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Bioconversion of Pineapple Solid Waste under Anaerobic Condition through Biogas Production

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Abstract

Biogas production from pineapple peel was to preliminary study for value added to this agro-industrial solid waste. The objective of this research was to fine the optimum condition for maximum biogas production. The experiments were performed in a lab-scale of 6 liters of bioreactors at ambient temperature (approx. 30 ^{o}C). The biogas production was conducted under single stage batch processes with initial COD concentration of 20,000 mg/l. The conditions affected biogas production, such as type of microorganism, pH value, carbon to nitrogen ratio, as well as the organic loading rate, were investigated. The results showed that pineapple peel solid waste can be generated successfully to be a methane gas of an attractive concentration of 48% at 20 days by using the indigenous microorganism. The optimum pH was at 7.0 with a controlled carbon to nitrogen ratio of 20. The removal of COD was 61.49 %. In further, the result of fed batch operating system indicated that the higher amount of biogas was achieved when operated with lower organic loading rate (1 kg of organic/ m^3/ day).

Keywords: Biogas, Pineapple peels, Bioreactor, Carbon to nitrogen ratio, Organic loading rate

1. Introduction

Pineapple peel from fruit canned industries is generated in large amount everyday approximately 35% based of raw material [1] or about 10 ton per day from one medium size industry [2]. Fewer occasions, pineapple peel can be used as animal feed. Normally, this large amount of fruit waste was dumped into the environment which the anaerobic digestion can be naturally occurred. Consequently, the environmental problems, including the formation of methane gas from oxygen deficit condition occur. Methane gas is one of greenhouse gases which have 25 times higher potential to cause global warming than carbon dioxide [3].

This agro-industrial fruit waste consists of high moisture content and full of carbon source, biogas production from this fruit wastes is effectively solution for waste management. The biogas has been accepted to be one of the best alternatives renewable energy [1]. The management with this appropriate technology can decrease an environmental problem, as well as reduce the global warming.

The biogas production mechanisms are composed of acidogenesis and methanogenesis processes through anaerobic digestion of organic matter. The produced biogas which achieved of 50% of methane has been addressed as a good quality of biogas [4].

In order to achieve this solid wastes management advantages, this research was to preliminary study to add the value to this agro-industrial solid waste by converting it to methane gas. The system was initiated with indigenous microorganism. As well as, the optimum condition for maximum biogas production in single stage reactor at room temperature was proceeded. The parameters affecting biogas production, such as, type of microorganism, pH value, carbon to nitrogen ratio, and organic loading rate on the COD removal performance were carried out.

2. Materials and Methods

The experiments were performed in closed bioreactors of 6 liters. The biogas production was conducted under batch and fed batch process at ambient temperature.

2.1 Substrates and seed cultures

Pineapple peel solid waste was collected from a fruit canned processing plant in Karnchanaburi province, Thailand, and stored at 4^{o}C before used. After that they were chopped into small pieces approximately 1 cm. in diameter before feeding into the reactor. The microorganisms used in this research were two kinds of mixed culture. One was collected from the same industrial sewage effluent and the other was the microorganism supported from one private company. Further, some chemical properties of pineapple peel were analyzed followed standard method [5].

2.2 Anaerobic bioreactors

The 6 liters bioreactors were custom built from polyethylene tanks. The middle of the reactor was installed with a shaft of impeller for mixing. Each reactor was equipped with two outlet ports; one for liquid sample withdrawal or for new organic loading in case of fed batch operation mode was running. The other was for gas passing to a gas collecting system base on water displacement by the existing gases.

2.3 Operation

Biogas production was started up by applying with chopped pineapple peel solid waste consisted of initial COD of 20,000 mg/l. This raw material was composed to fill up to approximately 4.8 liters working volume of the reactor. Single stage batch processes were operated at ambient temperature with 2 times of mixing per day for 30 days. The effects of pH value of the system, carbon to nitrogen (C/N) ratio were performed through the experiments. The observation of total amount of biogas was recorded everyday. Gas samples were taken every 5 days for methane analysis, as well as the liquids samples were collected for analysis of chemical oxygen demand (COD), total solid (TS), and volatile solid (VS).

In further, the discovered optimum condition was applied for fed batch mode operations. The organic loading rate of 1, 2, and 3 kg of organic / m^3/ day was fed and operated for the corresponding time of achieving maximum of methane. The total amounts of gas including of methane concentration were recorded. COD, TS, and VS were also analyzed in liquid slurries with the same methods as in batch processes.

2.4 Analytical methods

The liquids samples from sampling port were withdrawn every 5 days to analyze COD, TS and VS followed standard methods [5]. The total amount of biogas was measured everyday regarding to the amount of water volume displaced by the existing gases. Gas composition was analyzed off line by gas chromatography (Shimadzu GC-14B) equipped with a thermal conductivity detector (TCD) and 1 M Porapak Q (80-100 mesh) GC column. Helium was used as carrier gas with a flow rate of 25 ml/min. The column, injector and detector temperature were at 60, 120 and 120 ^{O} C, respectively.

3. Results and Discussion

3.1 Biogas production in batch process

In this study, the chemical properties of pineapple peel were analyzed in order to investigate the biogas generation potential of raw material (Table 1).

The accumulative gas recorded for 30 days with original pH (4.6) by using microorganism from sewage sludge was shown in Fig. 1. (Other seed microorganism was not made the system to generate gas, so the result was not shown). At present system, the acidogenesis process was occurred within 8 days of the experiment which appeared pH was lowest. After that the pH was gradually higher while the gas formation was noticeably accumulated for 20 days. However, less efficiency resulting from fewer amounts of total gas and methane were detected at this initial pH because of high content in both acid value and carbon to nitrogen ratio. This condition was not suitable for methane formation bacteria to grow up [4].

Table 1 The chemical compositions of pineapple peel solid waste

Compositions	Percentage
Moisture content (%)	79.97
pH	4.6
Total carbon (%)	53.83
Total nitrogen (%)	0.7
Carbon to nitrogen ratio	76.9

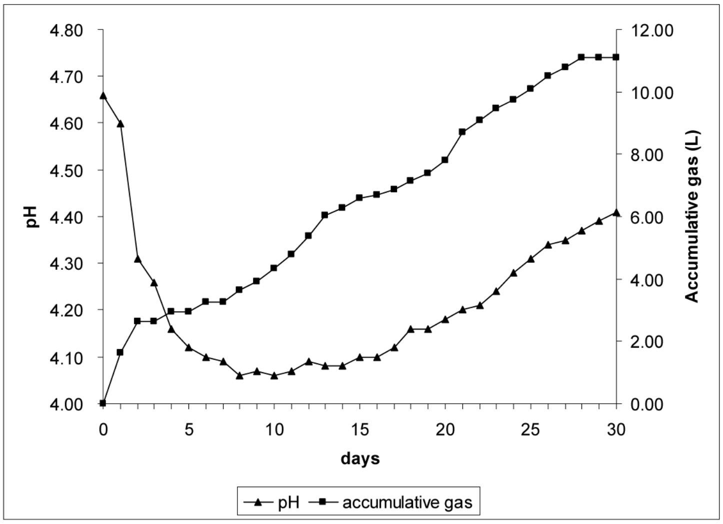

Figure 1. The change of generated gas and pH during the fermentation of pineapple peel

The comparison of gas generation between original pH (4.6) and controlled pH of 7.0 was conducted, since the pH value was important for biogas production. The amount of gas in system of pH 7.0 was generated faster and much more gas than that in uncontrolled pH system (Fig 2). The amount of gas was significantly increased from 11 liters within 28 days in original pH system to 50 liters within 10 days in the controlled pH system. Influence of pH to biogas system was previously mentioned by McCarty that the methanogenesis process in biogas production was preferred pH at 6.5- 7.5 [4]. However, the different result was also reported that the system performance to bioconversion of pulp and paper mill wastewater to methane did not fall down even of pH was lower than 6.0 [6].

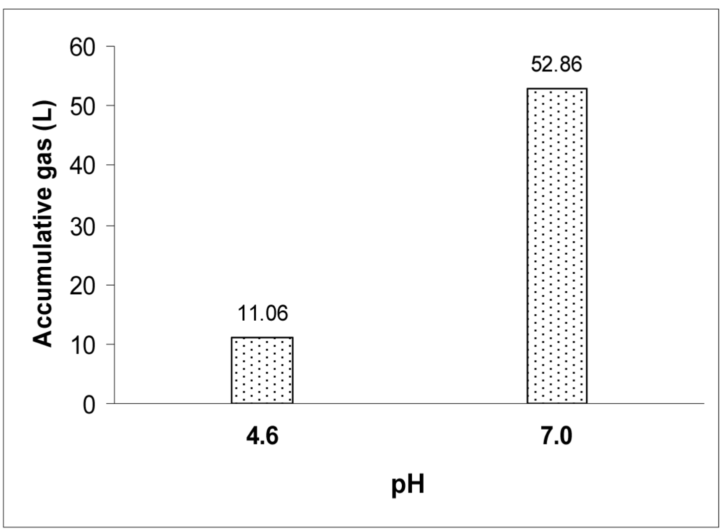

Figure 2. Accumulative gas obtained at original and controlled pH.

Nitrogen source was important for bacterial growth and considered to enhance biogas production [4]. Since the carbon to nitrogen ratio of the initial pineapple peel was very high (Table 1), this C/N ratio value was needed to be improved. As nitrogen can be supplemented to the system either in inorganic form (eg. nitrate) or in organic nitrogen forms as urea or animal manure [7], in this study, urea was selected as nitrogen source due to organic nitrogen was a nutrient and usually provided energy for the growth of microorganism, as well, it was easily digested by many microorganisms [8]. Inorganic nitrogen as nitrate was less suitable for nitrogen supplementation because nitrate generated oxygen when it broken down. Oxygen molecule disturbed methanogenesis process and consequently to diminish some quantity of methane [7].

In present work, the results revealed the total accumulative gases, as well as methane concentration generated during the fermentation at C/N ratios of 10 and 20 was higher than that at C/N ratio of 30 (Fig. 3). The enhancement of biogas was observed when the nutrient was supplemented. The maximum biogas production was obtained at 94 liters/ kg of COD removal at HRT of 20 days. This improvement was also elucidated by Viswanath et al. that bioconversion of mixed fruit and vegetable waste was completed at HRT of 20 days [9]. Further, the system which supplemented with nitrogen source to get C/N ratio at 20 could induce the methane concentration up to 48%. Other C/N ratios at 10 and 30, the methane content of 32.69% and 13.44% were achieved, respectively.

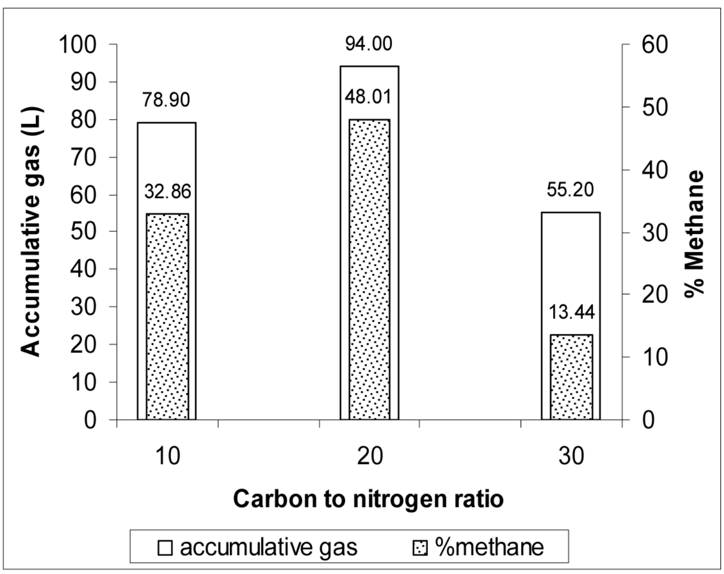

Figure 3. Biogas produced and percentage of methane achieved at various C/N ratio

The agreement to Rani and Nand was that the optimum C/N ratio for methane generation from ensilaged pineapple was at 20:1 [10]. Since nitrogen is an essential element for bacterial growth, the deficiency of nitrogen in the system of C/N ratio of 30:1 could inhibit growth of microorganism. On contrary, when nitrogen was excess in C/N ratio at 10:1, ammonia gas, which toxic to the microorganism, was produced and consequent to made total methane concentration to be decreased [11]. Nevertheless, this was not attentively detected because a covering digester prevented the mass transfer of ammonia from the liquid directly to the atmosphere [12].

In contrast, some opposite result expressed that the increment of nitrogen did not promote the biogas production from pineapple waste [7]. As well, the disagreement compared to Igoni et al. was indicated the remarkable condition for biogas production was at C/N ratio of 30, because carbon was degraded 30 times faster than nitrogen [13].

The biogas conversion from pineapple waste was obviously reported to yield of 0.3- 0.5 l/g dry substrate with 53 % methane content [14]. Also, the illustration of the amount of biogas produced from fresh pineapple waste was at 0.55 l/ g with 51% of methane, while biogas production from dried pineapple waste contained 41% of methane with biogas yield of 0.41 l/ g dry substrate [15]. Ensilage pineapple was also mentioned to produce 0.67 l of biogas per gram of substrate which contained a high content of CH_4 at 65% [8]. Nevertheless, the system performance of biogas production from pineapple waste in this study represented the biogas yield lower than those previously reported [14]. As a reason of the microorganism used in this study was different type and was not well acclimatized to the studied waste. However, the noticeable methane concentration in biogas was not significantly in differences from those previously reported [15].

Moreover, the system performance was represented by COD removal efficiency (Table 2). The total solid removal efficiency and volatile solid removal efficiency were also higher at C/N ratio of 20. It was about 60.36%, 61.44% and 57.32% of COD removal at C/N ratios of 10, 20 and 30, respectively.

Even of methane content in biogas at various C/N ratios was significantly different (Fig 3), but the noticeably COD removal was nearly the same (Table2). The discovered of Houbron et al., 1999 indicated the result of losing of some of organic carbon via denitrifcation in high nitrogen content liquid (C/N=10) and thus reduce the methane-producing potential to some degree [16]. In the other hand, at lower nitrogen concentration (C/N=30), bacterial performance was limit and induced to incomplete in methanogenesis process [12].

Table 2. The percentage removal of COD, total solid and volatile solid at various conditions

Percentage removal of	**Carbon to nitrogen ratio**			**Organic loading rate (kg/m ^{3}/day)**		
	10	**20**	**30**	**1**	**2**	**3**
COD	60.36	61.49	57.32	53.61	48.02	45.96
Total solid (TS)	43.57	44.26	42.29	33.91	23.94	21.10
Volatile solid (VS)	51.58	60.52	45.38	47.24	42.44	40.54

3.2 Biogas production in fed batch process

The amount of biogas and methane concentration at HRT of 20 days using various organic loading rates is illustrated in Fig 4. The results showed that at organic loading rate of 1 kg/m^3/day, the amount of gases as well as the percentage of methane was highest. The highest methane concentration was 32.96% at 1 kg/m^3/day of organic loading rate.

Also, COD, TS, VS removal efficiency at organic loading rate of 1 kg/m^3/day represented the highest removal efficiency over the other higher organic loading rate (Table 2). This indicated that COD removal, TS removal and VS removal efficiency were higher when the optimum condition was provided.

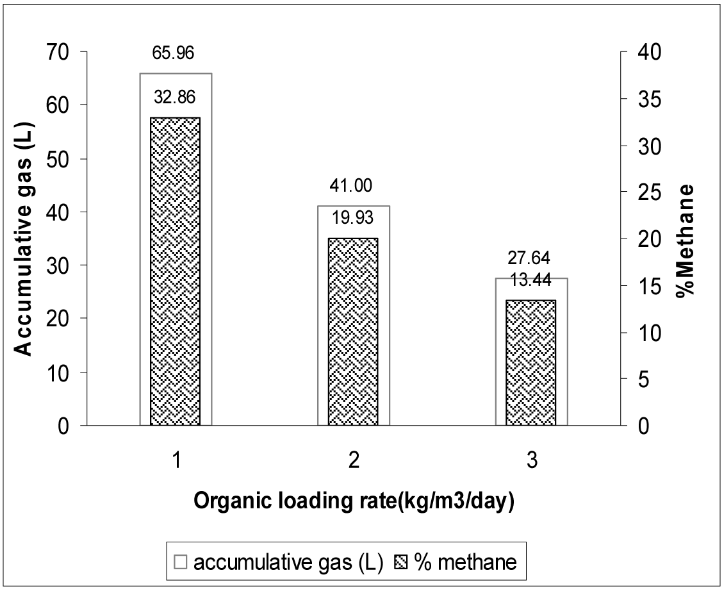

Figure 4. Biogas production and percentage of methane in biogas from various organic loading rates

The system performance in fed batch process compared to batch process in Fig 5 expressed the lower yield of biogas and methane in fed batch process. Regarding to the same operated hydraulic retention time (HRT), the higher organic loading rate influenced to lower degradation efficiency [17]. Since the biodegradation was not completely taken placed, the methane producing bacteria could not convert volatile acid to become methane resulting in a decrease in COD removal efficiency, lower the amount of gas, as well as the methane content [18]. This similar result was indicated that lower organic loading rate gave better biogas generation.

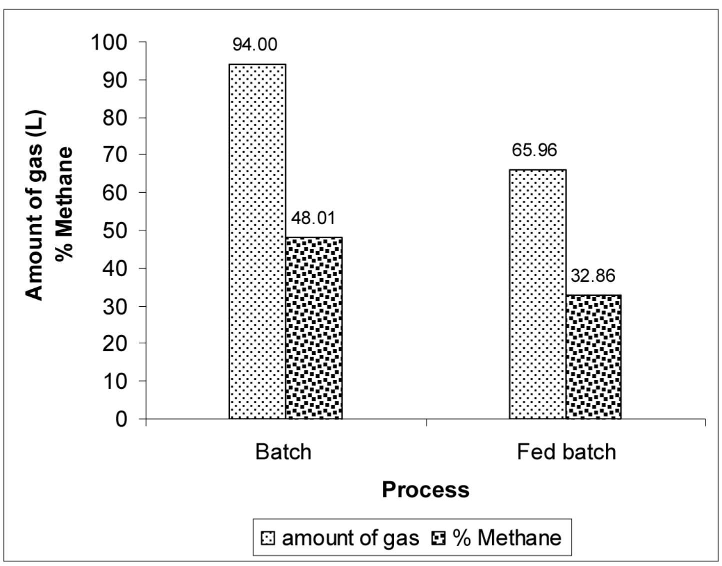

Figure 5. The amount of gas generated and percentage of methane comparison between batch and fed batch processes

4. Conclusions

Pineapple solid wastes were treated anaerobically to produce biogas. Methane gas, a main composition in biogas, was produced in both batch process and fed batch process, under significant difference performance. The efficiency of bioconversion to become methane in fed batch process was lower than that in batch process. The controlled pH value at 7.0 and adjustment carbon to nitrogen ratio to 20:1 was the suitable condition for biogas generation from this waste. The biogas containing 48% of methane was achieved in batch process. In fed batch process which applied with 1 kg organic/ m^3/ day of organic loading rate was the promising condition. The optimization of fed batch process is needed to be further studied. The biodegradation of pineapple peel solid waste to methane gas was expressed the potential for waste treatment through anaerobic digestion. Biogas production from this industrial fruit wasted was not only performed the environmental quality, but also provided the solutions for alternative green energy.

5. Acknowledgment

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