Optimum Co-digestion Conditions for Methane Production from Chicken Manure and Napier Grass by Single Stage Digestion

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Abstract
The purpose of this research was to examine optimum co-digestion conditions for methane production from inoculums, chicken manure and Napier grass by single stage digestion. Combined Mixture Process Design was used to determine the optimum methane production. The experiment consist of different level of factors which were temperature, inoculums, chicken manure and Napier grass with fermentation volume of 100 ml in glass bottle, hydraulic retention time (HRT) of 28 days, and total solids (TS) of 1.5%. The results showed that the optimum condition yielded biogas volume of 101 ml and methane of 73.6% when the temperature was controlled at 49 ^{o}C and ratios of inoculums : chicken manure : Napier grass was 46 : 3 : 52 of %TS. The experiment result was validated the optimum methane production by five confirmation experiments which their results were closely agreed with the theoretically predicted value.

Keywords: Methane production, Co-digestion, Chicken manure, Napier grass, Combined Mixture Process Design

Introduction

Energy is one of the factors that affect to human living in household to the global level. As energy consumption trends to increase steadily, in some countries are experiencing energy shortage and importing energy from other countries. Renewable energy i.e., biogas, wind power, hydro power is promising an alternative energy. Biogas energy is a waste-to-energy technology as a consequence; it is an interesting clean energy. Single material of organic waste fermentation e.g., food waste, crop waste, cow dung, livestock manure is a conventional fermentation but its characteristic of each material is inappropriate for methane fermentation. Organic waste which has carbon to nitrogen (C/N) ratio of 20-30:1 is a suggestion proportion for biogas fermentation because it is an ideal proportion for methane former bacteria growth. In general, crop waste which has high fiber show a high C/N ration while livestock manure show a low C/N ration. There is a report of chicken manure and Napier grass C/N rations which are 7.6 and 43.6, respectively [1]. As a consequence, it is possible to achieve high methane production yield by co-digestion of two different organic materials. The objective of this study was to find out an optimum co-digestion condition for methane production from two organic materials i.e., chicken manure and Napier grass. Besides the C/N ratio, there are other factors that contribute to methane yield i.e., pH, alkalinity, temperature, volatile organic acid (VOC), hydraulic retention time (HRT), and agitation. When an experiment deals with many factors: Design and Analysis of Experiment (DOE) is an effective technique to determine optimum conditions and the technique was used in this study.

Experimental Study

Materials Characterization

- Inoculums: seed sludge from biogas fermentation pond, Sriviroj Farm, Khon Kaen, Thailand.
- Chicken manure: layer chicken manure from Sriviroj Farm, Khon Kaen, Thailand.
- Napier grass: harvested age about 45 days and crushed to a size 0.5-2 cm.

Chemical and physical characteristics of all materials were characterized as follow: moisture, total solid (TS), Volatile Solid (VFA), Alkalinity (Alk), Volatile Fatty Acid (VFA), Chemical Oxygen Demand (COD), Nitrogen (N), total carbon (C), and C/N Ratio. Material characterization were followed by Analytical standards APHA AWWA,WEE, 2005 [2] and AOAC,1995 [3].

Design and Analysis of Experiment: DOE

Factors and levels were comprised of inoculums, chicken manure, Napier grass, and temperature (Table 1). Combined Mixture Process Design was used to apply for this experiment because it capable for finding out both of ration and optimum condition [4]. This research came up the 22 treatments with randomization of run order (Table 3). The experiments were done in glass bottles of 120 ml with fermentations volume of 100 ml, 28 day of fermentation, and TS of 1.5%. To validate the optimum condition of variables, five confirmation experiments were conducted at selected optimal levels.

Table 1 Factors and levels of experimental design.

Factors	Level		Units
	Low	High	
Inoculums	0	100	%TS
Chicken manure	0	100	%TS
Napier grass	0	100	%TS
Temperature	30	60	Celsius

Results and Discussion

Materials Characterization

Characterization of three materials i.e., inoculums, chicken manure, and Napier grass are presented in Table 2, it is clear that chicken manure and Napier grass capable to be a co-digestion because chicken manure contained a low C/N of 7.84 chicken manure while Napier grass shown a high C/N of 39.11.

Design and Analysis of Experiment: DOE

Combined Mixture Process Design and result of 22 treatments present on Table 3, it revealed that biogas volumes resulted in range of 4.5 – 95 ml and methane were about 0.20 – 63.76%. Statistical analysis of the experiments explained that inoculums, chicken manure, Napier grass, and temperature affected to biogas volume and methane percentage due to significant level of *P*-value less than 0.05 ($\alpha = 0.05$). In addition, R-squares of biogas volume and methane percentage were 0.9273 and 0.9212, respectively. The examinations of residuals illustrated that the residuals, biogas and methane, generally fell on a straight line, these imply that the error were distributed normally (Figure 1). The plots of the residuals versus biogas, methane, inoculums, and chicken manure explained that there were no obvious pattern and unusual structure (Figure 2).

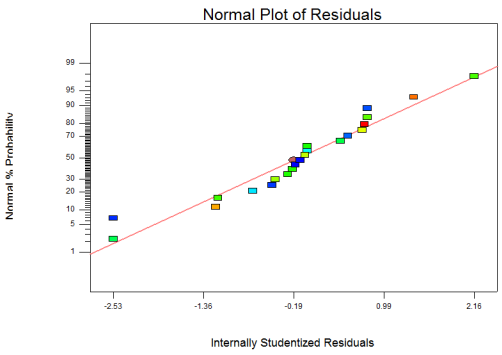
Table 2 Chemical and physical characteristics of materials.

Parameters	inoculums	chicken manure*	Napier grass **
1. Moisture ,%	-	28.47	83.07
2. Total Solid (TS) ,%	10.63	71.53	16.93
3. Volatile Solid (VS) ,%	6.63	44.06	14.83
4. Alkalinity (Alk) ,mg/l as $CaCO_3$	2,960	1,580	278
5. Volatile Fatty Acid (VFA), mg/l	1,250	625	187.5
6. COD ,mg/l	12,511	9,957	4,213
7. Total Carbon (C) ,%	2.21	24.48	8.24
8. Total Carbon (N) ,%	0.41	3.12	0.21
9. C/N	5.36	7.84	39.11

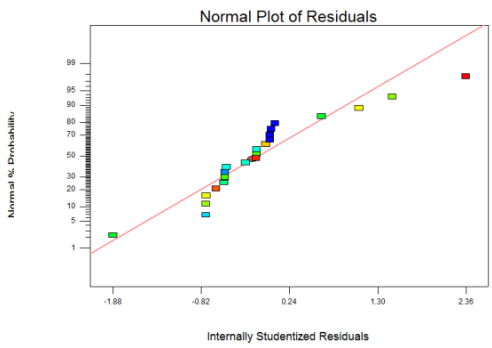
* % of dry weight, **% of wet weight

Table 3 Combined Mixture Process Design and result of 22 treatments.

Standard order	Run order	%TS			Temperature (^{o}C)	Biogas (ml)	Methane (%)
		inoculums	chicken manure	Napier grass			
1	14	42	42	17	60	53	19.20
2	19	42	17	42	60	80	51.53
3	16	42	17	42	30	64	58.54
4	22	17	42	42	60	27.5	13.82
5	12	17	42	42	30	52	41.33
6	10	0	0	100	60	4.5	0.22
7	9	42	42	17	30	55.5	47.58
8	3	100	0	0	30	42.5	36.78
9	8	100	0	0	60	8.5	18.26
10	17	0	100	0	30	58	36.22
11	7	0	100	0	60	11.5	9.15
12	13	0	0	100	30	9.5	0.23
13	4	67	17	17	45	85	63.76
14	5	0	100	0	45	25	28.82
15	11	0	0	100	45	13.5	0.65
16	1	17	42	42	45	43.5	40.41
17	15	100	0	0	45	56	24.30
18	21	42	42	17	60	52.5	17.82
19	6	42	17	42	60	95	47.23
20	18	42	17	42	30	67	61.44
21	20	42	42	17	30	70	29.78
22	2	0	0	100	60	5	0.20

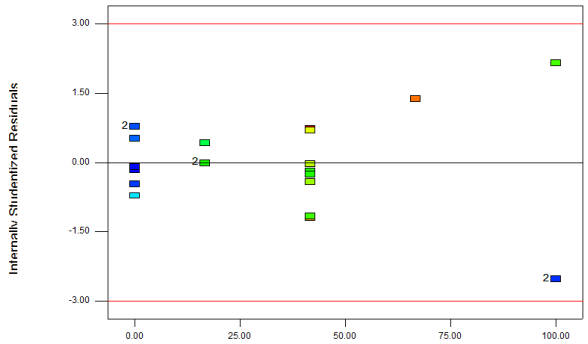


(a) biogas

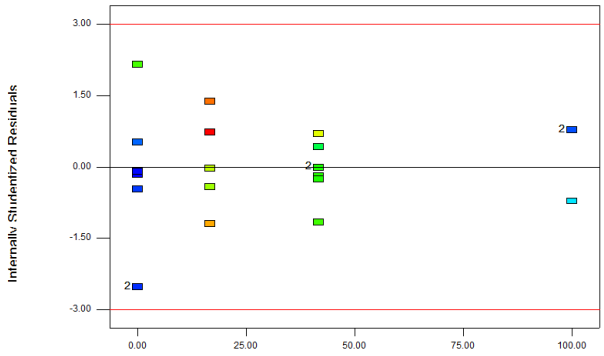


(b) methane

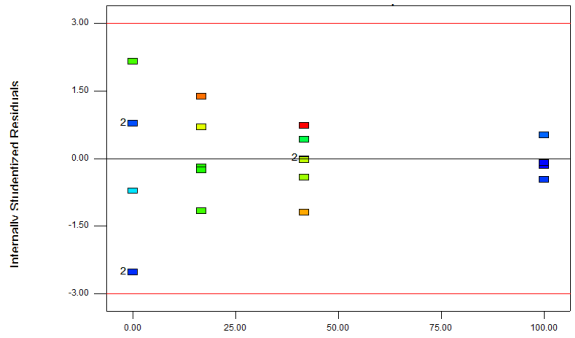
Figure 1: Normal distribution of residuals; (a) biogas and (b) methane



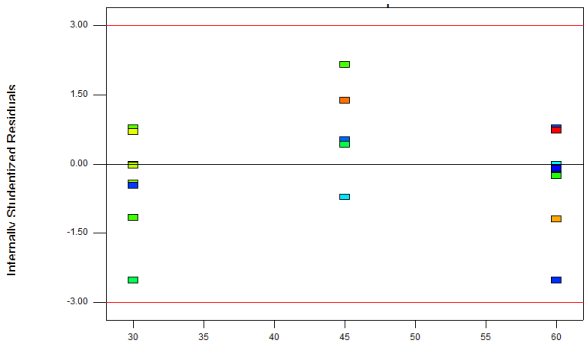
(a) inoculums



(b) chicken manure



(c) Napier grass



(d) temperature

Figure 1: Normal distribution of residuals; (a) inoculums, (b) chicken manure, (c)Napier grass, and (d)temperature.

The optimum conditions result shown that the optimum ratio of inoculums: chicken manure: Napier grass was 46 : 3 : 52 of %TS and temperature of 49 ^{o}C. This condition yielded biogas volume of 101 ml and methane of 73.6%. Then, this result was selected to validate the optimum combination of each material; five confirmation experiments were conducted at selected optimal levels and the results shown that the optimum ratio strongly agreed with the theoretically predicted value both of biogas volume and methane percentage (Table 3); biogas volume were in the range of 95 – 110 ml and methane fell in the range of 71.31 – 74.29% which was closely to the perdition result.

Table 3 Confirmative values of biogas volume and methane percentage.

Test no.	Biogas (ml.)	Methane (%)
1	95	71.31
2	98	72.28
3	100	72.75
4	102	73.83
5	110	74.29

Conclusion

Combined Mixture Process Design with 22 treatments was varied ratios of materials with various temperature form 30-60 ^{o}C and hydraulic retention time was controlled at 28 days. This method was successful to achieve the optimum ratio of inoculums: chicken manure: Napier grass which was 46 : 3 : 52 of %TS and temperature of 49 ^{o}C. This condition yielded biogas volume of 101 ml and methane of 73.6%. Statistical analysis both of R-square and normal plot confirmed that all experiments were accurate and reliable data. The validation experiment also confirmed that it was closely to the perdition result.

Acknowledgments

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