Determination of Bio-methane Potential as Renewable Energy of Beverage Industrial Effluents at Mekelle, Ethiopia

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Abstract. Industrial Effluents are a major challenge to be treated and disposed of without contamination of water and soil. Soft drinks Industrial effluents are having alcoholic compounds which are toxic to aquatic life as well as the environment. In the past, the increasing demands for energy and impending climate change have driven the search for renewable energy sources. Diminishing supplies of fossil fuels and production of pollution are the major challenges with the continued usage of fossil fuels. This paper aimed to give an account of biogas production from beverage industrial effluents as well as effluent treatment for environment safety. Besides, the study helped to compare the capacity of mixed substrates and pure beverage industrial effluents to release methane gas. The anaerobic digestion removed 68.95%, 65.30% and 71.74% of BOD_5, TS and VS, respectively from beverage industrial effluents. Mixed substrates comparatively produced more methane than beverage industrial effluents. Beverage industrial effluent released 323.5 ml of bio-methane with cumulative CH_4 yield of 76.15 ml per gram of VS which was added into the reactor per working volume of 1.8 L. Soft drink industry can establish a biogas plant to fulfil the energy needs of the industry.

1 Introduction

Industrial effluents, with limited treatment, are discharged into the environment causing damage to the surrounding soil, water and environment resources as well as the spread of diseases to the humans and livestock in Ethiopia [1]. Beverage as well as molasses-based distillery industries consume large volumes of freshwater and generate a huge amount of waste water [2, 3]. The primary sources of pollutants at alcohol & distillery industries are the spillage, cooling water from the condenser, and wastewater from fermenter [3, 4]. Raw Spent Wash (RSW) coming out of the distillery industry and 12–15 times by volume of the product alcohol, is one of the most difficult wastes to be disposed of due to its acidic reaction, dark brown colour and high ash content [5, 6]. It is having an extremely high concentration of organic and inorganic pollutants in terms of biological oxygen demand (BOD), chemical oxygen demand (COD), total solids (TS), sulfate, phosphate, phenols and various toxic metals [7].

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The prime contaminant in soft drink industry (SDI) is mostly sucrose due to the preparation of concentrated syrups, which causes an increase in the concentration of organic substances expressed in terms of Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), sodium, nitrates and phosphates [8]. This wastewater has to be treated by a conventional method to save the soil, water and environment.

Bioconversion processes are one of the most attractive ways to find alternative sources of energy and control pollution from waste streams [9]. Moreover, biological processes for the treatment and recycling of wastewater are considered to be cheap and environmentally safe. Anaerobic digestion (AD), once considered as a strenuous process, has been now applied at the industrial scale [10]. In this context, biogas generated from alcohol and soft drink - based industrial wastewater will play a vital role in future. Biogas is a versatile renewable energy source, which can be used for substitution of fossil fuels. Methane-rich biogas can replace natural gas as a feedstock in the production of chemicals and materials [11]. Throughout the world, AD has become a major focus of interest in waste management. It is an environment-friendly process to produce energy in the form of biogas and manure as residue [1]. AD mitigates several other environmental problems like production of foul smell, the spread of pathogens and emission of greenhouse gases.

In this study two Bio-methane potential (Bmp) tests were conducted, The first Bmp test was conducted to measure methane yield of a mixed substrate (subs) (25%RSW+75% MSDIE; meaning thereby that 25% of the working volume was RSW & the remaining 75% was filled with MSDIE). The second Bmp test was conducted with pure MSDIE. The Bmp tests were conducted as laboratory-scale batch experiments using 2 L anaerobic reactors. Characteristics of Raw and Bmp test industrial effluents were analysed.

2 Methodology

Desta Alcohol and Liquor Industry (DALI) and Moha Soft Drink Industries (MSDI) are located at Qiha and Kedamay Weyane sub-cities of Mekelle city, respectively. DALI uses sugar cane molasses to produce ethanol for preparing the products like dry gin, denatured spirit, Vodka and processed alcohol. MSDI uses acidulants, stabilizers, preservatives, flavours, colourants (Sunset yellow, Caramel) and sugar to produce Mirinda Orange, Mirinda Tonic, Pepsi, 7Up and Sprite.

2.1 Sampling

Samples were collected from the outlet of DALI effluents (Raw spent wash (RSW)) as well as during fermentation of cane molasses. Samples from MSDI were collected from the outlet of the industrial effluents after screening. Since effluent generated from MSDI has different characteristics over time due to variation in product type, water consumption & operation type, samples were collected by grab time phase composite method. The samples were collected from DALI and MSDI two times for both trial-1 and trial-2 of Biomethane production (Bmp) tests and quality analysis to identify the bio-methane potential of these industrial effluents. To avoid any biochemical reaction, substrates were stored at 4 °C.

A Sampling of Moha Soft Drink Industrial Effluents (MSDIE), Trial-1 and Trial-2. The samples from MSDI were collected at four stages i.e. during production, rinsing of final syrup, mixing and cleaning Internal part (CIP). CIP has two sub-stages one having three steps and another four steps. Mirinda and Pepsi production is for 5 days and 2 days, respectively in a week. CIP will be every Sunday. The sample volume was dependent upon the volume of the effluent from different products and operations generated every day. The samples of MSDI were collected after 25 days of the first Bmp test for trial-2 like the first sampling (Table 1).

Inoculum Sampling. The inoculums used to inoculate the Bmp reactors were collected from a mesophilic anaerobic digester obtained from DALI which was used to treat effluents of the industry. The inoculum was collected at different heights of sampling points at 2 m, 4 m, 6 m, 8 m and 10 m from the ground. An equal volume of inoculum (200 ml) was taken at each height of sampling point and it was mixed into one sample holder. The inoculum was sieved during sampling using 2 mm size mesh. It was taken four times, first for first Bmp test of mixed substrates of MSDIE & RSW and pure MSDIE, the second for control tests of both Bmp tests of mixed substrates & pure MSDIE, the third for the second Bmp test of mixed substrates & pure MSDIE and fourth for control test for second tests of mixed substrate & pure MSDIE. Inoculums were stored at Bmp test temperature or at ambient Temperature for less than five days to keep them fresh [12]. Sample of inoculums was stored for one day and then analysed for Total Solids (TS) & Volatile Solids (VS) putting on water a bath at a process temperature of 36.5 °C.

2.2 Analysis of Raw, Bmp Test Effluent and Inoculum

Analysis of Basic Parameters. The collected samples of DALI, MSDI industries and inoculum were analyzed using CP – 505, ORION STAR A211 and HI 5522, USA P^H meters, respectively. The Physicochemical Sample analysis was undertaken by triple analysis. COD of all raw samples and effluents from the Bmp test were measured by using HI 839800 COD REACTOR & test tube heater 2008 series. COD values of the samples were measured with COD meter (AL200, COD Vario) after measuring the COD value of the blank sample. DO of the RSW was measured directly after sampling by using DO meter (HQ40d). DO was measured with triple analysis. BOD of all raw samples, inoculum & Bmp effluents including their control tests was analyzed two times for both trials in a triple manner. BOD_5 of the Bmp test effluent of all reactors which was filled with substrates & inoculum also measured after digestion.TS and VS are compulsory parameters for substrates (subs) as well as inoculum analysis. TS & VS was analyzed by Gravimetric method with Ovens BINDER D78532 Tuttlingen and Bahnhofstr 20, 28865 Lilienthal/Bremen, of Germany, respectively.

Analysis of Inoculum. pH & Temp of the sieved inoculum was measured at the industry laboratory. The DO, BOD_5, TS and VS of sieved inoculum was analysed using standard methods. Determination of VS of inoculum was important in Bmp test because it was helpful to fix the volume of the sample and the inoculum. The volume of inoculum used for all Bmp tests of all main and control experiments was calculated depending upon VS

Table 1. The volume of sample collected from various sources of MSDI, trial-1 & trial-2.

Operation type	Time (min)	Flow rate (m^3/h)	Discharge (m^3/d)	Sample vol. (ml)	Time (min)	Flow rate (m^3/h)	Discharge (m^3/d)	Sample Vol. (ml)
Mirinda production	–	–	585.15	2500	–	–	518.33	2500
Pepsi production	–	–	585.15	1000	–	–	518.33	500
7 up production	11.61 ± 2.38	14.06 ± 0.78	8.162	7.874	–	–	518.33	500
Rinsing of final syrup line, filler & mixer	–	–	3	2.894	11.25 ± 2.2	13.96 ± 0.74	18.328	17.680
Three steps CIP	–	–			–	–		
Caustic	23.75 ± 4.79	14.65 ± 0.53	0.828	0.799	26.67 ± 1.86	14.6 ± 0.44	0.927	1.788
Caustic rinse with cool water	6.5 ± 1	14.55 ± 0.41	0.225	0.434	5.33 ± 1.03	14.65 ± 0.4	0.186	0.359
Final rinse	11.25 ± 2.5	14.8 ± 0.43	0.396	0.765	11.67 ± 2.58	14.6 ± 0.44	0.406	0.782
Total			1.450	1.998			1.519	2.930
Five step CIP	–	–			–	–		
Caustic	29.5 ± 4.20	14.85 ± 0.47	1.043	1.006	27.5 ± 2.26	14.3 ± 0.68	0.936	1.806
Caustic rinse with warm water	25 ± 4.08	14.05 ± 0.99	0.836	0.807	26.5 ± 1.97	13.93 ± 0.84	0.879	1.696
Sanitize	56.25 ± 6.29	14.3 ± 0.81	1.915	1.847	53.33 ± 4.08	14.20 ± 0.82	1.803	3.479
Final rinsing	11.25 ± 2.50	13.65 ± 0.90	0.366	0.353	10.83 ± 2.04	13.83 ± 0.75	0.357	0.688
Total			4.160	4.013			3.975	7.67

of substrates and VS of inoculum. To know the performance of the anaerobic reactor, characteristics of the effluent from anaerobic digester was analyzed. This helped to know the per cent removal of TS, VS & BOD_5 of the raw effluent which was added to the reactor. Quality of Bmp effluent from mixed subs and per cent removal of the impurities was analyzed in terms of TS, VS & BOD_5. TS, VS & BOD_5 were analyzed like the raw effluent. Temp, P^H, Ash, DO & COD of the Bmp test effluents also analyzed like the raw industrial effluents.

Determination of Volume Inoculum for Bmp Test. To minimize acidification or inhibition problems the portion of VS from the inoculum should be greater than that from the subs; for easily degradable subs Inoculum and Substrates (I/S) ratio should be greater than or equal to four [12, 13].

2.3 Experimental Description

The Bmp tests were initialized to measure the methane potential of two different samples, one for mixed subs (25% RSW+75%MSDIE) with a working volume of 1.4 l and the second for pure MSDIE with a working volume of 1.8l. All Bmp tests including their control tests were conducted in duplicate. For main test trial-1 of mixed subs with total VS of 18.151 g, the volume of inoculum was 269.031 ml (VS = 16.867 g/l) and 283.175 ml of inoculum (VS = 17.86 g/l) was used for the second trial of mixed subs with total VS of 20.23 g. The volume of inoculum for the main test of MSDIE of trial-1 with total VS of 3.996 g was 59.228 ml (VS = 16.867 g/l) and 62.99 ml of inoculum (VS = 17.86 g/l) was used for the second trial of MSDIE with total VS of 4.5 g. The Original P^H of the mixed substrates before pouring into the reactor and mixing with an inoculum of main tests of trial-1 & trial-2 was kept at the neutrality range (7.0 to 7.8) suitable for methanogenic activity [14]. The original P^H was in the neutrality range (7.34 and 7.46, respectively). The original P^H of MSDIE was 8.27 & 8.61 and adjusted to working P^H of 7.38 & 7.32 of trial-1 & trial-2, respectively adjusted using 6M HCl & 2M NaOH.

Bmp Test Experimental Setup and Operation. The wastewater was first characterized according to the standard procedure before being poured into the digester. Bmp test was conducted in duplicate in batch operation using 2 L anaerobic reactors. Water-column based gas measuring method was applied. In particular, the method allowed produced methane passed as bubbles through 2M NaOH solution, that pushed the alkaline water level down in the column & the volume of displaced alkaline water was taken as the volume of biomethane. The Anaerobic batch digester was connected to a gas measuring cylinder. An 8 mm diameter L-shape glass tube used for gas flow was inserted into rubber stopper which was used to cover the opening of the reactor. The rubber stopper which was placed on the opening of gas measuring cylinder held two L-shape 8 mm glass tubes, one to receive gas from the reactor and other for flow of the displaced solution. A plastic tube was used to connect the glass tubes between the reactor & gas measuring cylinder.

To maintain the anaerobic condition, the oxygen present in the reactor was sucked by using a suction pump for a few minutes. To prevent the re-entry of the oxygen, rubber stoppers were placed immediately in the opening of the reactor & silicon gasket was applied to seal the rubber stopper. To obtain pure methane or to clean the biogas, the biogas produced from the anaerobic digestion (AD) of subs and inoculum was allowed to pass through the alkaline solution (2M NaOH) to absorb CO_2 using phenophetalin as an indicator. The gas measuring cylinder (inverted in the bucket) and the bucket were filled with a reddish colour alkaline solution.

After arranging the gas measuring set up, the reactor was submerged in a water bath (SY-2L4H WATER BATHS) maintaining the mesophilic temperature of 36.5 °C. To maintain the homogeneity of the subs or to maximize the contact between substrates and microorganisms, mixing should be applied in several ways: turning up and down once a day, using stirring magnet bar & using an external agitation system [14]. In this Bmp test manual up and downmixing was applied once in a day during each day of digestion. The water bath was filled with water periodically as and when its water level decreased. Biogas production was monitored for continuous 25 days (Fig. 1).

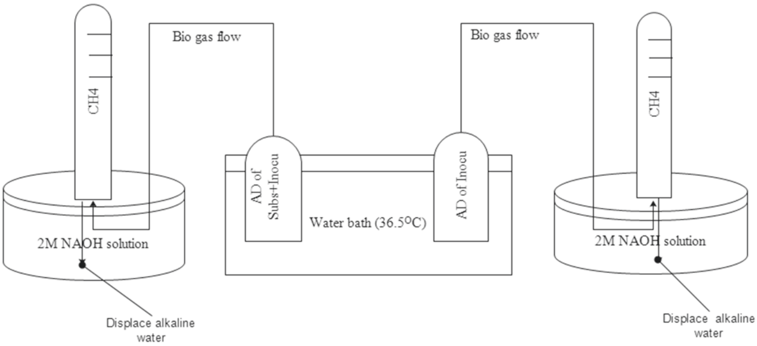

Fig. 1. Arrangement of Bio-methane production (Bmp) test

Conducting Control Test. The Bmp test for the control test was also conducted using similar volume (2 L) of the reactor, and due to equipment restriction it was conducted after the Bmp tests of the samples. The control test was conducted to measure the methane potential of the residual organic content present in the inoculum. The experimental setup and methane yield measurement were similar to that of the main experiment. The volatile solids (g) of the inoculum added to the control test of each sub was equal to the sample but the volume of inoculum was not equal due to inoculum characteristics varying with time. The volume of distilled water added for the control test was equal to the sample volume which was added to the main experiment. The control test trial-1 of mixed subs contained 18.15 g/L of VS, while the inoculum (308.69 ml) contained 14.70 g/L VS. The second trial of mixed subs contained 20.23 g/L of VS, while inoculums (237.08 ml) contained 21.33 g/l of VS. The control test trial-1 of pure MSDIE contained 3.99 g/L of VS, while the inoculum (67.959 ml) contained 14.70 g/L. The second trial of pure MSDIE contained 4.5 g/L of VS, while inoculums (52.736 ml) contained 21.33 g/l of VS. The P^H of the control tests was adjusted to neutrality range similar to that of the main experiment.

2.4 Process of Biogas Production

The process of AD occurs in a sequence of stages involving distinct types of bacteria [15]. That can be described by four key steps, i.e., hydrolysis, acidogenesis, acetogenesis and methanogenesis [16]. In the first step hydrolysis, involves the breakdown of large organic polymer like carbohydrates, proteins, and fats chains into smaller molecules such as simple sugars, amino acids and fatty acids by hydrolytic bacteria, in the second step Acidogenesis, fermentative bacteria utilize & convert products of hydrolysis to organic acids & alcohol. In the next step acetogenesis; acetogenins consume hydrogen gas & produce acetic acid, carbon and energy sources. Finally, methanogens utilize and convert the intermediate products of the preceding steps into biogas (CH_4 and CO_2) and trace gases [17].

2.5 Electricity Production from Biomethane Capacity

Based on the collected data concerning the kind and amount of waste from the FAB industry, the potential for methane production was calculated. The methane potential was determined as [18]

$$Q = \sum_{i=1}^{n} RiLi \tag{1}$$

Where, Q is the methane production potential in the industry (m^3 of CH_4/year), Ri is the amount of the i^{th} kind of waste generated in the industry (tonnes/year), and Li is the methane production efficiency from the i^{th} kind of waste in a given branch (m^3 of CH_4/tonne).

3 Results and Discussion

In this section quality parameters of the Raw and Bmp test effluents of industrial effluents & inoculum results are listed and discussed. The bio-methane produced from the mixed subs & pure MSDIE was presented graphically and quality improvement i.e. removal of the raw effluents was expressed in terms of TS, VS & BOD_5.

3.1 Characteristics of Raw and Bmp Test Effluents

Characteristics of RSW. The quality parameters of RSW having dark brown colour were characterized as very high in terms of BOD_5, COD, TS, VS, ASH, Temp and P^H (Table 2). The quality of RSW was comparable with the results of other studies [19–22]. The quality of RSW was very high compared to the quality of MSDIE.

Characteristics of Raw and Bmp Test Effluent of Mixed Substrates. The raw mixed substrates were characterized as medium to strong waste with 6470 m g/l of BOD5, 17100 mg/l of COD, P^H of 7.41 & VS of 13.71 g/l. The Bmp test effluent of mixed subs was characterized by medium strength with 2,185.32 mg/l of BOD_5, 10,100 mg/l of COD, P^H of 7.43 & 4.12 g/l of VS (Table 3).

Table 2. Characteristics of Raw effluent of RSW

Parameter	Before digestion
Temp (°C)	52.9 ± 0.28
P^H	4.2 ± 0.13
DO(mg/l)	2.00 ± 0.08
BOD_5(mg/l)	47,380 ± 1,456.61
COD(mg/l)	99,000 ± 4,242.64
TS(g/l)	76.43 ± 1.76
Ash(g/l)	28.67 ± 3.03
VS(g/l)	47.75 ± 2.98

Table 3. Characteristics of raw and Bmp test effluent of mixed substrates.

Parameter	Before digestion	After digestion
Temp (°C)	10.1 ± 0.17	33.58 ± 0.46
P^H	7.41 ± 0.08	7.43 ± 0.06
DO(mg/l)	6.88 ± 0.47	0.15 ± 0.01
BOD5(mg/l)	6,470 ± 14.14	2,185.32 ± 139.72
COD(mg/l)	17,100 ± 989.95	10,100 ± 424.26
TS(g/l)	21.48 ± 0.76	9.12 ± 0.70
Ash(g/l)	7.77 ± 1.00	5.00 ± 1.28
VS(g/l)	13.71 ± 0.84	4.12 ± 1.4

Characteristics of Raw and Bmp Test Effluent of Pure MSDIE. Pure MSDIE have medium quality with 40.9 mg/l of BOD_5, 502 mg/l of COD, 2.36 g/l of VS & P^H. A comparatively low P^H of 6.92 of MSDIE was measured during rinsing of syrup tanks, while a high P^H of 12.63 was measured during cleaning with caustic. Use of caustic soda for cleaning & effluent from raw water treatment (RO) may be a reason to increase the P^H and TS of MSDIE [21, 23]. The Bmp test effluent with 12.7 mg/l of BOD_5, 710 mg/l of COD, P^H of 7.43 & 0.67 g/l of VS (Table 4) was characterized as low strength effluent.

3.2 Bmp Test Results and Quality Improvements

During the Bmp test, all trials of both substrates including their control tests produced high methane volume on the first day of the digestion (Table 5). This indicated that the I/S which was used in all Bmp test prevented the initial buildup of materials, meaning thereby, that the volume of inoculum added to the reactors was enough to degrade the VS present in both substrates.

Table 4. Characteristics of raw & Bmp test effluent of MSDIE.

Parameter	Before digestion	After digestion
Temp (°C)	24.9 ± 0.17–55.13 ± 0.12	31.4 ± 1.37
P^H	6.92 ± 0.08–12.63 ± 0.00	7.43 ± 0.03
DO(mg/l)	5.16 ± 0.03–6.64 ± 0.08	0.180 ± 0.01
BOD_5(mg/l)	40.9 ± 1.83	12.70 ± 1.49
COD(mg/l)	502 ± 25.46	710 ± 14.14
TS(g/l)	3.17 ± 0.57	1.1 ± 0.30
Ash(g/l)	0.807 ± 0.63	0.433 ± 0.22
VS(g/l)	2.36 ± 0.41	0.667 ± 0.23

Table 5. Inoculum characteristics used for all Bmp tests

Parameter	Trial-1		Trial-2	
	For both subs	For control tests	For both subs	For control tests
Temp (°C)	22.93 ± 0.06	24.4 ± 0.20	23.3 ± 0.25	24.66 ± 0.11
P^H	7.81 ± 0.00	7.24 ± 0.01	7.71 ± 0.02	7.31 ± 0.17
TS(g/l)	38.53 ± 1.29	39.83 ± 1.40	48.57 ± 0.75	48.2 ± 2.23
VS(g/l)	16.87 ± 2.06	14.7 ± 1.49	17.86 ± 1.87	24.66 ± 2.42
DO	0.14 ± 0.01	0.13 ± 0.02	0.16 ± 0.01	0.15 ± 0.01
BOD_5	2033.3 ± 237.98	2070.00 ± 96.44	1876.67 ± 66.58	2273.33 ± 166.53

Bmp Test Results and Quality Improvements of Mixed Substrates. There was an improvement in the quality of effluent from mixed subs under Bmp test. There was a removal of 57.55% of TS, 69.93% of VS and 66.22% of BOD_5 of mixed subs during AD. The percentage removal of COD of mixed subs was lower than documented pieces of evidence elsewhere [7, 15, 24], this could be due to the residual COD of inoculums.

Bio-methane was produced from the main experiment & control test of both trials during the whole digestion time. Comparatively higher methane volume was measured during the second trial of Bmp test for both main experiment & control test. This was due to the higher organic content of subs in the second trial compared to the first trial [21, 24]. The degassing of inoculum will be 2–5 days at process temperature [25]. But during the Bmp tests of control and both substrates, bio-methane was produced for more than ten days of digestion. The decline in degassing of inoculums by two to five days should deplete the residual organic content, which is present in the inoculum. The total yield of bio-methane production was 260.07 ml per gram of VS for mixed substrates. The cumulative methane production after 25 days was 4991 ml (Table 6).

Table 6. Bmp test result of mixed subs and its control tests of both trials in ml of CH_4.

Time day	Trial-1			Trial-2			CH_4 product		CH_4 yield	
	Subs	Inocu	Net	Subs	Inocu	Net	Ave net	Cumu	Ave Net	Cumu
1	630	44	586	780	90	690	638	638	33.245	33.245
2	122	2	120	380	68	312	216	854	11.255	44.500
3	150	2	148	410	12	398	273	1127	14.225	58.725
4	220	44	176	330	26	304	240	1367	12.506	71.231
5	340	16	324	260	22	238	281	1648	14.642	85.874
6	280	14	266	250	10	240	253	1901	13.183	99.057
7	370	12	358	270	16	254	306	2207	15.945	115.002
8	220	6	214	355	12	343	278.5	2485.5	14.512	129.514
9	270	12	258	340	10	330	294	2779.5	15.320	144.834
10	300	10	290	265	14	251	270.5	3050	14.095	158.929
11	270	10	260	190	14	176	218	3268	11.359	170.288
12	250	10	240	110	12	98	169	3437	8.806	179.094
13	210	8	202	140	16	124	163	3600	8.494	187.588
14	190	10	180	215	14	201	190.5	3790.5	9.927	197.514
15	205	10	195	235	8	227	211	4001.5	10.995	208.509
16	190	4	186	155	2	153	169.5	4171	8.832	217.341
17	165	0	165	140	4	136	150.5	4321.5	7.842	225.184
18	145	0	145	110	10	100	122.5	4444	6.383	231.567
19	122	4	118	122	12	110	114	4558	5.940	237.507
20	98	20	78	126	10	116	97	4655	5.054	242.562
21	78	6	72	120	2	118	95	4750	4.950	247.512
22	64	4	60	82	0	82	71	4821	3.700	251.212
23	58	0	58	80	4	76	67	4888	3.491	254.703
24	46	0	46	76	4	72	59	4947	3.074	257.777
25	38	2	36	62	10	52	44	4991	2.293	260.070

The volume of methane produced during Bmp test of all substrates and their control tests is given in Figs. 2, 3, 4, 5, 6 and 7. The net gas produced in every day of Bmp test of a substrate was obtained by subtracting the CH_4 produced by inoculum. The average net CH_4 of subs was obtained for both trials (Fig. 2 and 3).

The yield of CH_4 was measured as the volume of CH_4 per gram of VS of the substrates and calculated by dividing total cumulative or average net methane volume of substrates by total gram of VS of the substrates present in Fig. 4. The cumulative CH_4 product of substrates was calculated by adding the average net CH_4 product in each day showed in Fig. 4.

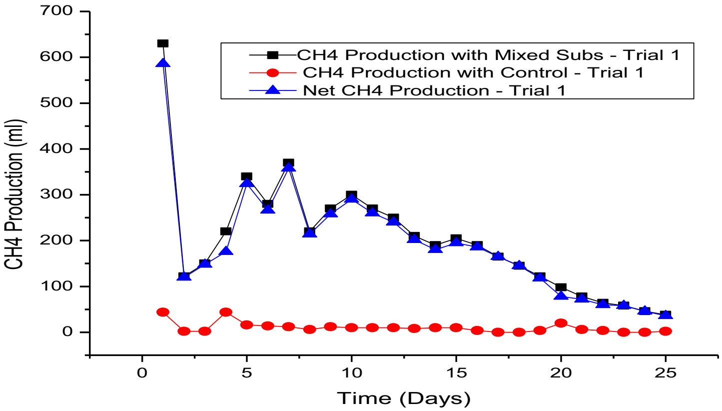

Fig. 2. CH_4 production (ml) of main experiment & control test of mixed subs vs. Time (day), trial-1

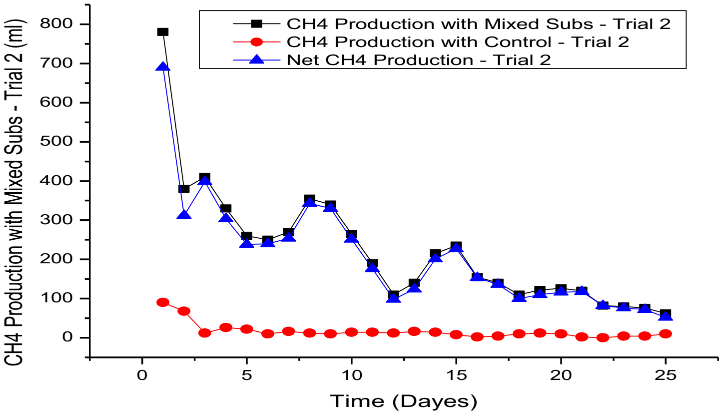

Fig. 3. CH_4 production (ml) of main experiment & control test of mixed subs vs. Time (day), trial-2

The cumulative methane production from mixed substrates was shown in Fig. 5. Methane production per gram of VS with time was shown in Fig. 5. The cumulative production of methane increased up to 25 days and after that, it was stopped the production.

Bmp Test Results and Quality Improvements of Pure MSDIE. There was an improvement in the quality of effluent from MSDIE under Bmp test. There was a removal of 65.27% of TS, 71.78% of VS and 68.95% of MSDIE during anaerobic digestion. The residual COD of inoculum might be the reason to increase the COD of Bmp test effluent. The percentage of impurity removal which was recorded during the Bmp test was comparable with other studies [26–28].

After 21 days of digestion, there was no bio-methane production from the main experiment, while methane production of control tests was stopped after the 10th day

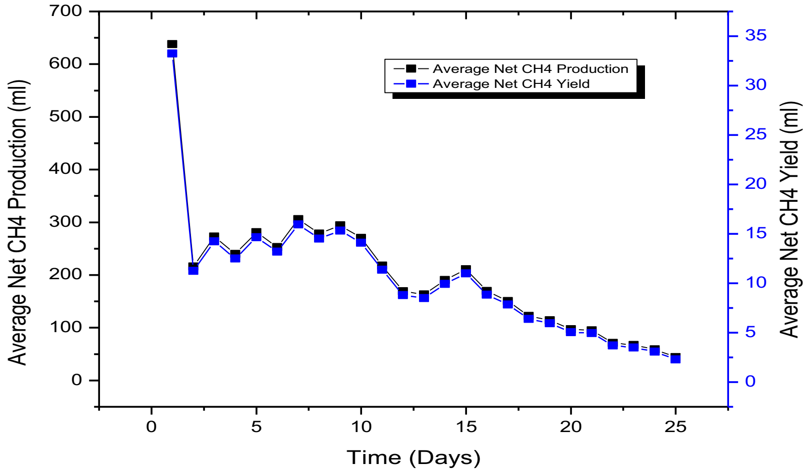

Fig. 4. Average net CH_4 production & CH_4 Yield of mixed subs vs. Time (day)

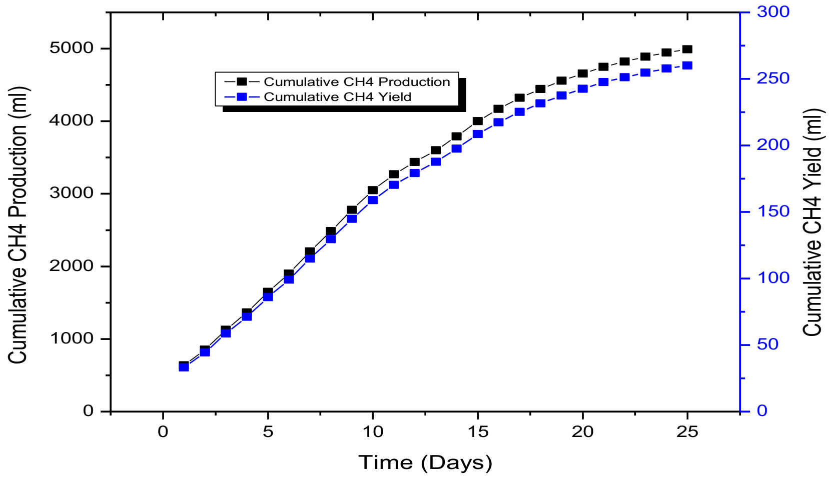

Fig. 5. Cumulative CH_4 production (ml) CH_4 yield (ml) of mixed subs vs. Time (day)

of digestion (Fig. 6). Comparatively higher methane volume was measured during the second trial of Bmp test for both main experiment & control test (Fig. 7). This was due to the higher organic content of subs in the second trial compared to the first trial [17, 26, 29]. The bio-methane yield was comparable with other results of Bmp test of MSDIE (Fig. 8). The cumulative bio-methane yield of MSDIE was 76.15 ml per gram of VS which was added at the startup of the digestion with a cumulative biomethane product of 323.5 ml (Fig. 9).

Electricity Production. In this research Moha soft drinks industry can establish the Anaerobic Digestion unit to produce biomethane which can convert into electricity to

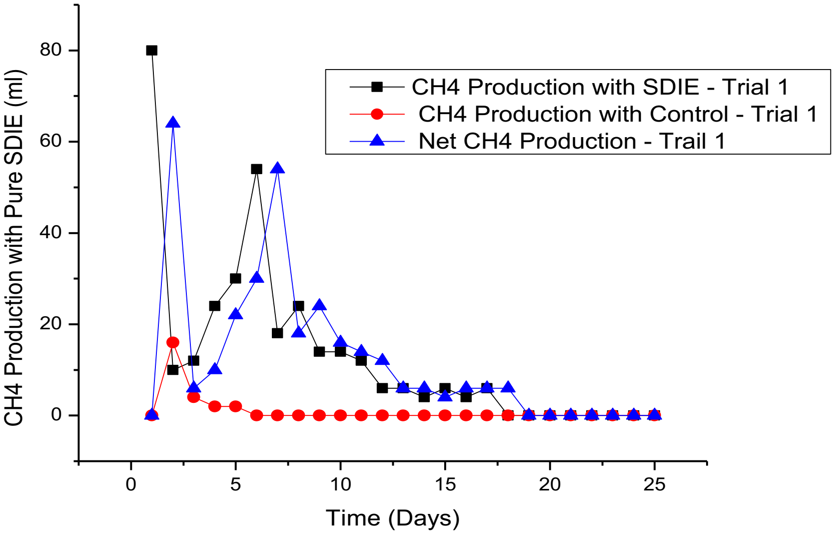

Fig. 6. CH_4 production (ml) of the main experiment of SDIE & its control test vs. Time (day), trial-1

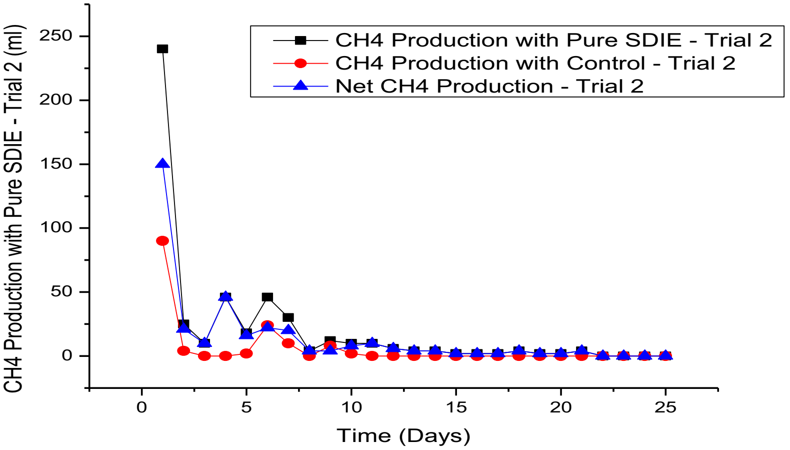

Fig. 7. CH_4 production (ml) of the main experiment of SDIE & its control test vs. Time (day), trial-2

fulfil the need of the industry. In this research used 2 L anaerobic digestion unit to produce methane, the highest cumulative production of biomethane after 25 days was 4991 ml means 4.991 kg or 4.991 m^3 of methane was produced. Theoretically (actual average) from 1 m^3 of biogas, 2.1 kWh electrical energy can be produced [18]. As per the records Moha soft drinks industry producing 17,000 cases of soft drinks per day and using 300000 L of water per day. The effluents might be approximately 283000 L per day. The production of biogas within a day will be 9408.335 m^3 (First-day methane

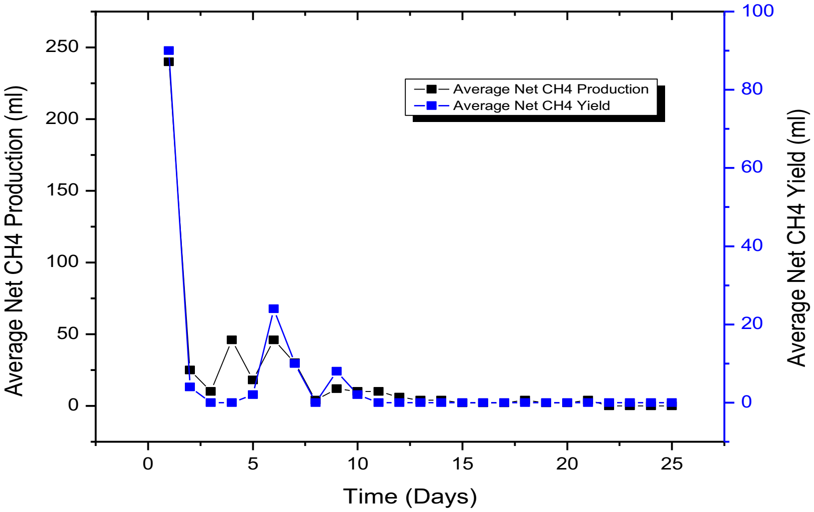

Fig. 8. Average net CH_4 production (ml) CH_4 yield of SDIE vs. Time (day)

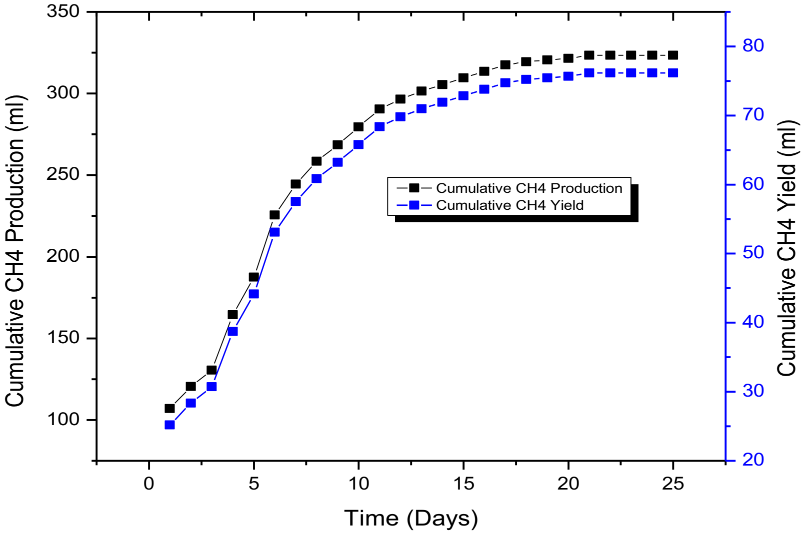

Fig. 9. Cumulative CH_4 productions (ml) & CH_4 yield (ml) of pure SDIE measured in ml of CH_4 vs. Time (day)

production was 33.245 ml). As per the Eq. 1, the electricity production capacity will be approximately 19757.50 kWh per day.

4 Conclusion

The parameters were measured during rinsing of syrup tanks & during washing of syrup tanks, filler & mixer using caustic soda respectively for Moha soft drinks industrial effluents. RSW was characterized as strong waste which was dark brown in colour. The Bmp test removed 57.55% of TS, 69.93% of VS and 66.22% of BOD_5 from mixed substrates and 65.27% of TS, 71.78% of VS & 68.95% of BOD_5 from MSDIE. The quality of Bmp effluent of MSDIE was within the standards of WHO to dispose of water bodies safely. The neutral range of pH was suitable for mesophilic activity was observed. Comparatively high bio-methane volume was produced from mixed substrates than MSDIE. The total yield of bio-methane production was 260.07 ml per gram of VS for mixed substrates. The cumulative methane production after 25 days was 4991 ml. The electricity production possibility from the effluents of Moha soft drinks industry will be 19757 kWh per day which can fulfil the energy needs of the industry.

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