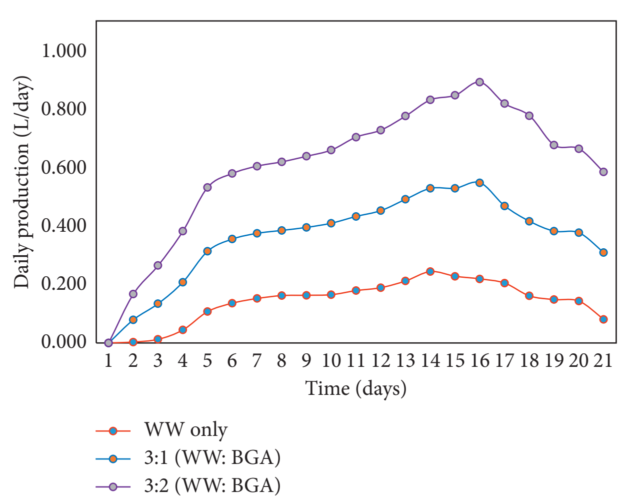

Figure 7: Daily production of each mixing ratio.

3.5.1. Identification of Optimum Mix Ratio for Maximum Biogas Production. The rate of production of biogas was measured by H_2O displacement, and the volumes of the biogas collected were recorded during the experiment period. The production of biogas was used mainly as an indication of the progress of the digestion process. The cumulative biogas produced for the digestion of WW and its co-digestion, MA, is indicated in Table 4.

The quantity and quality of biogas produced with a different mix ratio of WW to MA (WW only, 3 : 1, and 3 : 2) are shown in Table 4. Starting from WW only to 3 : 2 (WW : MA), there is a slightly increment of biogas. Thus, 24 mL CH4/g COD, 37 mL CH_4/g COD, and 44 mL CH_4/g COD were produced for WW to MA (WW only, 3 : 1, and 3 : 2), respectively. Therefore, comparatively the optimum mix ratio is at WW to MA (3 : 2). This might be because of the replacement of nutrients lost from MA to WW. At the optimum mix ratio, the optimum methane produced is 44 mL CH_4/g COD, which is much lower than volumes of gas STP conditions, which is 350 mL CH_4/g COD. This is because the value is very low, since the substrate used in this study was wastewater, which contains less organic matter for biodegradability compared with organic wastewater sludge [36]. In addition, the wastewater was sampled at the inlet of oxidation pond after the organic matter was settled down along its flow from its source, in which the source and inlet of oxidation pond are far from each other. Therefore, to improve the production rate of another substrate, wastewater sludge should be recommended.

3.6. Estimation of Biofertilizer Values. The term fertilizer often refers to any mixture containing all three important elements listed as N (nitrogen), P_2O_5 (phosphate equivalent), and K_2O (potash equivalent) [37, 38]. Urea contains 46% N and is graded as (46-0-0), and its current price is 740 ETB per 100 kg. Diammonium phosphate (DAP) grade (18-46-0) contains 18% N and 46% P_2O_5 [19], and its current price is 800 ETB per 100 kg. Potash grade (0-0-60) contains 60% K_2O, and its price is 620 ETB per 100 kg.

3.6.1. Nitrogen Fertilizer. The equivalent urea for nitrogen content in WW after digestion is given as follows [39]:

$$\text{Mass of Urea} = \frac{\text{Mass of nitrogen}}{0.46}, \qquad (2)$$

$$\text{Mass of nitrogen in waste water} = \text{conc.} * \text{rate of flow} = 60.66\ \text{mg/l} \times 36 \text{m}^3/\text{d}.$$

Assuming 365 days in a year, the mass of nitrogen is 797.07 kg/year. Mass of urea is therefore dividing the value by 0.46 and equals 1732.77 kg/year. This saves the capital to pay urea that costs 12,822.50 ETB to be obtained from urea produced during the process.

3.6.2. Phosphorus Fertilizer as P_2O_5. Equivalent DAP for phosphorus as P_2O_5 content in WW after digestion is given as follows [39]:

$$\text{Mass of DAP} = \frac{\text{Mass of phosphorus as } P_2O_5}{0.46}. \qquad (3)$$

Mass of phosphorus in the WW = 3.61 mg/l × 36 m^3/d × 365 day/year = 47.44 kg/year. Mass of P_2O_5 after digestion is given using conversion factor 0.748, which is equal to 35.49 kg/year; then, mass of equivalent DAP is 77.14 kg/year and the price is equal to 617.15 ETB. Mass of nitrogen in the DAP is 13.89 kg/year, which is 102.75 ETB; therefore, the price of phosphorus fertilizer as P_2O_5 is 617.15 ETB-102.75 ETB = 514.40 ETB.

3.6.3. Potash Fertilizer. Potash fertilizers are quantified by their K_2O equivalent. Mass of potassium in the WW after digestion as K_2O using the conversion factor 1.21 from potassium to K_2O = 6.85 mg/l × 1.21 × 36 m^3/d × 365 days/year = 108.91 kg/year. The K_2O equivalent of the mass of potash fertilizer is 174.26 kg/year, which is equal to 1080.40 ETB.

4. Conclusion

The wastewater is loaded with an organic portion, which contains the most valuable element, carbon, for the formation of CH_4, whereas microalgae contain excess valuable nutrients for anaerobes, which leads to the co-digestion of the two wastes to the high degree of methanization process. The mix ratio (60% by volume of WW to 40% by volume of MA) was observed to produce the maximum quantity of biogas with the maximum percentage of CH_4 or 44 mL CH_4/g COD biogas with 57.4% CH_4. This shows that co-digestion of WW and MA increases the amount of biogas produced when percentage mix of MA increases, but this AD process is not sufficient as compared to STP of biogas production.

The average percentage removal of TS, VS, and COD increases with the mix ratio of the WW and its co-substrate (MA). The experimental results showed that using AD of WW considerable amount of CH_4 can be captured from being emitted into the atmosphere to prevent the greenhouse effect. Therefore, the study can be used as an input for further study of anaerobic digestion process [17].

Data Availability

All necessary data used to prepare the manuscript are included within the submitted article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Supplementary Materials

Supplementary files contain tables named from Tables S1–S4. Table S1 indicates the daily record of biogas production for wastewater only with an average record of triple experiment. After adjusting Table S1, the percentage of biogas produced for wastewater only was obtained. The same holds true for Table S2 for 3 : 1 (WW : MA) and Table S3 for 3 : 2 (WW : MA). Finally, Table S4 indicates the daily and cumulative production of biogas for 21 days for each mix ratio. From Table S4, it is possible to compare that cumulative biogas is more produced in 3 : 2 (WW : MA) ratio. (*Supplementary Materials*)

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