ENHANCING OF METHANE PRODUCTION FROM PALM OIL MILL EFFLUENT BY CO-DIGESTION WITH EMPTY FRUIT BUNCH PRESSED WASTEWATER AT MESOPHILIC CONDITION USING AN ANAEROBIC BATCH REACTOR

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Abstract- The pressing of palm oil fruit bunch (EFB) is new technology that is added in to palm oil process in order to recover oil that may result product yield and reduce oil in wastewater. This process also product high polluted wastewater with high VFA and COD that could be used as co-substrate for biogas production from palm oil mill effluent (POME). Therefore this study aimed to investigate the co-digestion of EFB pressed wastewater and POME in order to optimize the substrates co-digestion for higher methane production. The POME was mixed with various EFB pressed wastewater volume, 2.5%, 5% and 10% and the effect of seed concentration (35%, 50% and 75%) was determined. The result found was the maximum methane yield obtained was 218 mL CH4/g VSremoved with the condition of 0.9:0.1:1 of POME:EFB pressed waste water: seed. This co-digestion have been found to improve biogas and CH4 production yield by 96% and 97% respectively, in comparison to non-added co-substrate.

Keywords- Biogas, Methane, Wastewater, Palm Oil Mill Effluent (POME), Palm Oil Fruit Bunch (EFB)

I. INTRODUCTION

The palm oil industry is an important industry in southern Thailand due to this region is the main area of oil palm plantations. The palm oil process used wet extraction method generates a large amount of wastewater (palm oil effluent; POME), 0.87 m3/ton of fresh fruit bunches.

POME is composed of high organic matter, more than 20,000 mg/l. An anaerobic treatment of POME is widely used because of its low operational cost and effectiveness in removal of organic matter.

During anaerobic treatment, a large amount of biogas is produced and can be used as a renewable energy recycled into palm oil process. Oil palm empty fruit bunch (OPEFB) is the other waste also generated from extraction palm oil process.

OPEFB still contains residual oil content therefore some palm oil extraction plant added step of pressing for OPEFB in order to increase production yield for the manufacturing. Pitak Palm Oil Ltd. is one factory that added pressing of OPEFB in the process.

The pressing of OPEFB can reduce moisture in OPEFB from 64.8% to 42.3% per wet weight. OPEFB pressed produced the wastewater by 22.5% per wet weight of OPEFB.
EFB pressed wastewater contains high COD, BOD, suspended solids and nutrients that can be used to produce biogas.

This research aims to study the optimal condition of the co-digestion of POME and EFB pressed wastewater in order to increase methane production. Parameters of the fermentation process at various mixed substrate were analyzed, including methane yields and biogas yield.

II. METHODS

II.I. Characteristics of the POME, EFB pressed wastewater and inoculums POME and EFB pressed wastewater were collected from the receiving tanks of Pitak Palm Oil factory. The inoculums used was collected from the anaerobic wastewater treatment plant of the same factory.

They were analyzed their characteristics including Chemical oxygen demand (COD), Biological oxygen demand (BOD), pH, suspended solid (SS), total solid (TS), volatile solid (VS), alkalinity, volatile fatty acid (VFA), ammonia nitrogen (HN3-N) , total Kjeldahl nitrogen (TKN) and Grease and oil (G&O).

II.II. Batch assay of methane fermentation
The batch assay experiments to determine BMP (biochemical methane potential) were carried in 1 L glass bottles batch reactors filled with 0.5 L of working volume.
The reactors were fed with main substrate (POME), different percent of co-substrate (EFB pressed wastewater), 2.5%, 5% and 10% v/v and different percent

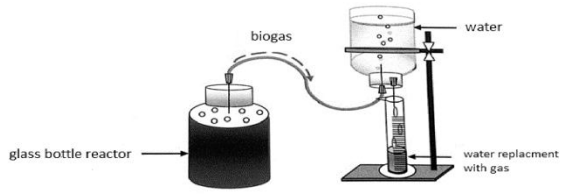


Fig. 1. fluid displacement method

of seed containing 35%, 50% and 75% v/v. Batch experiments were conducted in duplicate at each proportion of mixed substrate. The pH of mixed substrate was adjusted to 7.0±0.2 with K2HPO4 buffer solution. The reactors were put in a water bath and controlled the temperature at 35° C±1. The cumulative biogas and methane gas volume was monitored until the biogas was not produced.

II.III. Analytical methods

Production of biogas volume was measured by fluid displacement method (Fig.1) and methane composition were analyzed by a gas chromatograph (GC) equipped with a thermal conductivity detector (TCD) fitted with a 1.0 m stainless steel column with HP-plot/Q. Helium was used as a carrier gas at a flow rate of 16.0 mL/min . The temperatures of the injection port, oven and detector were 250° C, respectively. The gas samples (0.2ml) were injected in duplicate.

Chemical oxygen demand (COD), pH, suspended solid (SS), total solid (TS), volatile solid (VS), alkalinity, volatile fatty acid (VFA), ammonia nitrogen (HN3-N) and total Kjeldahl nitrogen (TKN) were determined with the procedures described in the Standard Methods.

III. RESULTS AND DISCUSSION

III.I. Characteristics of the POME, EFB pressed wastewater and inoculums Physical characteristics of POME is dark brown color, foul-smelling, and dark brown with suspended sediment. Physical characteristics of EFB pressed wastewater is yellowish-brow color, smell like oil, brown with suspended sediment and the fat floating in the surface. As show in table. I , POME and EFB pressed wastewater contain high COD content, 61,000 mg/l and 74,750 and BOD content, 29,789 mg/l and 31,339 mg/l respectively.

The POME and EFB pressed wastewater were acidic with pH 4.6 and 4.9 respectively. Its contain organic acid in complex forms that may be suitable to be used as carbon sources of microorganisms for biogas production in anaerobic condition. The ratio of BOD5/COD of POME and EFB pressed wastewater were 0.49 and 0.42 respectively, indicating that two wastewater have the ability to be biodegradable by microorganisms because of their BOD5/COD ratios were more than 0.1.

Table. I Characteristics of the POME and EFB pressed wastewater.

Parameter	POME	EFB pressed wastewater
pH	4.6	4.9
COD (mg/L)	61,000	74,750
BOD_5 (mg/L)	29,789	31,339
TKN (mg/L)	550	325
NH_3-N (mg/L)	2.75	5.25
G&O (mg/L)	970	8,590
TS (mg/L)	20,010	96,320
SS (mg/L)	16,250	91,240
VFA (mg/L)	5,288	10,613

However, the analysis of nitrogen content of POME and EFB pressed wastewater found that the ratio of COD:TKN were 110:1 and 110:0.5 respectively. The instruction COD:TKN on the anaerobic system was 150:1 thus, the POME was in suitable range but EFB pressed wastewater was less than the recommended value. In the anaerobic digestion process, the microorganisms need the substrates that has high carbon content, but also its need other nutrients such as nitrogen and phosphorus to be used for new cells creation.

III.II. Batch assay methane production

The detail of experimental batch fermentation at various mixed substrate are shown in Table. II.

Table. II. The conditions of experimental batch fermentation at various mixed substrate

Experiment	POME (%)	EFB pressed wastewater (%)	Inoculums (%)	Co-digestion ratio
1	65	-	35	1.85:0:1
2	62.5	2.5	35	1.78:0.07:1
3	60	5.0	35	1.71:0.14:1
4	55	10	35	1.57:0.28:1
5	50	-	50	1.0:0:1
6	47.5	2.5	50	0.95:0.05:1
7	45	5.0	50	0.9:0.1:1
8	40	10	50	0.8:0.2:1
9	25	-	75	0.33:0:1
10	22.5	2.5	75	0.3:0.03:1
11	20	5.0	75	0.26:0.06:1
12	15	10	75	0.2:0.13:1

(-) = non added co-digestion

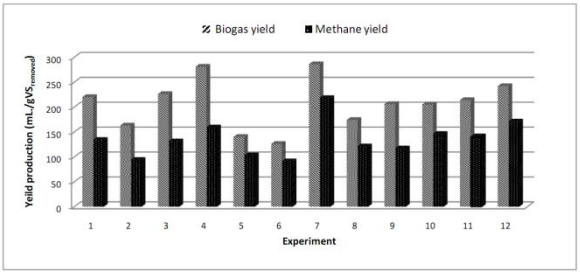


Fig. 2. Biogas yield and Methane yield production of various co-digestion ratio.

Table.III showed none added EFB pressed wastewater yielded lower cumulative biogas and methane production than co-digestion experiment in all conditions.

Table.III. Biogas yield production, methane yield production and methane content in the different co-digestion ratio in batch reactor.

Experiment	Biogas yield (mL biogas/g $VS_{removed}$)	Methane yield (mL biogas/g $VS_{removed}$)	Methane (%)
1	220	134	69%
2	163	94	62%
3	226	131	67%
4	281	159	63%
5	140	103	75%
6	126	91	71%
7	286	218	78%
8	174	121	72%
9	206	117	59%
10	205	146	73%
11	214	140	69%
12	242	171	73%

Fig. 2 presented the experiment #7 produced the highest methane volume because of its condition is suitable for methane production system. There are caused by many factors including COD:TKN that was 126:1 and in according the instruction COD:TKN on the anaerobic system, VFA/Alkalinity was 0.2 when the effective biological degradation could occur at VFA/Alkalinity is in the range of 0.4-0.8.

At the end of the 10^{th} days of digestion, The experiment#7 gave the maximum biogas and methanes by 286 mL biogas/g VSremoved and 218 mL CH4/ g VSremoved with the condition of 0.9:0.1:1 of POME:EFB pressed wastewater:seed in the comparision to the control experiment #5 that gave 140 mL biogas/g VSremoved and 103 mL CH4 / g VSremoved with the condition of 1:0:1 of POME:EFB pressed wastewater:seed.

All experiments found that the VS effluent, COD effluent and VFAeffluent decreased, indicating that the decomposition of organic matter in the system converted into biogas and methane. When biodegradation by microorganisms occured in the system, many factors was changed including pH, Alkalinity, HN3-N and TKN. Low methane yield at high substrate concentration which indicated that POME and EFB pressed wastewater were concentrate substrate.

They have high content of VFA and low pH which could potentially inhibit the methanogens. However, the analysis results showed that pH, Alkalinity, NH3-N and TKN increased at the end of the process. The increasing of NH4 concentration caused by the decomposition of nitrogen content.

As a result, the pH is higher than 8 because of the imbalances in metabolism of microorganism that can cause toxic effects on the function of methane producing bacteria. The appropriate pH for methane producing bacteria was in the pH range of 6.5-7.5.

CONCLUSION

POME is an important source of inland water pollution when released into the river or lake. Currently, most of palm oil mill plants use POME as feedstock to produce biogas as a renewable energy. In addition, co-digestion has been widely implemented because of need to improve digesters biogas production. The result of experimental batch fermentation at various mixed substrate at mesopheric condition gave the maximum biogas and methane yields at 286 mL biogas/g VSremoved and 218 mL CH4 / g VSremoved at the optimal condition of 0.9:0.1:1 of POME:EFB pressed wastewater: seed. The result confirmed that the EFB pressed wastewater could be used as co-substrate for methane production from POME. With optimal mixing condition, it yielded higher methane production than that of POME conventional digestion by double. For further research, the optimal condition obtained will be investigated by up-scale reactor and continuous assay.

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