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Research Article

Ballast Weight Review of Capsule Husk *Jatropha curcas* Linn. on Acid Fermentation First Stage in Two Phase Anaerobic Digestion

Praptiningsih Gamawati Adinurani[1], Roy Hendroko Setyobudi[2, 3]*, Satriyo Krido Wahono[4, 5], Maizirwan Mel[6], Anggi Nindita[7], Endang Purbajanti[8], Soni Sisbudi Harsono[9], Andoniana Rakoto Malala[10, 11], Leopold Oscar Nelwan[12], and Andi Sasmito[13]

[1]Faculty of Agrotechnology, Merdeka University, Jl. Serayu, PO. Box 12, Madiun 63131, Indonesia
[2]Indonesian Association of Bioenergy, BPPT Building II, 22nd Floor Jl. MH. Thamrin No. 8 Jakarta 10340, Indonesia
[3]Ma Chung Research Center for Photosynthetic Pigments, Villa Puncak Tidar N-01 Malang 65151, East Java, Indonesia
[4]Future Industry Institute and School of Engineering, University of South Australia, Mawson Lakes SA 5095, Adelaide, Australia
[5]Technical Implementation Unit for Development of Chemical Engineering Processes, Indonesian Institute of Sciences, Yogyakarta, 55861, Indonesia
[6]Department of Biotechnology & Engineering, Faculty of Engineering, International Islamic University Malaysia, Gombak, Kuala Lumpur, 50728, Malaysia
[7]Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, Indonesia
[8]Agricultural and Animal Science Faculty, Diponegoro University, Jln. Prof Sudharto SH, Tembalang Semarang, 50275, Indonesia
[9]Faculty of Agricultural Technology, University of Jember (UNEJ), Jl. Kalimantan 23,Jember 68121 Indonesia
[10]Centre de Formation et d`Application du Machinisme Agricole (CFAMA) Route Betafo Ambaniandrefana – B.p. 109, Antsirabe, Madagascar
[11]Agricultural Science, Kobe University 1-1 Rokkodai, Nada-ku, Kobe, 657-8501, Japan
[12]Department of Mechanical and Engineering Biosystem, Faculty of Agricultural Engineeringand Technology, Bogor Agricultural University, Kampus IPB Darmaga, Bogor 16002, Indonesia
[13]Alumnus Department of Biology, Faculty of Mathematics and Natural Sciences Bogor Agricultural University, Bogor 16680, Indonesia

Abstract: Increasing biogas production through the use of Dried Capsule Husk - *Jatropha curcas* Linn. (DH-JcL) as raw materials study was conducted at PT Bumimas Ekapersada experiment field, in Bekasi, West Java, Indonesia from September 2013 to March 2014. Four HDPE pipes with 5 L volume used as first stage-hydrolysis digester, while an HDPE (high-density polyethylene) drum with working volume 80 L was used as second phase - methanogenesis digester. DH-JcL at the first stage was pressed by a 1 800 g ballast, which was to be compared to a 900 g ballast pressed, diluted in water with volume ratio of 1:8. One third of the second stage digester was filled by immobilized growth of random packing system on special plastic design. Organic Loading Rate was predetermied at 3 000 cc $\cdot$ d^{-1} with Hydrolic Retention Time of 4 wk. This study was repeated three times and conclusion was made using t test as inferential statistics. The test concluded that 900 g ballast produced the best result. DH-JcL biogas productivity is increased, by two phase system, as much as 163 % when compared to semi continuous single phase system. Furthermore, the set up produces methane content higher (90 % to 91 %) than semi continuous single phase system (83.15 %). VFA average decrease of 16 %, and average alkalinity decreased by 11 %. Average ratio of VFA/ alkalinity is 0.5 similar with semi continuous single phase system.

Keywords: Acid fermetation, biogas, capsule husk, *Jatropha curcas* Linn., two phase anaerobic digestion

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*Corresponding author: Roy Hendroko Setyobudi; Email: roy_hendroko@hotmail.com

1. INTRODUCTION

Praptiningsih et. al. [1] stated that DH-JcL (Dried Husk *Jatropha curcas* Linn.) used as raw material for methane fermentation of biogas digester produced unsatisfactory result. This statement was supported also by several other studies [2, 3]. However, it must be understood that those unsatisfatory results of DH-JcL biogas was conducted due to zero waste principle reason. A reference [4] stated that DH-JcL produced biogas quantity similar with rice husk on semi-continuous single phase digester. Moreover, it produced higher methane content than others biogas raw materials, such as cowdung, solid waste of tapioca production process, cassava skin, fruits and vegetables wastes. However, Praptiningsih et al. concerned about VA/Alk ratio showing 0.5 value [4]. This ratio exceeded or approached the threshold which was recommended by some researchers [5–10].

Several researchers suggested to apply two phase digester, particularly for solid form feeding, which is not easily degraded, having high carbohydrate content, highly toxic, unbalanced C:N:P content, having hydrolysis and liquefaction problems, and unstable process [11–16]. Some study of DH-JcL as raw material concluded that two phase digester was better than single phase digester [17–22]. This research was conducted to review comparison results between laboratory scale and pilot plant scale on two phase biogas digester of DH-JcL as raw material. The research also studies improvement of DH-JcL biogas productivity and VA/Alk ratio on two phase digester

2. MATERIALS AND METHOD

The study was conducted at PT Bumimas Ekapersada's experiment field, in Bekasi, West Java, Indonesia, from September 2013 to March 2014. JcL husk was collected from JatroMas toxic cultivar which was sun dried, to reduce moisture content up to 5 %. An HDPE (high-density polyethylene) drum with a total volume of 90 L and working volume of 80 L was used as methanogenesis digester/ second digester (Fig. 1). There are three holes on methanogenesis digester. Two holes were closed by drum, the first was used for flowing biogas into the holder and the second hole was used for feeding slurry DH-JCL from hydrolysis digester. The feeding pipe's end was submerged into slurry at about 10 cm to prevent O_2 from entering into digester. The third hole was located under the drum for slurry dispensing and for analysis sample taking. One third volume of methanogenesis digester was filled by organic artificial immobilized growth of random packing system on special plastic design. Methanogenesis digester was filled by rain water and 10 % v/v [23] of semi-artificial starter from DB-JcL digester. From 1 d until 10 d operation, methanogenesis digester was provided by synthetic feeding of 25 g $\cdot$ L^{-1} brown sugar for 3 000 cc [4]. At the 11 d, if biogas bubbles are produced in the water holder, then synthetic feeding was replaced by slurry from hydrolysis digester. Organic Loading Rate (OLR) was calclated at 3 000 cc $\cdot$ d^{-1} with Hydrolic Retention Time (HRT) of 4 wk [4].

Fig. 1. The first and second digester.

Hydrolysis digester/ first digester used 5 L volume of HDPE pipe which was closed tightly (Fig. 1). On the bottom part, there is a slurry discharge hole to move the slurry to methanogenesis digester periodically. On the top part, there was another discharge hole to release gas production and a covered hole to pour the water diluent consisting of 375 g sun-dried added with 4 000 cc of rain water as diluent. The DH-JcL was pressed by ballast, so it submerged in water diluent [18]. There were four hydrolysis digesters for feeding a methanogenesis digester, because the slurry was harvested every 4 d based on the previous studies [17, 19, 22]. 3 000 cc d^{-1} of slurry from hydrolysis digester was transferred to methanogenesis digester. Hereafter, 3 000 cc of 1:8 concentration rain water [21] was filled to soak

DH-Jcl d^{-1}. The soaking was conducted in hydrolysis digester for 4 wk [19].

pH and temperature reading was conducted every day during experiment by digital measurement tools. Biogas volume of hydrolysis and methanogenesis digester was determined by water displacement method on the holder [25], and methane determination was conducted using orsat apparatus. Volatile fatty acid (VFA) content and alkalinity was analyzed by distillation and titration based on APHA 2320 [25]. This study was repeated three times and conclusion was obtained by using test as inferential statistics

3. RESULTS AND DISCUSSION

This paper is written to elaborate a study on the ballast weight on DH-JcL in hydrolysis digester. As reported by reference [18], the ballast application on DH-JcL bundle increased biogas productivity because the bundle did not flow. However, it can be seen that DH-JcL did not degrade perfectly, particularly on the inside part of bundle. It was so happened because the ballast weight was too heavy, so diluent water could not enter into the bundle. This study compared between maximum (1800 g) and minimum (900 g) ballast.

3.1 Review on Temperature and pH

This research was conducted on the temperature ranges which shown on Fig. 2 and 3. Fig. 2 shows that research condition in hydrolysis digester which is conducted at average temperature of 29.71 °C (27.0 °C to 32.3 °C range) for maximum ballast, and average temperature of 29.2 °C (26.6 °C to 31.50 °C range) for minimum ballast. This research was conducted at ideal temperature of 30 °C to 35 °C [26] and/or 30 °C to 38 °C [27]. The average temperature was relatively similar for two treatments, but the minimum ballast has lower temperature because of the lower temperature effect on the 1 d to 11 d. Fig. 3 shows research condition in methanogenesis digester which is conducted at average temperature of 29.89 °C (27.8 °C to 32.1 °C range) for maximum ballast and average temperature of 29.95 °C (27.7 °C to 31.9 °C range) for minimum ballast. Methanogenesis digester temperature on this study was conducted at ideal temperature of 30 °C to 35 °C [26] and/or 30 °C to 38 °C [27]. The average temperature was relatively similar for the two treatments, although the maximum ballast has lower temperature.

Based on the varied temperature results, the minimum ballast was more suitable, which was shown by lower relative temperature on the 1 d to 11 d. Hereafter, the temperature increased until the end of study period. This increasing temperature had positive impact to arachea methanogen [28]. pH observation of this research is shown on Fig. 4 and Fig. 5.

Fig. 4 shown that this study was conducted on average pH of 6.26 (range pH 5.60 to pH 6.80) for maximum ballast and average pH of 5.93 (range pH 5.00 to pH 7.00) for minimum ballast. This research was conducted on ideal pH because some references reported the ideal pH value of 5.00 to 7.00 [20]. The average pH of the minimum ballast was lower, which mean it produced more acid. The lower pH was expected to increase biogas production. pH curve of hydrolysis digester decreased from day to day, particularly on the minimum ballast which was reported also by reference [29, 30]. The decreasing pH will have negative impact to arachea methanogen. To minimize this impact, Lopez [30] on his research of single phase digester, conducted NaOH addition. However, Fig. 4 shows that pH of two phase digester is still have a normal pH range. The lower pH of the minimum ballast was happened because water diluent and DH-JcL was functioning well, therefore acidity process conducted optimally.

Fig. 5 shows that this study was conducted on average pH of 6.79 (pH range 6.0 to 7.3) for maximum ballast and average pH of 7.13 (pH range 6.80 to 7.50) for minimum ballast. This study was conducted on ideal pH because some references reported the ideal pH value of pH 6.0 to pH 8.5 for methanogenesis digester [20]. The average pH of the minimum ballast was higher than the maximum ballast. Because of arachea methanogen is appropriate with neutral-base pH [32], so this condition showed that the minimum ballast treatment is better producing biogas. However, the maximum ballast also shows the possibility of optimum biogas production. This possibility is shown by low pH on the early and then it's likelihood to increase. Increasing pH value happened because of better the balancing process between acetogen microbe growth and methanogen. Acid compounds, produced by acid-producing bacteria, were consumed by arachea

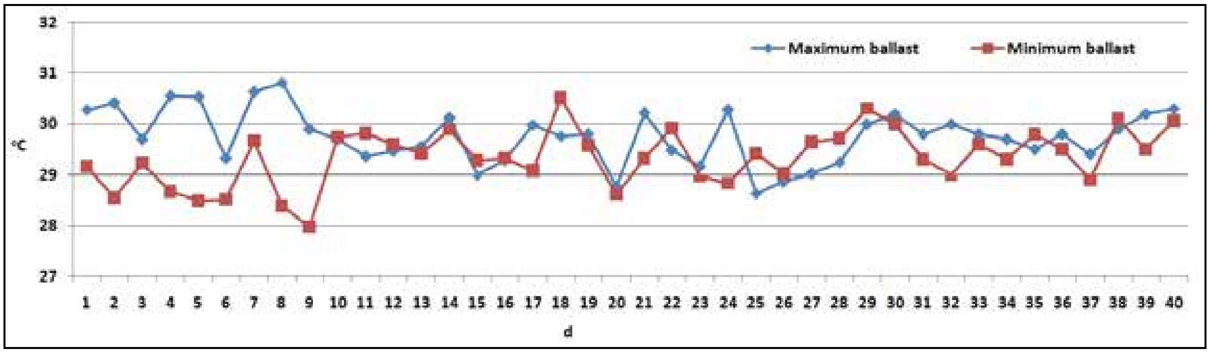

Fig. 2. Slurry outlet temperature of two phase DH-JcL hydrolysis digester system with maximum and minimum ballasts.

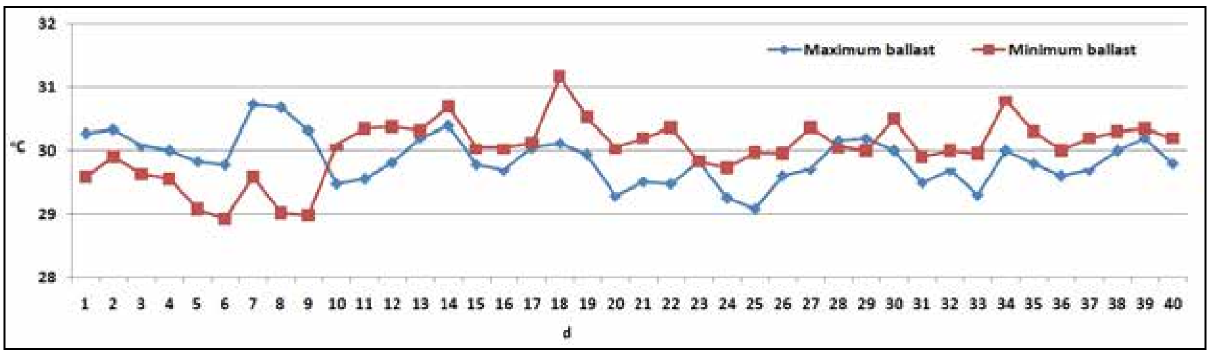

Fig. 3. Slurry outlet temperature of two phase DH-JcL methanogenesis digester system with maximum and minimum ballasts.

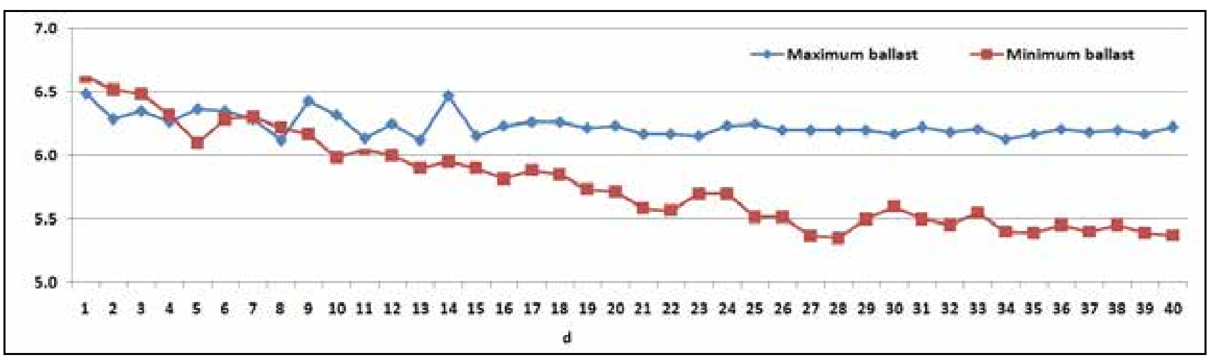

Fig. 4. Slurry outlet pH of two phase DH-JcL hydrolysis digester system with maximum and minimum ballasts

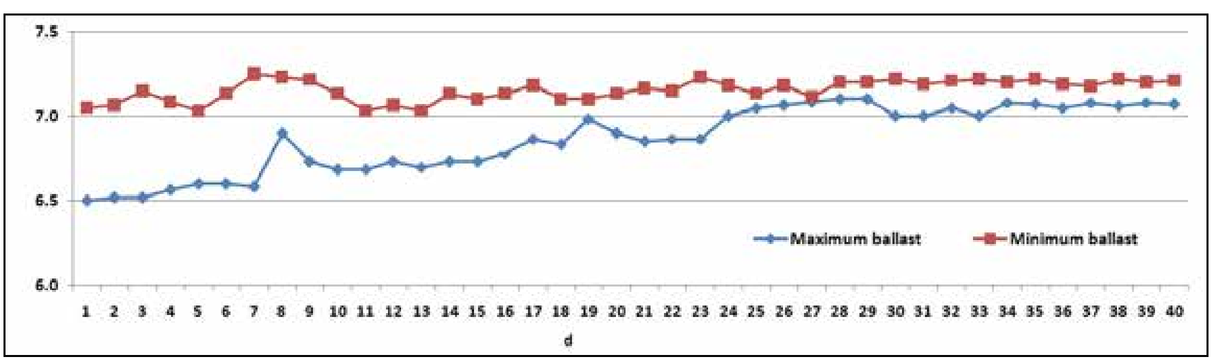

Fig. 5. Slurry outlet pH of two phase DH-JcL hydrolysis digester system with maximum and minimum ballasts.

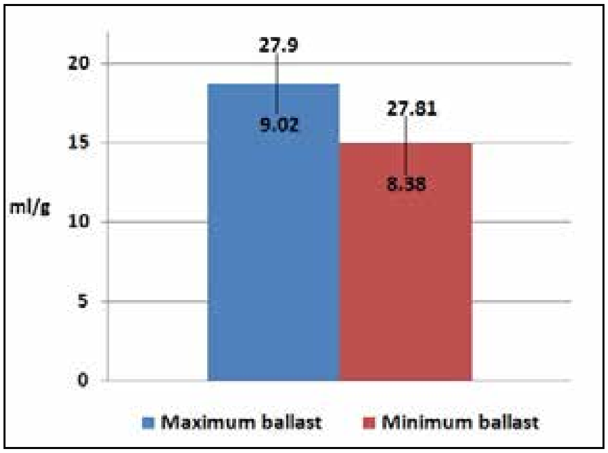

Fig. 6. DH-JcL biogas production in hydrolysis digester with HRT of 40 d for two type ballasts.

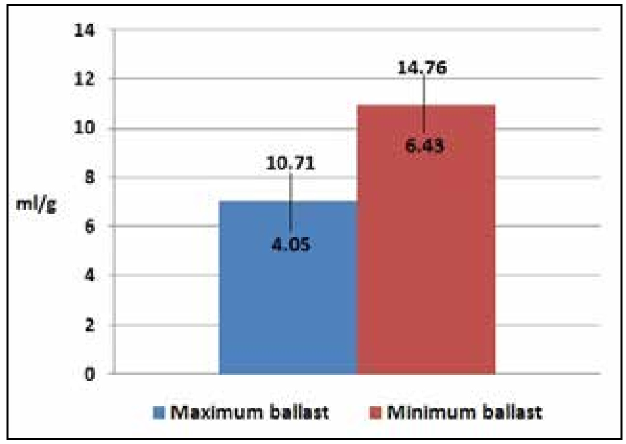

Fig. 7. DH-JcL biogas production in methanogenesis digester with HRT of 40 d for two type ballast.

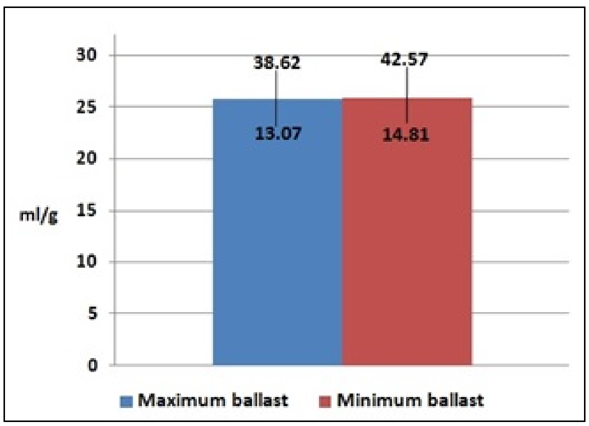

Fig. 8. Total biogas production of DH-JcL as raw material with HRT of 40 d.

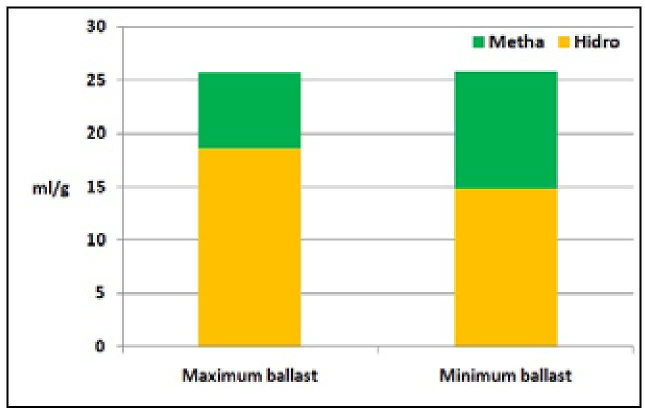

Fig. 9. Total biogas production of DH-JcL as raw material with HRT of 40 d on separation of hydrolysis and

methanogen quickly, so it produced much CO_2 which dissolved in water. It produced more bicarbonate ion (HCO_3^-) which caused solvent more alkaline and system changed from neutral to base [33, 34].

3.2 Review on Biogas Production

Fig. 6 and Fig. 7 show biogas production from hydrolysis and methanogenesis digester. Fig. 6 showed biogas production of hydrolysis digester on the minimum ballast is lower than the maximum ballast. This data, showing that the minimum ballast produce lower biogas, indicated that degradation occured slowly. This condition was expected to optimize hydrolysis process because DH-JcL contain carbohydrate particularly high cellulose which degrade slowly [12, 35]. This condition is one of benefits resulted from two phase system. Increasing HRT on hydrolysis process of single phase system was hard to apply [36] because acidity process impacted negatively to arachea methanogen [37]. Whereas, increasing HRT was able to enhance degradation efficiency [38].

The maximum ballast on hydrolysis digester produced more biogas because degradation process was conducted only on solid feeding partially. On this treatment, there was small part of solid feeding which contacted with diluent water, so degradation process was conducted faster [39] and biogas production was produced also faster. Whereas, Fig. 7 shows that methanogenesis digester of the minimum ballast produces biogas higher of 157.14 %. This data elucidated that methanogenesis digester is better for arachea methanogen growth which is shown by Fig. 3 about temperature observation and Fig. 5 about pH observation.

Fig. 8 and Fig. 9 show total production of hydrolysis and methanogenesis digester with HRT of 40 d. Fig. 7 shows total biogas production of hydrolysis and methanogenesis digester. Furthermore, Fig. 9 is separation biogas production of Fig. 8 which shows biogas production of hydrolysis and methanogenesis digester as shown by Fig. 6 and Fig. 7. Fig. 8 shows that production of two treatments is similar relatively of 0.026 $m^3 \cdot kg^{-1}$ DH-JcL. This production data represents an increase of 163 % than DH-JcL in single phase digester which produce of 0.016 $m^3 \cdot kg^{-1}$ DH-JcL [4]. The production data of DH-JcL biogas on this research shows cow dung biogas productivity range of (0.023 to 0.04) $m^3 \cdot kg^{-1}$ [40, 41], which is higher compared to rice husk biogas production (0.014 to 0.018) $m^3 \cdot kg^{-1}$ DM [42].

The increased biogas production of 163 % was relevant because some of previous researches reported the increasing productivity of two phase digester than single phase digester. Demirer and Chen [43] noted the increase of 150 % to 167 %; Hagesawa et al. [44] reported increasing of 150 %; Sarada and Joseph [45] stated 124 % to 144 %. However, this result was lower than the results of Sirirote et al. [46].

Statistical inference by t test on biogas production at methanogenesis digester and total biogas production of hydrolysis and methanogenesis digester was shown by Table 1. Table 1 supports Fig. 7 that biogas production of methanogenesis digester on minimum ballast produces biogas more than maximum ballast and it is very significant different of statistical. It also supports Fig. 8 that every treatment of ballasts produces similar total biogas relatively and it is not significant different of statistical. Determination of methane content with orsat apparatus is shown by Table 2.

Table 2 shows that biogas content average of minimum ballast is higher than maximum ballast. Table 2 also shows that methane content of two phase digester is higher than single phase digester [4] which supports Parawira [11] and Paranjpe et al. [47]. Table 2 shows that "the weakness" of this study because Deublein and Steinhauser [28]; Quang [48] said that hydrolysis digester produced CO_2 and H_2 only. Whereas, Table 2 shows that there is high methane content. Moreover, Fig. 9 shows that biogas production percentage of hydrolysis digester is higher than methanogenesis digester which is showed also by Table 3. This was related with the delay time of hydrolysis digester which was suspected too long. This was suspected also that this research was conducted on rain season, so DH-JcL had been degraded on harvesting which was different with previous references [17, 19, 22].

However, this study was stated "wrong", if it referred to system of Hutnan et al. only [49] which suggested capturing and flowing biogas from methanogenesis digester only. Some other researchers [50, 51] suggested about collaboration system of biogas production from hydrolysis and methanogenesis digester. Furthermore, there was also another system, namely capturing and flowing biogas production separately between hydrolysis and methanogenesis digester [12, 52].

3.3 Review on VFA/ Alk. Ratio

Table 4 VFA average, Alkalinity, and VFA/alkalinity data in two phase digester of methanogenensis was compared to single phase digester with DH-JcL as raw material

Total volatile acid (acetic acid) ratio to total alkali (calcium carbonate) – VFA/Alk is an important indicator to check acid and base balancing or process stability of digester [23, 53, 54]. This data is shown by Table 4. Table 4 shows average of VFA/Alk on two phase digester of 0.50 which is similar with previous research on single phase digester [4]. This average ratio is higher than recommendation of reference [9] of < 0.25 or ratio recommendation reference [35] of 0.1 to 0.25. However, Bolzonella [55] said that high carbohydrate material, such as DH-JcL which shown by reference [1], was recommended by ratio of > 0.3. Drosg [56] supported that ratio parameter of VFA/Alk was not generalized because every type of digester has different ratio standar value which was affected by processed raw material.

The review shows that there were some researches who reported ratio of > 0.5. Kaosol and Sohgrathok [57] said that ideal ratio was 0.4 to 0.8; Powar et al. [58] stated that ideal ratio was 0.5 to 0.8; Schon [59] and Acton [60] stated that ideal ratio was > 0.9 to < 1.0. Therefore, based on reference [56–60], ratio average of 0.5 which was resulted by this research and previous research [4] was able to deem as "fair". Moreover, average ratio on two phase digester with minimum ballast

Table 1. t test for biogas production d^{-1} in two phase digester of DH-JcL with two ballast treatments.

Treatment	Biogas Production			
	Methanogenensis Digester		Total	
	Average	Sig	Average	Sig
Maximum ballast	0.1768		0.6436	
Minimum ballast	0.2739*	0.000	0.6464**	0.962

*) Significant different
**) Not significant different on trust level of 95 %

Table 2. Methane content of hydrolysis and methanogenesis digester.

Treatments	Biogas Content	
	Hydrolysis	Methanogenesis
Maximum ballast	79.73	89.55
Minimum ballast	81.81	91.13

Table 3. Biogas production percentage of hydrolysis and methanogenesis digester compared to total.

Treatment	Hydrolysis	Methanogenesis	Total
Maximum ballast	73.08 %	26.92 %	100 %
Minimum ballast	57.69 %	42.31 %	100 %

Table 4. VFA average, Alkalinity, and VFA/alkalinity data in two phase digester of methanogenensis was compared to single phase digester with DH-JcL as raw material.

No.	Content	Two phase metanogenesis digester					One phase *)	+/- One/ Two Phase
		1st wk	2nd wk	3th wk	4th wk	Average		
1	VFA**)							
a	Maximum ballast	1 239	1 293	1 486	1 297	1 329		-13 %
b	Minimum ballast	1 521	1 253	1 213	1 015	1 251		-18 %
	Average					1 290	1 532	-16 %
2	Alkalinity***)							
a	Maximum ballast	3 572	4 408	3 420	3 534	3 734		+16 %
b	Minimum ballast	1 860	1 820	2 064	2 290	2009		-37 %
	Average					2 872	3 211	-11 %
3	VFA/Alk Ratio							
a	Maximum ballast	0.35	0.30	0.40	0.40	0.40		-20 %
b	Minimum ballast	0.80	0.70	0.60	0.40	0.60		+ 20 %
	Average					0.50	0.50	0 %

*) Praptiningsih et al, [4]. (one phase = single phase digester)
**) mg Acetic Acid L^{-1}
***) mg $CaCO_3$ L^{-1}

of 0.6 was not able to conclude that minimum ballast was worse than maximum ballast. Table 4 shows that ratio value of minimum ballast decrease from 1 wk to 4 wk (0.80 to 0.40). It indicated that performance of hydrolysis and methanogenesis digester on minimum ballast works optimally. Table 4 also shows that two phase digester is better than single phase because decreasing VFA average of 16 % with minimum ballast treatment of 18 %. For alkalinity average, it is decreased of 11 % for minimum ballast of 37 %.

4. CONCLUSIONS

DH-JcL biogas productivity is increased in two phase system, with resulted increment of 163 % compared to semi continuous single phase system. Furthermore, it produces methane content (90 % to 91 %), higher than semi continuous single phase system (83.15 %). VFA average decrease of 16 %, alkalinity average decrease of 11 %, and average ratio of VFA/ alk is 0.5.

The two-phase treatment is hydrolysis digester with DH-Jcl and diluent water of 1:8 as feeding. Ballast pressure placed on the DH-JcL bundle with 50 % weight of original one produced the best result. Methanogenesis digester is attached to growth system with immobilized growth which is produced by special plastic design and placed on random packing.

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