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BIO-REFINERY STUDY IN THE CRUDE JATROPHA OIL PROCESS: CO-DIGESTION SLUDGE OF CRUDE JATROPHA OIL AND CAPSULE HUSK JATROPHA CURCAS LINN AS BIOGAS FEEDSTOCKS

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ABSTRACT

One of the cultivation failure reasons of *Jatropha curcas* Linn (JcL) in Indonesia was that it was only recommended for Crude Jatropha Oil (CJO) production which is processed into biodiesel. CJO is only 17-25% of dry seed weight, while the waste residue is called seed cake. Another waste product is dried capsule husk (DH-JcL) which is about 30-80% of the fresh fruit weight and sludge CJO (S-CJO) or about 2-5% of the CJO. S-CJO was unutilized which is bad for the ecology when it is disposed. The research objective was the utilization of the S-CJO waste for bio-refinery and improvement productivity of biogas made from DH-JcL.The study was conducted at the research garden of PT Bumimas Ekapersada, Bekasi, West Java in November-December 2012. A liter one-stage digester was compiled completely as a randomized design (CRD) with three replications in a water bath at a temperature of 32^{o}C. The materials used were DH-JcL of JatroMas cultivars in the toxic category which were mixed with the sludge S-CJO as a co-substrate about with 10% water at a ratio of 1:8. Observation variables were biogas production volume (water displacement method), pH and temperature in the outlet slurry. The preliminary study concludes that S-CJO is appropriate as the co-substrate DH-JcL. It can increase the biogas productivity with feed in less than 10% of S-CJO allocation per day.

Keywords: Biogas; Capsule husk; Co-digestion; Jatropha curcas Linn; Sludge crude jatropha oil

1. INTRODUCTION

The usage of Indonesia's energy relies on fossil oil. However, considering things such as the reduction of the availability of fossil fuels and the increasing price, increasing energy subsidies, and the impact on the ecology, Indonesia plans to switch gradually into a renewable energy with a target of 2025, known as the 25/25 program (Sumiarso, 2011). In the 25/25 program, Bio-energy/biofuels will occupy the largest share, which is 8.9% (Warnika, 2012). However, bio-energy is often contrasted with the provision of food and feed related to edible oil. *Jatropha curcas* Linn (JcL) is a non-edible energy crop, but it failed to be developed in Indonesia.

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One of the JcL cultivation failure reasons in Indonesia is that the farmer was recommended to produce Crude Jatropha Oil (CJO) only. CJO is processed into Pure Plant Oil (PPO) or Straight Jatropha Oil (SJO) and further processing occurs into biodiesel (Hendroko et al., 2012). In fact, a number of experts (Makkar & Becker, 2009; Manurung & Heeres, 2009; Popluechai, 2010) suggested to apply a bio-refinery along with the JcL cultivation. A bio-refinery is the zero waste process which involves waste from one process used as raw material and then it is transformed to another process for increasing efficiency and/or income (Kaparaju et al., 2009; Omolola, 2007).

CJO is only 17-25% of dry seed weight (Jongschaap et al., 2007; Singh et al., 2008), while the waste residue is called seed cake (jatropha curcas press cake, jatropha curcas defatted waste) and Sludge CJO (S-CJO) which is about 5-10% of the CJO. Another waste product is dried capsule husk (DH-JcL) (jatropha fruit coat, fruit husk, hulls, shell, fruit shell, peel, fruit encapsulate) measuring up to 80% of the fresh fruit weight (Hasanudin & Haryanto, 2010) or 8-15% of dry weight (Praptiningsih et al., 2010). Seed cake was able to be used as a mixture of animal feed, while the DH-JcL was recommended for biogas feedstocks (Salafudin et al., 2011). However, S-CJO was unutilized which is bad for the ecology when it is disposed.

Solving the S-CJO waste problem, a preliminary study was undertaken for co-digestion utilization in the biogas digester with DH-JcL as the feedstock. Co-digestion is the simultaneous digestion of more than one type of waste in the same unit (Agunwamba, 2001) and was first introduced in Denmark in the late 1980's. A number of studies reported that two or more waste mixtures as a substrate increased biogas production compared to a single substrate (Iyagba et al., 2009). Another shows that the biogas manure production increased two times with 5-20% fatty washes as a co-substrate (Ahring, 2003). In particular, one study reported that 5% of the JCO as a co-substrate with DH-JcL could increase 32.17% of the biogas production (Praptiningsih et al., 2013).

2. METHODOLOGY

The study was conducted at the research garden of PT Bumimas Ekapersada, Bekasi, West Java in November-December 2012. On this laboratory scale, a liter glass laboratory digester was used as a one-stage digester which was compiled in a completely randomized design (CRD) with three replications in the water bath at a temperature of 32^{o} C (Figure 1).

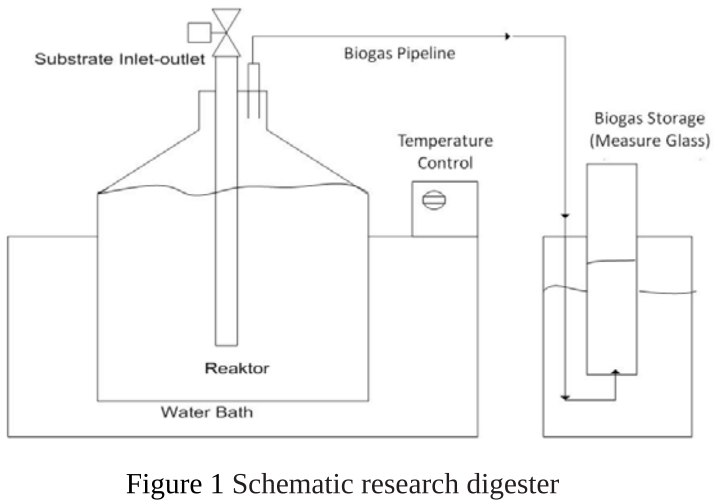

Figure 1 Schematic research digester

The materials are DH-JcL from the JatroMas cultivars in the toxic category which was mixed with sludge S-CJO as a co-substrate with about 10% water at a ratio of 1:8. DH-JcL was mixed with water in 1:8 ratio as a control treatment. Slurry from the DH-JcL digester with 4 weeks of retention time was used as an innoculum. Four grams of DH-JcL and 36 cc of water were added and removed from the digester everyday based on a draw and fill method (Velmurugan & Ramanujam, 2011). When the biogas production decreased, the volume reduction actions were conducted in the incoming feed. Treatment trials in the incoming feed volume were 0% (no pass through), 50% (2 g DH-JcL), and 100% (4 g DH-JcL) with the 1:8 ratio in additional water concentration every day. Observation variables were biogas production volume (water displacement method) (Parajul, 2011), pH (pH meter) and temperature (digital thermometer) in the outlet slurry.

3. RESULTS AND DISCUSSION

Observation of pH during the preliminary study is presented in Figure 2. Figure 2 shows the pH data of the treatment test compared with the control. The results showed that pH average of the outlet slurry of the treatment and control about 5, with the pH value of the treatment that was relatively lower than the control, especially at 1st and 2nd week. Acidic pH associated with low bicarbonate alkalinity was one of problems in the DH-JcL digester. Research at the laboratory of National University de Ingenieria, Managua, Nicaragua reported that DH-JcL digester pH value was between 5.18–5.80. Acidic pH is not the ideal pH for the biogas process and it is able to add NaOH at the preliminary process. However, NaOH were not the appropriate chemicals because there was not the problem of low bicarbonate (Gerardi, 2003). In this study, NaOH addition was not conducted to examine the S-CJO ability as a co-substrate for biogas productivity acceleration, especially in one stage digester.

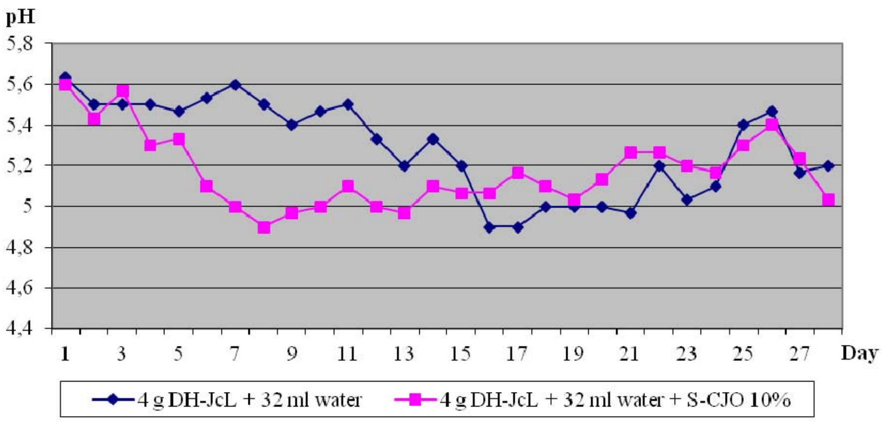

Figure 2 Comparation of pH curves for outlet slurry of the treatment than the control

The curve in Figure 2 had a similarity with previous studies (Salafudin et al., 2011; Hendroko et al., 2012; Praptiningsih et al., 2013) in which the pH decreased at the beginning and also at intervals of one time increases. The increasing of pH happened at the 16th day when the hydrolysis was at the optimum stage. Table 1 shows the biogas production and the pH levels in the first week

Table 1 The biogas production and pH outlet slurry in the first week

Variable	pH	Biogas production average/day	Production Enhancement
Treatment	5.33	60.2 ml/g VS	15.24%
Control	5.73	52.24 ml/g VS	-

Table 1 shows the treatment of DH-JcL with S-CJO (10%) as a co-substrate which produce biogas at a higher rate (15.24%) than at the control level. Table 1 supports the statement that fatty or oily wastes are able to increase biogas production since they have a much higher concentration of organic material (Ahring, 2003; Deublein & Steinhauser, 2008; Al Setiadi & Lukehurst, 2012). As can be seen from Figure 2, there is the enhancement ability indicative of biogas productivity. More acidic pH value in the treatment would have ability to stimulate acetate acid production as the main precursor of methane formation. However, as can be seen on Table 1, production enhancement is relatively smaller than in previous studies (Praptiningsih et al., 2013) using CJO as a co-substrate. This case happens as the negative impact of lower pH value occurs. There is only one bacteria genus of methane formation in pH 6.5 (from 7 genus of methanogen bacteria) which could survive, namely *Methanosarcina* (Deublein & Steinhauser, 2008). The second week's condition is showed in Table 2.

Table 2 The biogas production and pH outlet slurry in the second week

Variable	pH	Biogas production average/day	Production Enhancement
Treatment	5.00	14.38 ml/g VS	-
Control	5.39	21.96 ml/g VS	52.71%

Table 2 shows that the condition is reversed if it compared to Table 1, then the biogas production in the control was higher than the treatment at a level of 52.71%. There is decrease in the biogas production at the second week compared with the first week, in the amount of 76.11% for the treatment compared with 60.27% for the control. As can be seen, the pH value in both treatments is more acidic, lower pH is suspected due to the overgrowth of acid-producing bacteria so the impact of acidic production is more than the number of methanogen bacteria consumption. It leads to an unbalanced system and the obstructed methanogen bacteria which impacts the decrease of biogas production. A chemical application such as sodium bicarbonate, potassium bicarbonate, sodium carbonate (soda ash), potassium carbonate, calcium carbonate (lime), calcium hydroxide (quick lime), anhydrous ammonia (gas), or sodium nitrate is suggested in order to increase alkalinity (Gerardi, 2003). Calcium hydroxide was used because it is relatively inexpensive, although these kinds of chemicals are inappropriate in dealing with bicarbonate alkalinity.

Based on ecological considerations, especially to minimize chemicals usage, slurry recirculation into the digester was able to solve the problem of imbalanced bacterial growth (Salafudin et al., 2011). One of the slurry recirculation functions was to increase the methanogenic bacteria population, which was washed out in the digester outlet. Other actions that can suppress the growth of acid-producing bacteria, was interrupting the feed and allowing the methanogenic population time to reduce the fatty acid concentration and thus raise the pH. Interrupting the feeds obstruct the activity of the fermentative bacteria and thus reduce acid production (Deublein & Steinhauser, 2008). Therefore, reducing the feed entrance test was conducted in the third week to the digesters A, B and C respectively. It was 0% (no pass through), 50% (2 g DH-JcL), and 100% (4 g DH-JcL). Table 3 shows the pH value and the biogas production which was the result of the action.

Table 3 shows that the daily biogas production ranks respectively in 2nd week occurs in Digesters A, B, and C. The worst condition occurs in Digester A. The feed was set to 0% (no feed) during a week-long period. Digester B was set at a 50% feed level (2 g DH-JcL), and Digester C was set at a 100% feed (4g DH-JcL). The results of the variations in feed level at the 3rd week can be seen in Table 3.

Table 3 pH value and biogas production after volume reduction treatment of incoming feed

Information	Digester A (week)			Digester B (week)			Digester C (week)		
	2nd	3rd	4th	2nd	3rd	4th	2nd	3rd	4th
pH value	4.96	5.14	5.25	5.0	5.13	5.20	5.05	5.15	5.27
Biogas production (ml/g VS)	10.93	26.83	23.85	13.91	16.90	22.08	22.86	14.90	15.90
Rank of biogas production	3	**1**	**1**	2	2	2	**1**	3	3

Digester A rose to the 1st in ranking with 26.83 ml / g VS and then it was followed by Digester B and C respectively with 22.08 ml/g VS and 14.90 ml/g VS. At the 4th week, given the assumption that the condition had been resolved, Digesters A, B, and C were given feed levels of 50% (2 g DH-JCL). This action shows that the daily biogas production results in Digesters A, B and C respectively. Table 3 also shows that 5% (2g DH-JcL) feed levels were more stable in producing biogas than the others. Besides that, Table 3 shows that the pH value of about 5 had a difference in the biogas production volumes for Digesters A, B, and C. The pH value was not the appropriate variable for monitoring biogas fermentation especially which contained highly buffered substrates such as agricultural wastes (Gerardi, 2003; Boe, 2006; Bjornsson, 2000). DH-JcL was suggested to have these properties since another JcL waste (the seed cake) was reported as having a very high buffering capacity (Schmidt, 2011).

4. CONCLUSION

The preliminary study concluded that S-CJO was proper as a co-substrate for DH-JcL since by increasing the biogas production, the pH value can be resolved by reducing the levels of feed or no feed into the digester and that the pH value alone was not proper for monitoring the DH-JcL digester. The research is currently in progress to solve the problems of acidic pH in which biogas production is not optimal. The study has been conducted by reducing the S-CJO volume to about 50%, using urea as an additive and application in two-stage digestion.

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