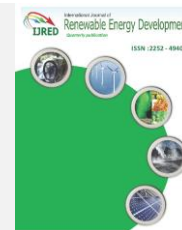




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Optimization of Concentration and EM4 Augmentation for Improving Bio-Gas Productivity from *Jatropha curcas* Linn Capsule Husk

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ABSTRACT: Most literature suggests that two-phase digestion is more efficient than single-phase. The series of two-phase digestion studies have been conducted from 2011 to 2013 at the research farm of PT Bumimas Ekapersada, West Java, Indonesia. This paper reports on a research on optimization of concentration and augmentation of EM-4 (effective microorganism-4), a local commercial decomposer, as efforts to stabilize a biogas technology which made from husk capsules of *Jatropha curcas* Linn (DH-JCL). The studies of increasing organic loading rate (OLR) for the two-phase digestion was conducted to improve efficiency. The concentration variable studied was 1: 8 (1 part DH-JCL and 8 parts water), compared to 1: 12 as a control. The augmentation treatment is the addition of EM-4 by 5% (v/v). It was also examined the augmentation of F2-EM4 (150 times duplication of EM-4) due to cost consideration. The studies were conducted in the laboratory which using a liter and two liters of glass digester and glass wool as immobilized growth. The results of this study support the previous studies: the optimum concentration was 1: 8, EM-4 was able to increase biogas production in two-phase digestion, yet biogas production decrease at single-phase. F2-EM4's ability to support production of biogas were equivalent to that of EM-4.

Keywords: biogas, concentration, EM-4, *Jatropha curcas* Linn capsule husk, two-phase anaerobic digestion

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1. Introduction

Biogas is categorized as renewable energy and modern cooking oil (World Bank 2011). Fang (2010) stated that biogas production is the biomass conversion to efficient energy. Development of biogas technology is considered prospectful for Indonesia due to the

country's richness in biomass. Utilization of biogas raw material and gaseous biofuels is relatively broad (Soerawidjaja 2011), minimizing global warming, and not competing with food crops (Warnika 2010). With relatively simple technology, household-scale biogas equipments are able to be made in Indonesia. The tropical climate in Indonesia is able to support inexpensive conversion process (Praptiningsih *et al.*

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2011), minimize groundwater pollution (Benzah *et al.* 2010), and produce nutrient-rich organic fertilizer (Praptiningsih *et al.* 2013 a) as an improvement to soil fertility.

Biogas was produced in anaerobic vessel which called a biogas plant and also commonly known as a bio-digester, bioreactor or anaerobic reactor/digester. (Sonni 2007). In the bio-digester, multi-step biological reactions was occurred (Gerardi 2007) which divided into three stages namely acid fermentation, acetogenesis, and methanogenesis or four stages namely hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Hendroko 2013). There are several types of digesters in use today. The basic requirements of an anaerobic digester design which allow for a continuously high and sustainable organic load rate, need a short hydraulic retention time (to minimize reactor volume) and produce the maximum volume of methane. Ward *et al.* (2008) stated that there are three main groups of digester, namely batch digester, single-phase digester, and two-phase digester.

Hendroko *et al.* (2013 a) studied have summarized the previous research results on two-phase digestion, elucidating that it has some advantages than single-phase digestion. The experiment were using water treatment, sewage dairy, sugar beet waste, residual waste processing, vegetable and fruit waste, potatoes, tomatoes, sweet sorghum, wine waste processing and municipal waste. Therefore, a series of studies on biogas made from capsules husk of *Jatropha curcas* Linn (DH-JcL) has been conducted and reported by Bumimas Ekapersada Team (Hendroko *et al.* 2012 a,b, 2013 a,b,c; Praptiningsih *et al.* 2011, 2012, 2013 a,b,c; Salafudin *et al.* 2010, 2011).

DH-JcL was suggested to run in two-phase digestion due to its characteristics of having relatively small density, floating in the substrate solution with inlet digester clogging effects and incomplete hydrolysis reaction, relatively high C/N ratio, not ideal composition of N, P, K and S contents, high capacity buffer, high antinutrients and bulky (Praptiningsih *et al.* 2011, 2012, 2013c; Salafudin *et al.* 2011). A series of previous research improve the efficiency biorefinery JcL cultivation as producing liquid biofuels - biodiesel. The improvement technology of Bumimas Ekapersada, however, was not optimal until now. Lack of consistency production was occurred on biogas made from DH-JcL in a two-phase digestion. This paper reports a study on optimization of concentration and augmentation of EM-4 for Bumimas Ekapersada's biogas technology improvement, and validating data consistency and comparing them with the previous studies.

2. Materials and Methods

The research was conducted at the research farm laboratory of PT Bumimas Ekapersada, Bekasi, West Java, from October 2011 until November 2012. Single-phase digester is that used a liter glass. Two-phase digester was using metagonenesis and two liter glass as hydrolysis digester. The experimental design was the CRD (completely randomized design) with three replications in a 32°C water bath, as shown in Fig. 1 and Fig. 2. Fourty grams of glass wool was used as immobilized growth which put into the metanogenesis digester. The research material is DH-JcL cultivars JatroMas toxic category, an a semi-artificial inoculum (the slurry of DH-JcL digester) was used as starter (Kamaruddin *et al.* 2005).

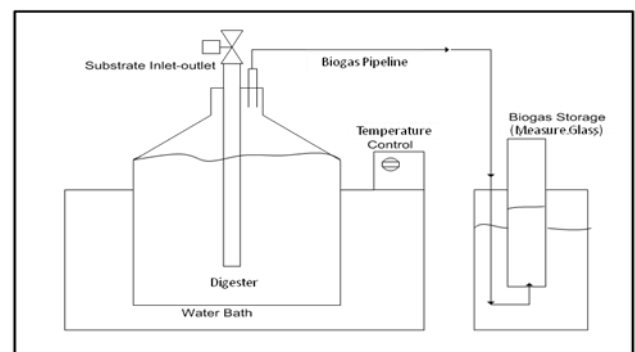


Fig 1. Schematic of single-phase digester

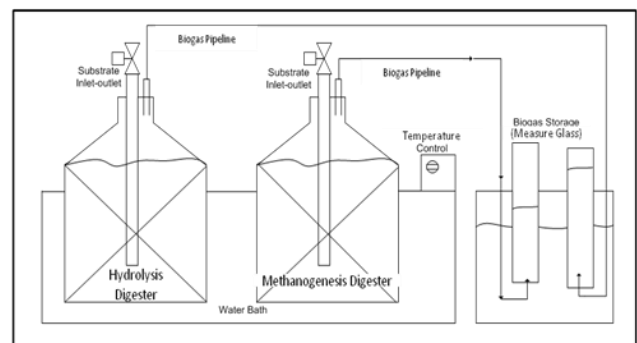


Fig 2. Schematic of two-phase digester

This research consists of two studies. The first study is the comparison of concentration optimization treatments in the single-phase digester and two-phase digester. The observed concentration was 1 : 8 than 1 : 12 as a control. In this part of research, an augmentation studies about the effects of microbial introduction (Fang *et al.* 2004) on increasing biogas production was also conducted. The observations were made on 5% (v/v) EM-4 (effective microorganism-4; a local commercial decomposer) introduction as an artificial starter (Kamaruddin *et al.* 2005).

EM-4 contain 80 genus of microorganisms, including bacteria of the genus fermentation of *Lactobacillus*, fermenting fungi, Actinomycetes, phosphate solvent bacteria and yeast (Herawati & Wibawa 2010). The Duncan's Multiple Range Test (DMRT) at $\alpha=5\%$ was used to compare treatment means.

The second study was done with consideration to increase the efficiency of EM-4 utilization, whose price was considered relatively expensive. In this part, 5% F2-EM4 (v/v) was filled into a hydrolysis digester of two-phase system. F2-EM4 was made by 150 liters of water, 1 liter of EM-4, 1 kg of brown sugar, 50 grams of urea which kept in a drum for a week. The aim of this study was to observe the performance of F2-EM4 comparing with the pure EM-4. A two-replications experiment was conducted, and responses to the treatments were compared using t-Test.

Digester hydraulic retention time in the two studies above was set for five weeks. DH-JcL and solvent (water) were included and excluded from the hydrolysis digester based on "draw and fill" method every day (Velmurugan & Ramanujam 2011). Substrate from the hydrolysis digester was filled into methanogenesis digester. The observed variables were the biogas production volume by water displacement method (Budiyono & Kusworo 2011), pH and temperature in the effluent by pH meter and digital thermometer, and acetic acid content by titration method.

3. Result and Discussion

3.1 Comparison of the optimization concentration in the single-phase digester than two-phase digester

This study was conducted at temperature of 31.17-34.37°C in the hydrolysis digester and 31.10-34.09°C in the methanogenesis digester. The ideal temperature for mesophilic bacteria was 30-35°C (Hendroko 2013); it was assumed that this study was conducted in ideal conditions. pH observations during the study are shown in Table 1.

Table 1.
pH Data on the single-phase, two-phase, concentration, and EM-4 augmentation of DH-JcL substrate

Treatment	pH		
	Min	Max	Average
A. Single-phase digester			
Concentration 1 : 12 EM4	5.10	6.50	5.75
Concentration 1 : 12	5.70	7.20	6.23
B. Two-phase digester			
a. Hydrolysis digester			
Concentration 1 : 8 EM4	4.60	6.30	5.34
Concentration 1 : 8	5.50	6.55	5.93
Concentration 1 : 12	6.00	7.20	6.77
b. Methanogenesis digester			
Concentration 1 : 8 EM4	6.90	7.70	7.32
Concentration 1 : 8	7.20	7.65	7.45
Concentration 1 : 12	6.90	7.80	7.53

Table 2.

Biogas production per day from DH-JcL at single-phase and two-phase digesters in substrate concentrations of 1 : 12 and 1 : 8 and the EM-4 augmentation

Treatment	Biogas production per day (ml/ g VS)	Notation *)
Single-phase digester		
Single-phase 1 : 12 EM-4	38.04	ab
Single-phase 1 : 12 (control)	54.02	ab
Two-phase digester (methanogenesis)		
Two-phase 1 : 8 EM-4	65.43	b
Two-phase 1 : 8	38.69	ab
Two-phase 1 : 12 (control)	28.70	a

*) Treatments with the same letter were not significantly different according to Duncan Test 5%

Table 1 shows that the EM-4 augmentation affect in decrease of pH. This condition is expected more acetic acid production as the precursor of CH₄. Table 1 also shows the pH in the two-phase (methanogenesis digester) is higher than in the single-phase. Some literature shows that an ideal pH in biogas digester is between 6.0 and 8.5 (Hendroko 2013), hence a two-phase digester should work better than a single-phase. Observations of biogas production are shown in Table 2.

Table 2 shows that the EM-4 augmentations at single-phase decrease biogas production, although not significantly different in statistic (38.04 < 54.02 ml/ g VS). EM-4 augmentation in two-phase digester has impact on biogas production improvement (65.43 > 38.69 & 28.7 ml/ g VS). Low biogas production at single-phase on the EM-4 treatment elucidated in Table 1. This condition indicates a buildup of volatile organic acids as an effect of EM-4, in which Fig. 3 reinforces this condition.

Fig. 3 shows acetic acid contents in the treatment of EM-4 is higher than without EM-4. This condition indicates that acetic acid production is not matched archaea methanogenics growth. The system becomes unbalanced and the activity of methane-producing archaea is inhibited (Dennis & Burke 2001) so that the biogas production decreases as shown in Table 2.

Table 2 shows EM-4 leads the biogas production in two-phase digester than in single-phase digester, supporting previous research (Hendroko *et al* 2013 b). Biogas production increase by EM-4 augmentation was due to separation of hydrolysis and methanogenesis digester in the two-phase system. This separation affects to rapid growth of bacterial fermentation which triggered by EM-4. Therefore, high production of organic acids (indicated with pH of 5.34 in Table 1) does not inhibit performance archaea methanogenics. This condition is indicated by the normal pH (7.32) of methanogenesis digester as shown in Table 1.

Table 2 also elucidated the biogas production in the concentration treatment of 1 : 12 (28.7 ml / g VS) in two-phase is lower than single-phase (54.02 ml / g VS). These results support previous research which suggests that it was caused by low organic loading rate (OLR) and/or highly water volume (Hendroko *et al.* 2012 a).

Fig. 4 shows the biogas production in hydrolysis digesters. It appears that the 1 : 12 concentration treatment produced the highest volume of biogas (3220.42 ml/ g VS). Manurung (2004); Saputro & Putri (2009) stated that high water volume resulted in a more rapid hydrolysis. This finding is supported by Fig. 5, suggesting that acetic acid as the main precursor of biogas (Hutnan *et al.* 2001) in 1 : 12 treatment is the lowest because most of them have been converted into biogas. In the last week of observations, Acetic acid production was accelerated as a result of the concentration effect. Low biogas production problems in 1 : 12 treatment can be overcome by increasing concentration to 1 : 8 as shown in Table 2. This data is supported by Fig. 5 which 1 : 8 concentrations produced acetic acid higher than 1 : 12. These results support previous research by Praptiningsih *et al.* (2012).

Fig. 6 and 7 shows biogas production and acetic acid contents in methanogenesis digester in correlation of biogas production (Fig. 4 and 5). Fig. 6 shows biogas production in methanogenesis digester on 1 : 12 treatment is the lowest because biogas has been produced on hydrolysis. The highest biogas production was occurred from EM-4 augmentation treatment (Fig. 6). These results support previous research (Hendroko *et al.* 2013b; Salafudin *et al.* 2011) and a study on EM-4 augmentation by Elisa (2010) which reported that EM-4 leads biogas production. The production of EM-4 treatment was not optimal production due to acetate acid contents increase on day 21 to day 35 (Fig. 7). The accumulation of acetic acid in that period is expected to occur because they cannot be converted by archaea methanogenics. The same treatment on 1 : 12 and 1 : 8 concentrations as an effect of acetic acid contents increase on hydrolysis digester was shown in Fig. 5. It appears that the acetic acid increase is relatively smaller in treatment 1 : 8 than in 1 : 12. The acetic acid contents increase in Fig. 7 could not be detected by pH observation (Table 1). This results also support previous research (Hendroko *et al.* 2013c), reporting that the pH is not a good indicator for monitoring the work of DH-JcL digester.

3.2 Observation of F2-EM4 and pure EM-4 performance

Inoculum artificial EM-4 price is relatively expensive, so the EM-4 replacement study was done by F2-EM4. Observations on biogas production in this study were shown in Table 3. Table 3 shows that DH-JcL biogas production with EM-4 and F2-EM4 augmentation was not significantly different. It can be concluded that F2-EM4, which is cheaper than EM-4, can be used to increase biogas production. This results support previous research by Hendroko *et al.* (2013b).

Table 3.
Biogas production with EM-4 and F2-EM4 augmentation

Observation	Biogas Production (ml/V _S)		t-Test*
	EM4	F2-EM4	
1	13.10	13.56	0.180
2	17.30	17.72	0.242

*) t-Test > 0.05 (not significant)

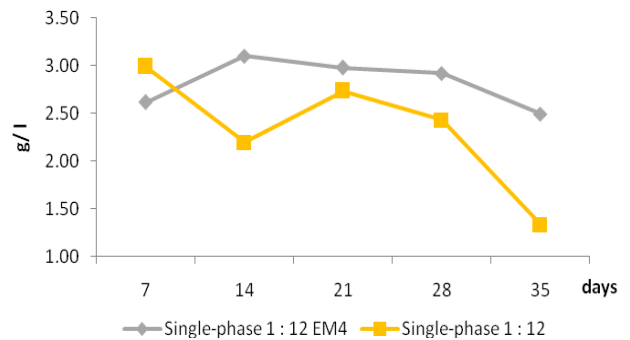


Fig. 3 Comparison of acetic acid contents in single-phase digester on the EM-4 than without EM-4

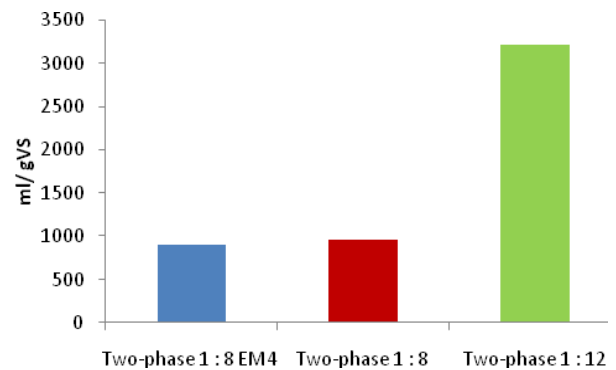


Fig. 4. Total biogas production in hydrolysis digester in 5 weeks

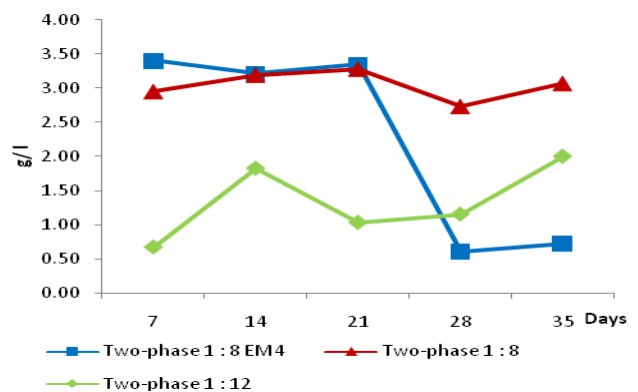


Fig. 5 Acetic acid production in hydrolysis digester

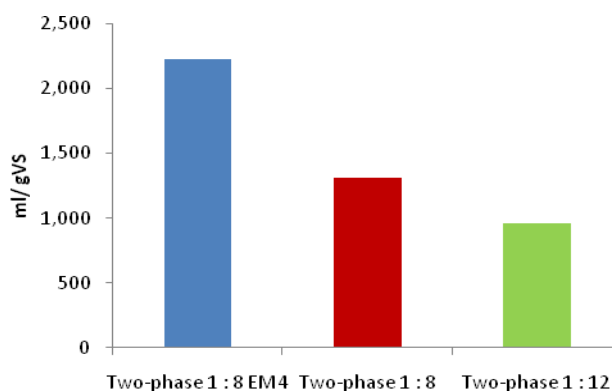


Fig. 6 Total biogas production in methanogenesis digester in 5 weeks

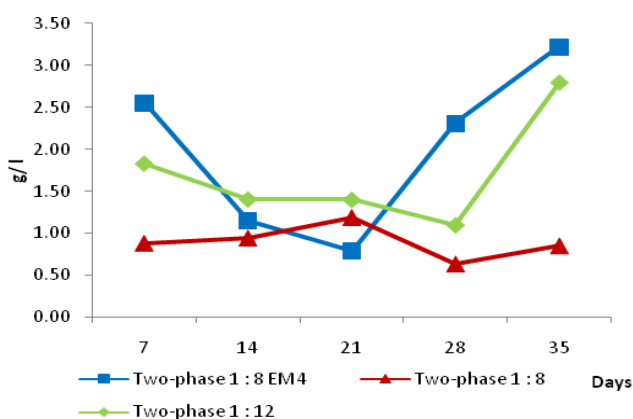


Fig 7. Acetic acid production in methanogenesis digester

4. Conclusion

The DH-JcL biogas production can be improved by applying DH-JcL-water mixture concentration of 1 : 8 and EM-4 and / or F2-EM4 augmentation in the hydrolysis digester of two-phase digestion system.

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