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Biogas Production and Optimization from Leftover Food and Solid Kitchen Wastes

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Abstract: Food leftover and solid kitchen waste disposed on open land surface, consequences different problems like air pollution, human health problem, ground water pollution, disturbance of ecosystem etc. For this problem recovering leftover food and solid kitchen waste for biogas production is critical solution. Sustainable energy production is the current issue for non renewable energy crises. The quality biogas determined by factors (temperature, PH, retention time and substrates). The method that determines the quality and quantity of biogas: first Data (leftover food and solid kitchen waste) was collected, characterize, then the slurry solution where prepared. At pH of solution (slurry) adjusted 4.6 – 6.3, at the temperature of Mesophilic range 25 – 40°C). The biogas production procedure: Hydrolysis - Acidogenesis – Acetogenesis – Methanogenesis. the volumew of biogas and CH_4 maximization is the objective of this syudies. depending on experiental result output optimization model equation was developed using design expert, central composite method. In this experimental design With the retention time of 29 days, the quality is tested at an different alternatives. From the substrate source of leftover food and solid kitchen wastes, using experimental input, optimization result output from design expert: 63.3% CH_4, 27.9% CO_2, 0.316% O_2 and 3.35L biogas quality and quantity respectively produced, from 1.75L of proportional slurry substrate prepared, at temperature 26.1°C and pH 5.51.

Keywords: Biogas, Digester, Methane, Carbon Dioxide, Substrate, Temperature, Slurry, Quality, Optimization

1. Introduction

Sustainable energy production is the most current issues over the world wide, non renewable energy (petroleum, natural gas, fossil fuel and others) are depilated from time to time and going to eliminates [1]. In other ways the output consumption of the non renewable energy affects natural environmental ecosystem by releasing excess oxide to the environment [1]. Biogas is a combustible mixture of gases and an eco-friendly heating energy sources [2]. It consists mainly of methane (CH_4) and carbon dioxide (CO_2) and is formed from the anaerobic bacterial decomposition of organic compounds, in the absence of oxygen [3]. The gases formed are the waste products of the respiration of these decomposer microorganisms and the composition of the gases depends on the feedstock being decompose [4]. Substrate types also influences the product of biogas. If the substrate consists of mainly carbohydrates, such as glucose and other simple sugars and high-molecular compounds (polymers) such as cellulose and hemicelluloses, the methane production is low, However, if the fat content is high, the methane production is high. Methane and whatever additional hydrogen there may be makes up the combustible part of biogas [5]. Methane is a colorless and odorless gas with a boiling point of -162°C that burns with a blue flame [6]. Methane is also the main constituent (77-90%) of natural gas) [7]. Biogas is a renewable fuel, so it qualifies for sustainable energy subsidies in some parts of the world, Biogas can also be cleaned and upgraded to natural gas standards when it becomes bio methane [8]. Biogas consists of 55-70 CH_4, 30-45 CO_2, 0- 2% H_2S and may small amount trace element or compound [9]. At normal temperature and pressure, methane has a density of approximately 0.75 kg/m^3. Due to carbon dioxide is somewhat heavier, biogas has a slightly higher density (1.15kg/m^3). Pure methane has an average calorific value of ranged between 10.7 and 13.0 MJ/kg, which correspond to 11.06 kWh/m^3. If biogas is mixed with 10-20% air, you get explosive air, which as the name indicates is explosive. Biogas is about 20% lighter than air and has an ignition temperature in the range of 650°C to 750°C. It is odour less and color less gas that burns with clear blue flame. Its caloric value is 20 Mega Joules (MJ)/m^3 and burns with 60% efficiency in a conventional biogas stove [10].

2. Materials and Methods

2.1. Materials

Weight measuring instrument: to determine the weight of food waste and kitchen waste samples, Oven dryer base: to measure moisture content, Mixer cylinder, Miller: to make substrate homogeneous, pH meter: to check acidity, Anaerobic batch digester tank, Food & kitchen waste, Fresh cow dung used as inoculums, Mixing tank used to mix water and food & kitchen waste, Measuring cylinder, pipe, valve, sodium hydroxide, Gas collector or bellow.

2.2. Methods

The method was experimental laboratory result analysis and software programming optimization. The biogas quality was analyzed at every alternative factor by using biogas analyser. To produce high quality and high quantity of biogas: temperature, PH and retention time are the basic measurements (factors) [11]. First food and kitchen wastes were weighted using weight measuring instrument. Homogenise the wastes and dilute with proportional at dilution rate of 1: 1.5 with water [12]. Check the composition (C/N ratio is 25: 1 to 30: 1) [13]. The pH of solution (slurry) adjusted at standard production rate (pH 4.5 – 7), at the temperature of Mesophilic range 20 – 40°C) [14] The sample where first mixed with water and inoculums and completely stirred until homogenized. The prepared slurry input to an aerobic Digester tank (batch reactor), and kept them it there until reaction completed (residence time or hydraulic retention time 20 -40 days). In this parameter ranges biogas quality product estimates CH_4 50% - 75% and CO_2 is 25% - 45% [15] Collect top products or biogas to gas collector and measure appropriately. Collect sludge and water in bottom product by different stream in (figure 1).

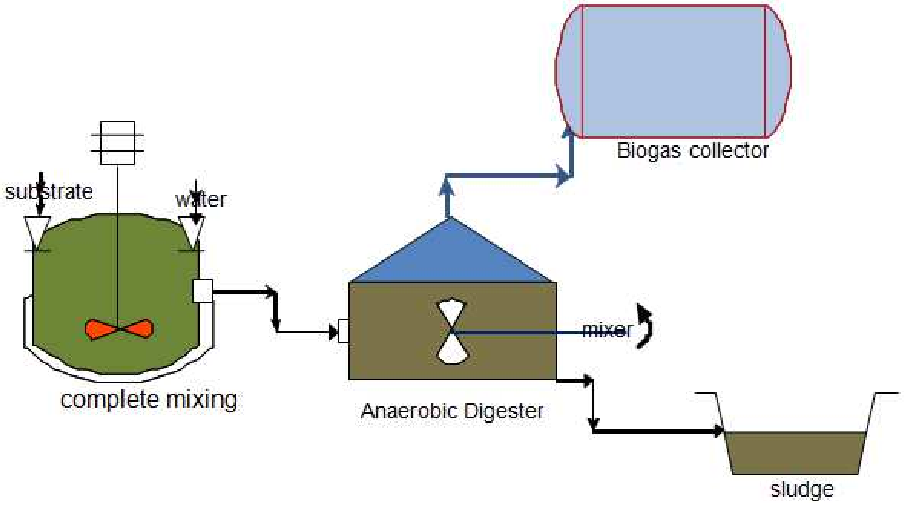


Figure 1. *Biogas production flow diagram.*

2.3. Experimental Procedures

Water bath is the automatic temperature controller machine by water. The water bath was adjusted at Mesophilic range (temperature of 40°C).

Substrate characterization: average of total substrate generation:

$$\frac{\text{total first data} + \text{totl second data colleted (kg)}}{2}$$

Protein determination:

$$\%\text{Crude protein} = \%N*6.25 \quad (1)$$

Equation (1) shows crude protein percent determination and constant 6.25 factor rates that multiplied by nitrogen atom in nutrition [16].

Fat determination:

$$\%\text{ Crude fat} = (W_2 - W_1)*100/S \quad (2)$$

W2 = weight of extraction flask after extraction
W1 = weight of extraction flask before extraction
S = weight of sample used for extraction

In equation (2) the crude fat is determined by extraction and balancing on the extraction unit operation [17].

Carbohydrate determination:

$$(\%)\text{ Carbohydrate} = [100 - (\%P + \%F + \%A + \%M)] \quad (3)$$

Where P =% protein; F =% fat; A =% ash and M =% moisture content [18]

Carbohydrate contents also determine using equation 3, and also shows protein, ash, fat and moisture content affects the amount of carbohydrate.

Ash contents:

After burning the sample at 650°C for 6 hours in furnace

$$M_d - M_v = M_a \quad (4)$$

Where Md = mass of dried sample

Mv = mass of volatile mater

M_a = mass of ash

$$\% \text{ ash} = \frac{\text{weight of ash left}}{\text{weight of sample}} * 100 \quad (5)$$

In equation (5) the ash content determination using furnace [19].

C: N ratio also calculated using the following mathematical formula

$$\text{C: N ratio} = \frac{\text{Mass of total organic carbon}}{\text{Mass of total kjeldahl Nitrogen}} \quad (6)$$

C =%fat* No C* mass of C +%protein* No C* mass of C +%carbohydrate* No C* mass of C

N =%p*No N*mass

1. Two plastic bottle digesters with two liters each were prepared.
2. 3.1 liter of Gas collectors (balloons) for each and gas pipe were prepared.
3. 3.5 liter of substrate with proportional inoculums was prepared and 1.75 L substrate was filled for each plastic bottle digester. And 0.25L of the digester volume was free for each. It is continue prepared and adjusted up to iteration completed.
4. The empty balloons were connected the free space top digester by gas pipe.
5. The water bath was filled by water and set adjustment of the temperature at (25 – 35)℃
6. The digesters were inserted in to water bath. And keep up to retention time were completed.
7. The volume of biogas produced was measured at each interval of two days. By insert gas collector in cylindrical water container and the amount of water displace is equal with the amount of gas in the gas collector.
8. For adjustment of pH the same buffer solution of Na (OH) were used in the interval of two days, the buffer solution droplets depends on concentration and volume of digester per 2 days for continuously 29 days and droplet of per 2 days for the rest interval days.

3. Result and Discussion

3.1. Experimental Data Collection

Data (leftover food and solid kitchen waste) was collected for two weeks continuously.

The data collected and measured with weight measuring balance, to know the total leftover food and solid kitchen wastes generated from JiT, and also meal profile index determined by percent (figures 2 – 4, Tables 1 – 4).

a b

Figure 2. Leftover food from student dining hall; (a, shows leftover food in garbage. b, shows leftover daily measuring).

Table 1. First data collected (leftover food at first data colleting).

Date	Leftover food	Total leftover food in kg	Total leftover food in kg /day
	Breakfast: rise with bread	120	
Monday	Lunch: shero wot by enjera	320	870
	Dinner: cheese bee by enjera	430	
	Breakfast: rise	121	
Tuesday	Lunch: cheese bee wot by enjera	306	934
	Dinner: meat wot by enjera	507	
	Breakfast: kinche	140	
Wednesday	Lunch: cheese bee wot by enjera	316	776
	Dinner: cheese bee wot by enjera	320	
	Breakfast: enjera firfir	97	
Thursday	Lunch: potato with meat by enjera	382	834
	Dinner: cheese bee wot by enjera	355	
	Breakfast: rise by bread	152	
Friday	Lunch: cheese bee wot by enjera	323	848
	Dinner: cheese bee wot by enjera	373	
	Breakfast: rise by bread	134	
Saturday	Lunch: shiro with vegetable by enjera	377	958
	Dinner: meat wot by enjera	447	
	Breakfast; enjera firfir	109	
Sunday	Lunch: cheese bee wot by enjera	244	643
	Dinner: potato with meat wot by enjera	290	
In week	Total leftover food		5863
In Year	Total leftover food in ten months		10*4*5863 = 234520

Table 2. *Second data collection (second measuring for accuracy).*

Date	Leftover food	Total leftover food in kg	Total leftover food in kg /day
	Breakfast: rise with bread	125	
Monday	Lunch: shero wot by enjera	325	875
	Dinner: cheese bee by enjera	425	
	Breakfast: rise	125	
Tuesday	Lunch: cheese bee wot by enjera	310	945
	Dinner: meat wot by enjera	510	
	Breakfast: kinche	144	
Wednesday	Lunch: cheese bee wot by enjera	320	779
	Dinner: cheese bee wot by enjera	315	
	Breakfast: enjera firfir	98	
Thursday	Lunch: potato with meat by enjera	388	836
	Dinner: cheese bee wot by enjera	350	
	Breakfast: rise by bread	150	
Friday	Lunch: cheese bee wot by enjera	325	835
	Dinner: cheese bee wot by enjera	360	
	Breakfast: rise by bread	140	
Saturday	Lunch: shiro with vegetable by enjera	370	960
	Dinner: meat wot by enjera	450	
	Breakfast; enjera firfir	120	
Sunday	Lunch: cheese bee wot by enjera	240	660
	Dinner: potato with meat wot by enjera	300	
In week	Total leftover food		5890
In Year	Total leftover food in ten months		10*4*5890 = 235600

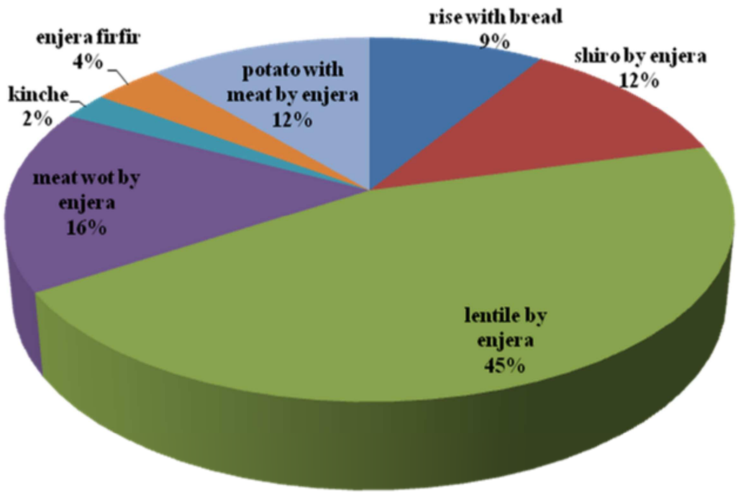


Figure 3. *Chart of leftover food composition (Is shows that the student meal profile in jimma university).*

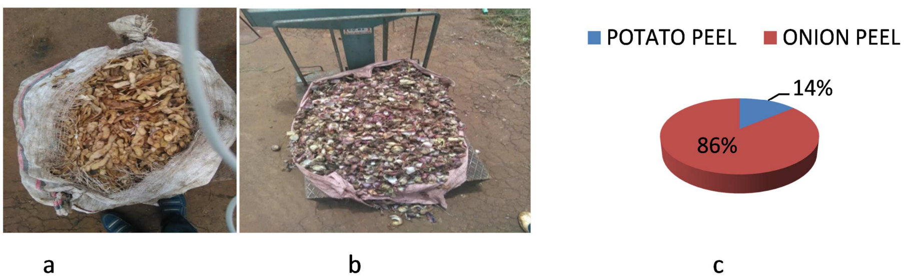


Figure 4. *Solid kitchen waste measuring (a, shows the potato peel and b, is the onion peels and they are the basic solid kitchen waste constituents, c, indicates that the percent representation of the basic kitchen wastes).*

Table 3. *First data collected solid kitchen wastes.*

Date	Kitchen food type	Total kitchen waste in kg	Total kitchen waste in kg /day
Monday	Breakfast: onion peel	21	108
	Lunch: onion peel	42	
	Dinner: onion peel	45	
Tuesday	Breakfast: onion peel	22	133
	Lunch: onion peel	44	
	Dinner: onion peel	67	
Wednesday	Breakfast: onion peel	30	150
	Lunch: onion peel	50	
	Dinner: onion peel	70	
Thursday	Breakfast: onion peel	29	138 onion peel And 80 potato peel
	Potato peel for lauch	80	
	Lunch: onion peel	67	
	Dinner: onion peel	42	
Friday	Breakfast: onion peel	24	153
	Lunch: onion peel	74	
	Dinner: onion peel	55	
Saturday	Breakfast: onion peel	34	183
	Lunch: onion peel	76	
	Dinner: onion peel	73	
Sunday	Breakfast: onion peel	32	175 onion peel And 95 potato peel
	Launch: onion peel	74	
	Potato peel for dinner	95	
	Dinner: onion peel	69	
In week	Total kitchen waste over		1215
I year	Total kitchen waste over		10*4*1215=48600

Table 4. *Second solid kitchen wastes data collected (second data measuring for accuracy).*

Date	Kitchen food type	Total kitchen waste in kg	Total kitchen waste in kg /day
Monday	Breakfast: red onion	22	119
	Lunch: red onion	47	
	Dinner: red onion	50	
Tuesday	Breakfast: red onion	20	130
	Lunch: red onion	40	
	Dinner: red onion	70	
Wednesday	Breakfast: red onion	35	159
	Lunch: red onion	55	
	Dinner: red onion	69	
Thursday	Breakfast: red onion	25	136 onion peel And 75 potato peel
	Potato peel for lauch	75	
	Lunch: red onion	63	
	Dinner: red onion	48	
Friday	Breakfast: red onion	28	161
	Lunch: red onion	66	
	Dinner: red onion	67	
Saturday	Breakfast: red onion	33	183
	Lunch: red onion	70	
	Dinner: red onion	65	
Sunday	Breakfast: red onion	35	188 onion peel And 96 potato peel
	Lunch: red onion	78	
	Potato peel for dinner	96	
	Dinner: red onion	75	
In week	Total kitchen waste over		1247
I year	Total kitchen waste over		10*4*1247=49880

Figure 2 Leftover food from student dining hall; (a, shows leftover food in garbage. b, shows leftover daily measuring). Average two weeks leftover food data 5876.5kg/week. 5876.5kg amount of leftover food can be disposed per week on the open land surface that causes the problem of environmental pollution. Average two weeks solid kitchen waste data 1231kg/week. 1231kg amount of solid kitchen waste can be disposed per week on open land surface that causes environmental pollution. The total leftover food and solid kitchen waste in week was 7107.5kg/week

From proximate and ultimate analysis of solid kitchen waste and leftover food for determination of fat, protein, carbohydrate, ash and C/N ratio

Ash: After burning at 650℃ for 6huors in furnace, from 15.72g of solid the ash is only 1.729g, and ash% was 11.6%

By nutritional analysis; Where F is fat, P is protein, A is ash, and M is moisture content of dry base:- F = 7%, P = 15.625%, A = 11.6%, M = 4.5%,%carbohydrate = 60.27%

In this experimental determination of nutritional analysis carbohydrate highest component when compared with other nutritional component, protein is the highest next to the carbohydrate. Therefore the substrate experimental results, high carbohydrate contents so faster consumed during anaerobic fermentation (figure 5).

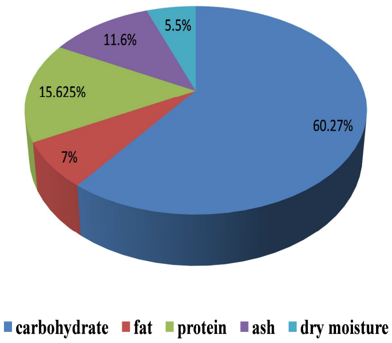


Figure 5. *Substrate percent composition which shows that mixed of kitchen and leftover food, by nutrients and proximate analysis.*

Table 5. *Basic nutrients composition and chemical formula.*

Substrate	chemical composition
Fat	$C_{15}H_{31}COOH$
Protein	C_4H_6ON
Carbohydrate	$C_6H_{12}O_6$

Total mass of carbon in the sample depending molecular formula of nutrients in (table 5):

C = 64.33g/mol and N = 2.1875g/mol, the C/N ratio was 29.4. So it was in the range of allowable ratio (21: 1 – 30: 1 is the result of experimental work and is less when compare with the previous work C: N is 31.65 [15]

3.2. Parameter Adjusted and Result Outcomes Digester

The food and kitchen wastes were weighted using weight measuring instrument. Homogenised the wastes and diluted with proportional at dilution rate of 1: 1.5 with water. Checked the composition (C/N ratio is 20: 1 to 30: 1) [13]. The calculated from experiment is 29.4, which is in the standard range [20]. The pH of solution (slurry) adjusted at standard production (pH 4.5 - 7, at the temperature of Mesophilic range (25 – 40℃). Input prepared substrate into an aerobic Digester tank (batch reactor), and kept it until reaction time completed (residence time or hydraulic retention time 20 - 30 days), it was 29days. From Experimental results, collect top products or biogas to gas collector and measure appropriately (figure 6: d, e, f and g). 3.3L of biogas where collected from each 1.5L substrate in parallel digesters though 29 days (table 6 and figure 8a).

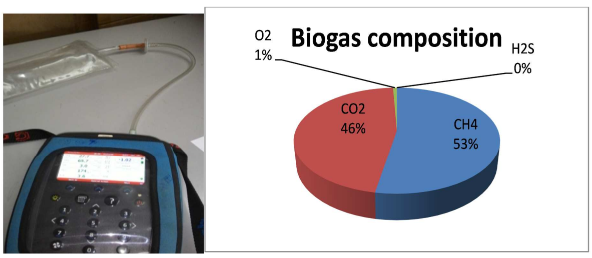
a b c d e f g

Figure 6. *Over all procedure of experimental production.*

(a, sample measurement, b sample homogenize with proportional dilution rate, c, digester setup with buffering, d, gas production at the end of 7days, e, gas production at the end of 14days, f, gas production at the end of 21 days, g, gas production at the end of 29days).

Table 6. *Gas production rate with the detention time of Mesophilic range.*

Average Gas (l)	0	0.4	0.75	1.4	1.75	2.1	2.55	2.8	2.95	3.0	3.07	3.32
Time (days)	1	3	5	7	9	11	13	15	17	19	21	29



a b

Figure 7. Gas composition analysis,(a, Portable biogas analyzer to detect and analyze hazardous concentrations of biogas, b, average percent composition of biogas gas).

3.3. Gas Composition Analysed

The biogas quality was analyzed by biogas analyzer. The biogas quality was depends on the gas components [21]. If the composition of methane is maximum biogas considered as high quality because of flammability and combustibility of biogas depends on methane composition [22].

The result also analyzed using biogas analyzer in each term and run, as shown in figure 7 which gives the gas composition listed in.

From the table 7 we have seen that three factor changing and minimum two repetitions, the output results also change accordingly. Depending on the factor changing and result output, there was model development for optimization using design expert, central composite method.

Table 7. *Experimental biogas analysis iterations and results.*

Runs	Temp. (°C)	pH	Time (day)	CH_4 (%)	CO_2 (%)	O_2 (%)	Volume (l)
1	35.0	5.5	21	55.7	40	0.5	3
2	25.0	6	7	37	60	1.2	1
3	25.0	5	7	32	62	1	1
4	35.0	5.5	21	59	42	0.57	3
5	35.0	5.5	21	58	43	0.56	3
6	30.0	5	14	52	43	0.65	2
7	30.0	5	14	50	43	0.7	2
8	34.0	5.5	21	57	38	0.65	3
9	37.0	6.3	29	62	35	0.34	3.3
10	30.0	6.3	14	54	43	0.6	2
11	25.0	5	29	61	38	0.45	3.3
12	25.0	6.3	7	35	61	1.4	1
13	30.0	4.6	21	54	30	0.67	3
14	40.0	5.5	7	38	60	1.3	1
15	30.0	6	21	59	32	0.7	3
16	40.0	6.3	29	61	28	0.45	3.3
17	25.0	4.6	14	50	48	0.56	2
18	40.0	4.6	29	63	28	0.4	3.3

From the experimental result table 8 shows the biogas quality increases with in retention time increases (figure 8 b). And also there were decreasing of CO_2 and O_2 production through the retention time (figure 8 c, d).

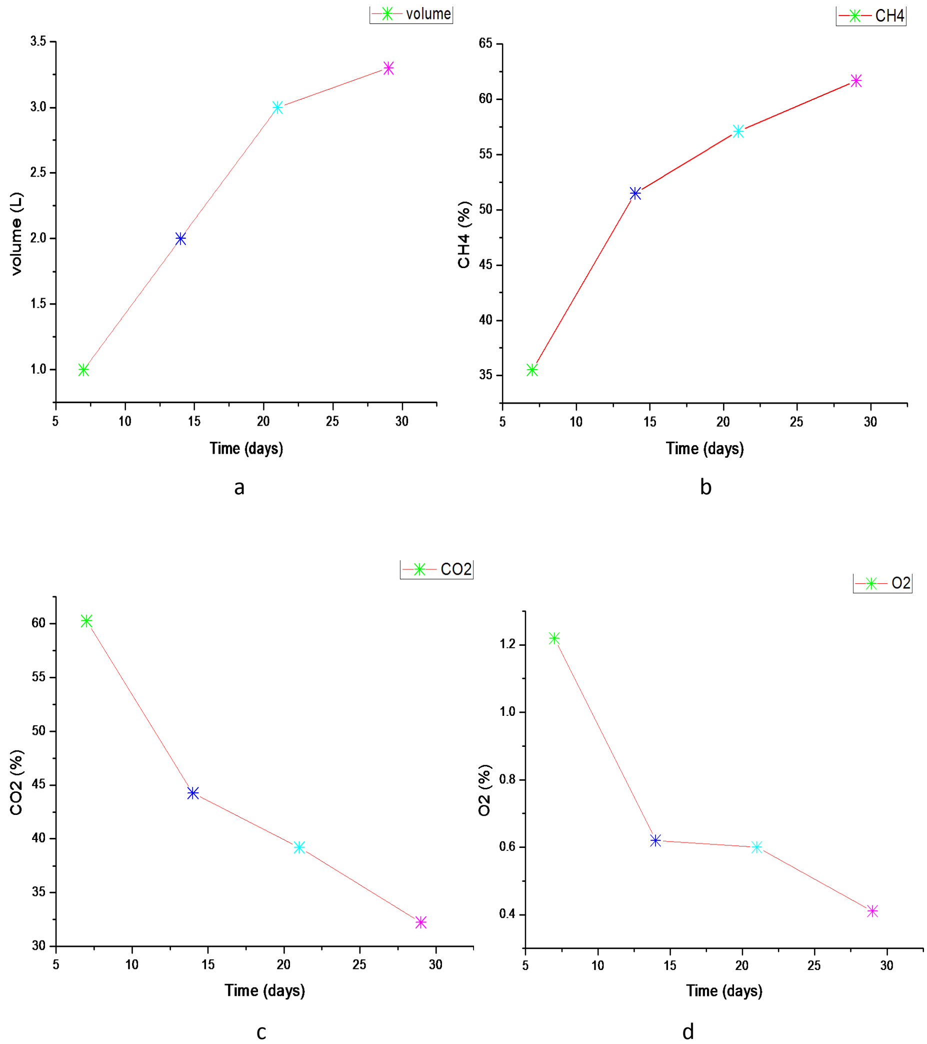


Figure 8. *Biogas quantity and quality determination with time (days). (a, shows the volume of biogas with time (L) generated in the interval of days; b, methane content increment in biogas generation c, d, CO_2 and O_2 decrement in biogas with volume and methane increment).*

Table 8. *Average gas product quality analysis in reactor.*

Time (days)	Gas volume (l)	pH	Temp (°C)	CH_4 (%)	CO_2 (%)	O_2 (%)	H_2S (%)
7	1	5.7	28.75	35.5	62.75	1.22	0.00002
14	2	5.23	28.75	52.5	46.25	0.63	0.00003
21	3	5.2	33.2	59.12	39.5	0.6	0.00056
29	3.3	4.8	35.5	62.75	36.25	0.41	0.00019
Average	2.325	5.23	31.55	52.5	46.2	0.71	0.0002

From table 9 there were analysis of constraints according to the targets and goals. In the ranges of variables or factors there were maximum and minimum result output values using Optimization methane by design expert software central composite method

Table 9. *Constraints.*

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Temperature	in range	25.0	40.0	1.00	1.00	3
pH	in range	4.6	6.3	1.00	1.00	3
Time	In rang	7.00	29.0	1.00	1.00	3
CH_4	Maximize	32	63	1.00	1.00	3
CO_2	Minimize	28	62	1.00	1.00	3
O_2	Minimize	0.34	1.4	1.00	1.00	3
Volume	Maximize	1	3.3	1.00	1.00	3

The target where maximizing CH_4 and volume, minimizing CO_2, O_2, by balancing these output values, the order of 10 alternative solutions desirability listed in table 10.

Table 10. *Solutions.*

Number	Temperature	pH	Time	CH_4	CO_2	O_2	Volume	Desirability	Suggest
1	26.1	5.51	29.0	63.3	27.9	0.316	3.35	1.00	Selected
2	25.9	5.57	29.0	64.2	28.0	0.319	3.34	1.00	
3	25.0	5.58	29.0	65.4	28.0	0.316	3.32	1.00	
4	25.2	5.41	28.9	63.5	27.8	0.305	3.34	1.00	
5	25.0	5.34	28.8	63.2	27.9	0.305	3.34	1.00	
6	25.1	5.34	28.8	63.1	27.9	0.305	3.34	1.00	
7	26.0	5.46	29.0	63.0	27.8	0.311	3.35	1.00	
8	40.0	4.60	28.3	62.8	28.0	0.312	3.31	0.998	
9	25.0	5.30	28.3	63.0	28.5	0.319	3.33	0.996	
10	40.0	5.10	29.0	60.5	27.9	0.330	3.43	0.979	

Number of Starting Points 10

Temperature	pH	Time
28.9	5.72	20.5
29.9	6.24	24.7
28.9	5.80	10.8
27.1	5.16	15.2
29.7	4.74	8.10
35.4	5.50	28.3
33.6	5.00	20.5
31.5	5.40	13.9
25.2	5.40	11.9
35.6	5.06	13.8

Final Equation in Terms of Coded Factors:

$$\text{volume} = 2.68 + 0.0160 * A + 0.0306 * B + 1.20* C - 0.0187* A^2 - 0.120* B^2 - 0.469* C^2 + 0.0365* A * B + 0.0386 * A * C - 0.0753* B * C \quad (7)$$

Equation (7) is model equation, that determination biogas volume using design expert central composite method coded factor.

Final Equation in Terms of Actual Factors:

$$\text{Volume} = - 5.59 - 0.0158* \text{temperature} + 1.80* pH + 0.278* \text{Time} - 0.000333*\text{temperature}^2 - 0.166* pH^2 - 0.00388* \text{Time}^2 + 0.00572* \text{temperature} * pH + 0.000468* \text{temperature} * \text{Time} - 0.00805 * pH * \text{Time} \quad (8)$$

Equation (8) is model equation, that determination biogas volume using design expert central composite method actual factor.

Final Equation in Terms of Coded Factors:

$$CH_4 = 54.6 + 0.285* A + 0.791* B + 13.0* C + 3.95 * A^2 + 1.71* B^2 - 9.43 * C^2 - 4.26 * A * B - 2.32* A * C + 3.10 * B * C \quad (9)$$

Equation (9) is model equation, that determination methane content of biogas using design expert central composite method coded factor

Final Equation in Terms of Actual Factors:

$$CH_4 = 43.9 - 0.378 * temperature - 9.09 * pH + 3.10 * Time + 0.0702 * temperature^2 + 2.3 * pH^2 - 0.0780 * Time^2 - 0.668 * temperature * pH - 0.0282* temperature * Time + 0.332* pH * Time \quad (10)$$

Equation (10) is model equation, that determination methane content of biogas using design expert central composite method actual factor.

According to the date analysis by design expert software, central composite method, the design model equation generates with respect to factors, thus equation (10) is optimum operation design equation.

Increasing the quantity of methane increases heat value of biogas [23]. In other way increase quantities of carbon dioxide in biogas, decrease heat value of biogas [24]. Average value methane (50 – 70%) and carbon dioxide (25 – 45%) [25]. From the experimental result the biogas quality increases with in retention time increases. From experimental result of biogas productions, the quality of biogas analysed by the machine of biogas analysers, reads the compound in biogas products on the screen. A CH_4 component increases from 35.5 to 62.75% from 7 to 29 days, in average 52.5% CH_4 though digesters. CO_2 gas decreases from 63 to 32.25% from 7 to 29 days, in average 43.7% and there is no significance O_2 that is 0.71% in average and 20ppm of H_2S through digesters (table 8 and figure 7b).

In the alternative solution optimization CH_4 ranges from 60.5% to 65.4%, CO_2 27.8 to 28%, at temperature range 25 to 40℃, pH 4.6 ton 5.58, time range 28 to 29 days. They methane phase takes place after 36th days, CH_4 and CO_2 production was stabilized with proportions respectively between 57% and 32 - 42% [15]. The gap shows that the raw material difference the municipal solid waste and food wastes which physical and chemical properties of raw material is one of factor that affects the quality of biogas production.

The low biogas quality was resulted from this experimental biogas production. Two measure assumptions that affect biogas quality in this experimental design.

The first free space left of in each digester: at the free space of digester actually occupied by atmospheric gases that more oxygen presence in, where the oxygen presence in the substrate, the reaction becomes aerobic digestion, resulting aerobic fermentative produces carbon dioxide and alcohol at the first around 7days. More amount of carbon dioxide was produced until the oxygen in free digester is completely consumed. In high percent amount of methane was produced after the oxygen in the free space of digester completely consumed.

Substrate type: the majority or almost all the substrate type was carbohydrate even if kitchen waste were mixed with leftover food, high amount of carbohydrate were exists. But the production rate was fast considering the other type of food waste.

The quality of biogas production depends on the substrate type. Highest amount of methane composition produced in biogas, if the substrate composition highest in lipid compared with protein and carbohydrate. And protein is the second for the biogas quality production next to lipid but it takes a time to degraded compared to other [26].

Therefore depending on the experimental biogas production design, two justifications could adjust the biogas quality production.

Remove the air from free space of digester and create vacuum, the reaction starts anaerobic fermentative.

Collecting biogas production after 6days started production, the major components of biogas before 6days were carbon dioxide.

4. Conclusion

Leftover food and solid kitchen waste is the major component of organic municipal solid waste that cause environmental pollution. For this pollution, anaerobic digestion results biogas and natural fertilizer is the way of the waste management and sustainable development. The total mixed leftover food and solid kitchen waste collected 7107.5kg per week contains 60.27% carbohydrate 15.625% protein and 7% fat. From experimental biogas production and optimization, 3.3L biogas produced from 1.75L substrate prepared with low biogas quality which contains about 52% methane, 46% of carbon dioxide and the others are trace compounds. The biogas quality was depends on the gas components. If the composition of methane is maximum biogas considered as high quality because of flammability and combustibility of biogas depends on methane composition. And also the quality parameter determination is one of biogas optimization; from software analysis the quality model equation formulated and became optimized. Depending on the current condition (range of temperature, Ph, and retention time) model equations of optimization were developed for gas volume and CH_4% using design expert software central composite method. The low quality of biogas resulted from experimental and software analysis were formulated from two assumptions (substrate type and free space that leaves in each digesters) in substrate characterization low volatile mater, and this resulted low fat component and C/N ratio 29.4: 1, maximum C/N ratio 30: 1. From the experimental result C/N ratio was high which shows high Carbon content and low Nitrogen content in sample. It suggested that extremely increment of C/N ratio results low CH_4%. The second suggested of the result of low quality of biogas was leaving free space in digester which oxygen presence, if there, the reaction become aerobic rather than anaerobic resulted more CO_2 rather than CH_4. And also the volume of biogas maximized formed using model analysis.

5. Recommendation

Depending on the output result and constraints it recommended that temperature, pH and detention time are the main factors that determine the quality as well as the quantity of biogas production in addition to substrate constituents. According the experimental output and model development, it is critical experimental results and is good optimization model for specified substrate. And it is better to use this model equation for large biogas production in such substrate types.

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