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The Production of Biogas from Cassava Tubers

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Abstract

We utilized a two-phase fermentation process for biogas production under anaerobic conditions using raw cassava tubers as substrate. Fifty grams of dried cassava tubers were ground, mixed with 200 ml of water and added into an acid tank with a working volume of 6 L. The methane tank had a working volume of 21 L. Fermentation was performed at ambient temperature with an average of 33^oC using seed culture from Kasetsart University (10% v/v). The highest biogas produced from the methane tank was 13.20 L per day after a fermentation period of 31 days. The efficiencies for the removal of COD, total solids, volatile solids and volatile fatty acids were 86.21, 84.11, 92.44% and 5,745 mg/l, respectively. The methane content of the biogas produced in this study was 64.3 %.

Keywords: Biogas, methane, cassava, anaerobic condition

1. Introduction

Biogas, usually produced from organic digestion under anaerobic conditions by a mixed population of microorganisms, is a flammable mixture of 50-80% methane, 15-45% carbon dioxide, 5% water and some trace amounts of H_2, NH_3 and H_2S [1,2]. Anaerobic digestion of agricultural, municipal and industrial wastes can be environmentally valuable because it can combine waste removal with biogas formation and solid or liquid residues can be used as fertilizers, soil conditioner or animal feed [1]. Biogas can be produced in four phases, i.e. hydrolysis, acidogenesis, acetogenesis and methanogenesis. If the process is well balanced, these phases are synchronized [1-3]. Methane gas produced from different raw materials has been used in Thailand and various parts of the world as an alternative energy source for domestic and industrial purposes such as the generation of mechanical, electrical and heat energy [1, 4-10]. The importance of biogas production from agricultural products has also been of interest as a source of energy supply in various countries [7]. Growing high-yield crops such as water hyacinth on a large scale to provide a "methane economy" has been considered [1]. Cheng and Liu [5] have reported that bioconversion of lignocellulosic wastes to biogas by a microwave-assisted alkaline pretreatment (MAP) method could enhance biogas production from herbal-extraction process residues (HPR).

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Thailand is one of the world's major agricultural countries and a large part of the irrigable land is allocated for cultivation of a wide variety of crops including cassava. The Thai government intends to promote the use of bioenergy from ethanol, biodiesel, biomass and biogas and these alternative fuels can be made from raw materials that are cheap and abundant such as cassava, sugar, rice, corn and palm oil [11]. The national average yield for cassava is approximately 22 tons per hectares which is higher than the world average [12]. Cassava or tapioca (*Manihot esculenta*), originally from the South America continent, has been cultivated in Thailand since 1786. Cassava is mainly cultivated in Nakhon Ratchasima Province, Northeastern part of Thailand. Two types of cassava are produced, i. e sweet type and bitter type. The sweet type due to its lower hydrocyanic acid content, is used for human consumption. The bitter type which contains a high quantity of hydrocyanic acid, is used as animal feed and industrial products [13]. A previous study used cassava tubers as raw material supplemented with urea for biogas production by a single phase fermentation and 67.92 % methane was obtained after a fermentation period of 30 days [14].

In this study we investigated the use of cassava tubers as raw material for methane production by utilizing two-phase fermentation.

2. Materials and Methods

2.1 Cassava

Raw cassava tubers (*Manihot esculenta*), bitter type, were obtained from Nakhon Ratchasima Province, Thailand.

2.2 Microbial cultures

2.2.1 Natural seed culture: Five hundred grams of dried cow dung from a cattle farm in Petchaburi Province, Thailand and 500 g of mud from King Mongkut's park, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand were mixed in a plastic container with the addition of water (5.8L) and left to ferment for 2 months at room temperature.

2.2.2 KU seed culture: Mixed seed culture from Kasetsart University (KU) was obtained from Dr. Pramote Sirirote, Department of Microbiology, Kasetsart University, Bangkok, Thailand.

2.3 Two- phase fermentation tank

Continuous stirred tank reactors (acid tank and methane tank) made from PVC pipes were designed for biogas fermentation as shown in Figures 1 and 2. The acid tank has a diameter of 16 cm with a height of 35 cm. The volume of the tank was 7 L with a working volume of 6 L. The methane tank has a diameter of 21 cm with a height of 77 cm. The volume of the tank was 24 L with a working volume of 21 L. Both acid and methane tanks were equipped with motors and stirrers (20 rpm). These tanks were then tested for leakage by the addition of water into the tank and observed for any leakage.

2.4 Biogas production

Dried cassava tubers (50g) were ground and made up as slurry by the addition of 200 ml water before adding into acid tank. Natural seed culture (3L) was then inoculated into the methane tank. The KU seed culture (3L, 10%) was later inoculated into the methane tank after 13 days of fermentation. Slurry of cassava tubers was semi-continuously fed into the acid tank every alternative day to maintain the working volume of the tanks at 6L and 21 L. HRT of acid tank was

24 days and of methane tank was 84 days. Fermentation process was done at ambient temperature with the average of 33°C.

2.5 Analysis of sample

2.5.1 The sample was measurement for pH by pH Meter (Ultra BASIC, U.S.A.) according to AOAC method [15].

2.5.2 Measurement of Chemical Oxygen Demand (COD) was done by Dichromate reflux method [16].

2.5.3 Measurement of total solids (TS) was according to the method described by Arnold [17].

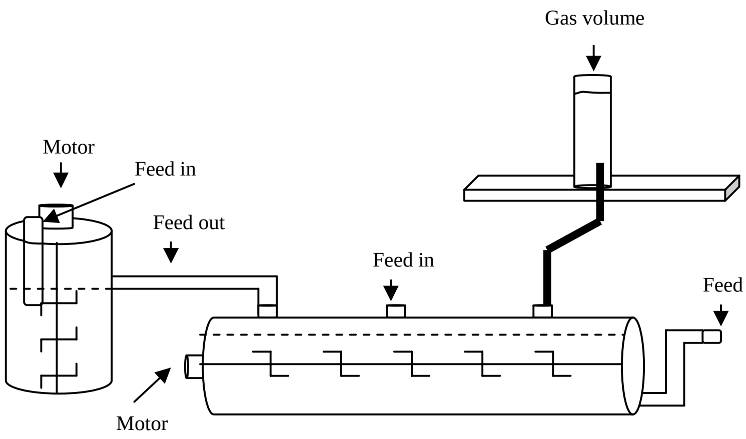

Figure 1 Diagram of two phase fermentation tank

Figure 2 Two phase fermentation tank

2.5.4 Measurements of volatile solid (VS) and volatile fatty acid (VFA) were according to the method described by Panswad and Wisuttisak [18]

2.5.6 The volume of total gas production was measured by the substitution of water volume in gas holder cylinder. Gas production was measured daily.

2.5.7 Methane gas was detected by Biogas meter (Japan).

3. Results and Discussion

3.1 Changes of parameters during fermentation

Various parameters such as pH, COD, TS, VS, VFA during fermentation are shown in Tables 1-2. When the natural seed culture was used for 11 days, no production of gas was found but with the addition of KU seed culture, gas production was detected with lower COD. The COD was reduced from 284,200 mg/L to 29,400 and 9,800 mg/L on days 11 and 31, respectively. At the end of fermentation, the average COD removal was 86.21%. After stabilizing stage on day 23 total solids were reduced from 82,320 mg/L to 9,480 mg/L and volatile solids were reduced from 79,343.33 mg/L to 3,416.67 mg/L and the average reductions of TS and VS were 84.11 and 92.44 %, respectively. The average VFA production was 5,745 mg/L. The maximum biogas production was 13.20 L/day (Table 3). Methane production from biogas measurement was 64.3 % (Figure 1).

Table 1 The average COD and pH values of effluent after fermentation with natural seed culture for 11 days and with KU seed culture for 31 days.

Days	**pH**	**Average COD (mg/L)**	**Average of percent removal**	**Gas production**
1-11	4.19	65,333	85.13	-
13-31	7.14	23,520	86.21	+

Note: Initial COD was 284,200 mg/L
Day 0 inoculated with natural seed culture
Day 13 inoculated with KU seed culture

Table 2 The production of TS, VS and VFA in fermentation tank.

Days	**Total solids (TS) (mg/L)**	**Volatile solids (VS) (mg/L)**	**Volatile fatty acid (VFA) (mg/L)**
Initial stage	82,320	79,343.33	3,900
1	13,210	6,840.00	6,000
3	14,840	6,460.00	5,025
5	13,603	7,046.67	4,875
7	14,287	6,210.00	4,275
9	9,480	3,416.67	8,550
Average of days 1-9	**13,084**	**5,995.00**	**5,745**

Note: Stabilizing stage on day 23

Table 3 The production of biogas in fermentation tank.

Days	Biogas (L/day)
1	1.29
2	1.78
3	0.91
4	2.30
5	3.26
6	5.46
7	12.48
8	13.20
9	9.12

Note: Day 1 means Day 23 in the fermentation system

Figure 3 Measurement of methane production by biogas meter.

3.2 General Discussion

Using cassava tubers as substrate in a two stage digester a maximum gas yield of 13.20 L/day with a methane content of 64.3% was achieved. When compared to the single stage digester, Anunputtikul and Rodtong [19] found that the biogas yield was 1.20 L/day. It could be explained that when the digester was initially fed, acid forming-bacteria quickly produced acid resulting in declining pH below the neutral pH and diminishing the growth of methanogenic bacteria and methanogenesis. For the single phase system pH has to be maintained by adding sodium bicarbonate to increase alkalinity condition in digester [14]. The average pH between 6.8-7.2 is optimum for biogas production [20]. Low methane content often results from high sulfur and ammonia content in biogas composition, high aerial dosage accompanying desulfurization as well as to coarse input material [4]. Li *et al*.[21] explained that there was close correlation between degradation of organic matters and biogas production and the change of VS removal corresponded to that of gas production rate. The two-phase digestion system which separated the digestion process into acidification phase and a methanogenesis phase showed good stability, which was mainly attributed to the strong buffering capacity with two-phase system.

4. Conclusions

The two phase digestion system could provide more suitable condition for acid-forming bacteria and methane forming bacteria than single phase digestion, thus enhance the overall activity in digester. Raw cassava tubers can be used as a good source for biogas production.

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