The modification for increasing productivity at hydrolysis reactor with *Jatropha Curcas* linn capsule husk as bio-methane feedstocks at two stage digestion

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Abstract

Indonesia energy depends on fossil fuel which its availability get decrease; the price get higher day by day and the environment impact get worse on global warming. As tropical and agricultural country, Indonesia has plenty of biomass; therefore it was feasible to develop bio-fuel. In other, bio-fuel production must be wise because there were competition among food – feed – fuel. *Jatropha curcas* Linn (JCL) was one of non-edible bio-fuel resources, but there was mistake in development at Indonesia. This paper describe 8\(^{th}\) study of gaseous bio-fuel from bio-methane with capsule husk as feedstocks, the waste of Crude Jatropha Oil (CJO). The study was conducted in Research Farm PT. Bumimas Ekapersada, Bekasi, West Java, from October until December 2011 to enhance the development of liquid bio-fuel – CJO / bio-diesel and gaseous bio-fuel – bio-methane in the concept of bio-refinery. Bio-methane was modern cooking fuel and the most efficient energetically. The utilization of industrial waste such as capsule husk will not compete with the food, but one of the problem was its low density, so the husk will float in the substrate. The problem can be solved by two stage digestion process, where hydrolysis reactor as process controlling. HDPE plastic drum with the volume of 160 liter was used as hydrolysis reactor. The reactors were arranged using Randomized Complete Design, three replications. The observed parameters were pH, temperature, substrate volume, volatile solid concentration, and acet acid concentration This paper was focused on reporting of application technology modification on placement of ballast as oppressor substrate in hydrolysis reactor. 19 kg of cement slabs is used to

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suppress 13 kg dried husk (DH) + river water with the ratio 1: 8. The ballast was installed on 4, 7, 10 and 14 days of harvest retention time of hydrolysis substrate. The result showed ballast application can increase of hydrolysis substrate volume from 33.19% until 47.25% even no significantly different by statistical analysis. There was increasing in acetic acid concentration (93.27% - 128.51%) and statistical analysis showed significantly different on 4 days treatment. There was increasing on hydrolysis solution production on 4 days treatment (229.48%) and it was significantly different according statistical analysis. As the conclusion, the usage of 19 kg ballast as oppressor can increase hydrolysis solution productivity on 160 liter HDPE hydrolysis reactor with concentration 1 : 8 on 4 days harvest retention time.

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Key words : Bio-gas/bio-methane, capsule husk, jatropha curcas linn, two stage digestion, bio-refinery

1. Introduction

The failure of Jatropha curcas Linn (JCL) in Indonesia is because JCL farmer was only recommended to produce CJO - Crude Jatropha Oil. CJO will be processed into Pure Plant Oil (PPO) or Straight Jatropha Oil (SJO) with the final product is bio-diesel. For the other, JCL farmer was recommended to burn JCL seeds directly in the bio-mass stove [1]. JCL does not attract for Indonesian farmer because they get unsufficient income from JCL process. Green energy from JCL does not able to compete with fossil fuel which is subsidized by government. CJO is only 17 – 25% from dry weight seed [2, 3, 4]; and the rest is waste called seed cake (Jatropha curcas press cake, Jatropha curcas defatted waste). The other waste is husk (jatropha fruit coat, capsule husk, fruit husk, hulls, shell, fruit shell, peel, fruit encapsulate) approximately 30 – 80% from fresh fruit weight [5, 6] or 8 – 15% from dry weight [7]. JCL seed is only 20 – 70% from fresh fruit weight of JCL.

Reference said that organic residue from JCL is big business [8 and 9] that can increase the income of JCL cultivation. Some experts [10-12] suggested to apply bio-refinery system management in JCL waste processing. Bio-refinery has zero waste system, waste from one process will become raw material for another process to increase efficiency or income [11, 13, 14]. Hasanudin, U., and R. Haryanto [6] reported from their research at Way Isem Self Sufficient Energy Village (SSVE), North Lampung, that integrated management among JCL cultivation, CJO processing and bio-methane has impact on increasing of income than without bio-methane. SSVE Way Isem used seed cake as bio-methane feedstocks [15]. It is not advisable application because seed cake has potency to be used as animal or fish feed [16]. JCL husk was claimed that it was not suitable for bio-methane substrate [10 and 17] because of slow degradation. But, other researchers [18 and 19] said that JCL husk was feasible to be used as bio-methane feedstocks. Lopez, et al., [20] showed from laboratory research scale in Nicaragua that JCL husk in up flow anaerobic filter can produce 2.5 L of biogas with 70% methane content. This data was supported by other researchers [5 and 21]. M.S. Dhanya, et al. [22] at digestion batch reactor in laboratory scale conducted study by mixing JCL husk and cattle dung. He got maximum methane quantity on ratio 2 : 1 (cattle dung : husk), with the result of methane was 403.84 L/Kg dry matter. On 100% of husk utilization, the methane was lower, 91%, than cattle dung. Salafudin, et al. [23] said that husk can produce 438 mL of bio-methane / g volatile solids in laboratory scale.

The reported production was bigger than Dhanya, M.S. et al. [22]. The production was also bigger than production from seed cake that was used as control, 147 mL of bio-methane / g VS. Ali N., et al. [24] said
that seed cake can produce bio-methane bigger than cattle dung in quantity. Based on that information, JCL husk has potency to be used as bio-methane feedstocks. Previous research [25, 26 and 27] said that problem of dried husk to be digester substrate is bulky, low density, slow degradation, high C/N ratio, and low buffer capacity. Solving the problems, Hendroko, R., et al [28] suggested using two stage digestions. The reason behind that solution is due to some researchers [part of them 29 and 30] in several papers on clean water processing, dairy cow manure waste, bit sugar waste, sisal processing waste, fruit and vegetable waste, potato processing waste, tomato, sweet sorghum, vine and municipal solid waste concluded that two stage is more efficient and effective than one stage/ single digester.

Hydrolysis phase is process controlling in two stage digestion. Several papers [part of them 29 and 31] claimed that statement. But in hydrolysis reactor with JCL husk as feedstocks will need further study, related to low dried husk density. Previous research [32] reported the effort to increase solution productivity in hydrolysis reactor in form of 160 liters HDPE plastic which done by controlling solution concentration and hydrolysis solution harvest retention time. As the conclusion, the optimum concentration with HDPE plastic drum was 1:8, but there was a problem because some JCL dried husk floated and it made hydrolysis solution productivity became not maximum. This paper will report on effect of modification in hydrolysis reactor to increase quantity and quality of JCL substrate as bio-methane feedstock.

2. Method

The research was conducted in Research Farm PT. Bumimas Ekapersada, Bekasi, West Java, from October until December 2011. The hydrolysis process was conducted by soaking 13 kg JCL dried husk (JCL-DH) cultivar JatroMas mix with river water on the concentration 1:8. The activity was placed in HDPE (high density poly ethylene) plastic drum. This HDPE plastic drum is available in Indonesia market as used or new good. Preventing JCL dried husk float in plastic drum, 19 kg cement ballast was used as oppressor of JCL dried husk and water.

The hydrolysis reactors were arranged using Randomized Complete Design in 3 replications, with t test method for statistical analysis. The volume of hydrolysis reactor is 160 liters and approximately 25% above from bottom is installed water valve. Periodically, every 4, 7, 10, and 14 days hydrolysis solution was taken out from plastic drum and distributed into methanogenesis reactor by semi batch method. The daily observed parameters are pH and temperature in hydrolysis solution. And periodically parameters are acetic acid concentration, volatile solid (VS), and hydrolysis solution volume.

3. Result and Discussion

In this research, there is modification to put ballast as oppressor JCL dried husk in hydrolysis reactor that shows at figure 1. The ballast is made from cement to prevent dissolution and corrosion if use metal material. It also prevents toxic impact for micro-organism in hydrolysis and methanogenesis reactor based on fixed dome reactor models. The hydrolysis reactor productivity with and without ballast is presented in Table 1. The submersion is conducted during 28 days with concentration of JCL-DH and river water is 1:8.
Table 1. The productivity of JCL – dried husk hydrolysis solution with and without ballast during 28 days of hydrolysis process

<table>
<thead>
<tr>
<th>Retention Time (days)</th>
<th>Hydrolysis Solution Volume (Liter)</th>
<th>Acetic Acid Concentration (mg/L)</th>
<th>Hydrolysis Solution Production (Liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>4</td>
<td>248.15</td>
<td>338.77</td>
<td>36.52</td>
</tr>
<tr>
<td>7</td>
<td>130.82</td>
<td>192.10</td>
<td>46.84</td>
</tr>
<tr>
<td>10</td>
<td>101.48</td>
<td>149.43</td>
<td>47.25</td>
</tr>
<tr>
<td>14</td>
<td>72.15</td>
<td>96.10</td>
<td>33.19</td>
</tr>
</tbody>
</table>

Note: A = Treatment without ballast; B = Treatment with ballast; C = % increase; *) = Significantly different by t test

Fig 1. Hydrolysis reactor and ballast as substrate oppressor

Table 1 shows 19 kg cement ballast can increase hydrolysis solution quantity that shown by increasing of hydrolysis solution volume. The increasing happened in all treatment (4, 7, 10 and 14 days) and the range of volume are from 33.19% until 47.25% even no significantly different by statistical test. It is due to cement ballast can suppress JCL – dried husk effectively so the trapped water in JCL-DH can release more in volume. The hydrolysis solution quality which is mentioned as acetic acid concentration (mg/L) also can be increased with cement ballast. The range of acetic acid concentration (mg/L) in 4 variables retention time treatments are 93.27% - 128.51%. It is because B treatment applied ballast as oppressor, so JCL-DH more submerged than a treatment.

Statistic test showed that 4 days treatment is significantly different than other treatments. Table 1 shows that 4 days treatment is the highest acetic acid producer, 1493.98 liters in 28 days which this conclusion supported by Hendroko, R. et al [32]. As shown in Table 1, the highest increasing of acetic acid production with adding ballast is shown in 4 days treatment, 229.48%. This percentage figure is result of rising acetic acid concentration. The statistical tests of two variables are significantly different. Previous research [32] assumed 28 days of submersion time was not optimum for JCL-DH. To study this assumption, time for treatment B (with ballast) was prolong. The pH observation during 56 days on JCL-DH hydrolysis with concentration 1:8 is shown in Figure 2.
Figure 2 shows the average pH from 4 treatments is 5.89 with range from 5.40 - 6.37. The average pH is getting higher on longer harvest retention time. Based from Figure 2, it concluded that by prolong the submersion time, pH especially on 4 days retention time was getting lower and hopefully, it will give good impact on acetic acid production. But, refer to previous researches, pH 5.89 is eligible pH for hydrolysis because some research [part of them 29 and 30] said that pH range for hydrolysis is 4 – 7. Figure 2 shows trend of pH which is relatively same in all 4 treatments, pH declining from day 1 and start to going up on day 10. Hendroko, R. et al. [25] report the same condition, pH start to increase on day 7. Previous research [33] said the optimum hydrolysis happened in that condition. At that condition, there is termination reaction of the polymeric bonds in polysaccharides, lipids and proteins. After optimum hydrolysis, pH will decline because of organic acid, such as butyric, propionic and acetic acid. Figure 2 shows this situation, there is declining on pH particularly on day 15.

Figure 3 shows temperature data from hydrolysis process in average temperature of 30.63°C or in range of 28.45°C – 34.28°C. This temperature is in mesophilic living temperature range as said several researchers [part of them 34] that is 13 - 40°C. Even two researchers [35 and 36] said 28.45°C – 34.28°C is optimum growth condition because mesophilic microbe lives in minimum temperature of 10 - 20°C, maximum temperature is in 35 - 45°C and optimum in 28 - 33°C. As the conclusion, 160 liter HDPE
plastic drum is feasible to be used as hydrolysis reactor with JCL-DH as feedstock because able to show optimum pH as shown in Figure 2 and optimum temperature to support life of microbe as shown in Figure 3.

4. Conclusion and Suggestion

From report of this 8th study which applying modification in hydrolysis reactor phase at two stage digestion, it can be concluded:

- The productivity of hydrolysis solution with JCL dried husk as feedstock in 160 liter HDPE plastic drum can be increased with add 19 kg cement ballast.
- The cement ballast as oppressor can increase:
  - Hydrolysis solution volume, 33.19% - 47.25% compared to no ballast
  - Acetic acid concentration, 93.27% - 128.48% compared to no ballast
  - Hydrolysis solution production, 157.16% - 229.48% compared to no ballast
- 4 days retention time is the highest acetic acid producer, 1493.98 liters in 28 days.
- 160 liters HDPE plastic drum is feasible to be used as hydrolysis reactor with JCL – dried husk as feedstock because it can keep pH and temperature in optimum range during 56 hydrolysis days.

It is suggested to do further study on impact of ballast in hydrolysis reactor and 4 days of hydrolysis solution harvest retention time on methanogenesis reactor.

References


[12] Popluechai S. Molecular characterisation of Jatropha curcas; towards an understanding of its potential as a non-edible oilseed-based source of biodiesel. Faculty of SAgE Newcastle University, School of Biology, November 2010.


